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"Doubling Farmers' Income by 2022: The Role of Weed Science"

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PREFACE

Weeds pose a serious biotic constraint in agricultural production systems globally. Besides reducing crop yield and quality, weeds adversely affect biodiversity, animal health and environmental security. Despite of enormous efforts made by scientists towards weed management, the problem of weeds has been virtually increasing due to adoption of high input-intensive farming methods which also enhance the growth and development of weeds. Further, problem is aggravating due to climate change, globalization of trades and development herbicide resistance in weeds. Realizing the increasing weed infestations in the cropped and non-cropped lands, agricultural scientists have been undertaking research and sharing their findings at various platforms.

Hon'ble Prime Minister of India, Shri Narendra Modi has called for doubling farmers' income by 2022. At a conservative estimate, weeds account for about one-third loss of productivity in different crops. In addition, there are indirect losses on account of nutrient drain by weeds, increased cost of crop production due to higher incidence of pests and diseases, harvesting and processing, and other agricultural operations. Appropriate weed management has the potential for reducing the cost and increasing the income of the farmers significantly. This is essential to realize our Prime Minister's dream of doubling farmers' income by 2022, coinciding with Platinum Jubilee of India's independence. In order to address the emerging challenges and for doubling farmers' income over the next 7 years, the Biennial Conference of the Indian Society of Weed Science is being organized during 1-3 March, 2017 at Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan with a theme "Doubling Farmers' Income by 2022: The Role of Weed Science".

This compilation is based on keynote lecture, presidential lecture, plenary lectures, lead presentations, rapid fire presentations and poster presentations. The members of the publication committee (Dr Sushil Kumar, Dr Prashant Bodake, Dr P.P. Choudhury, Dr Bhumesh Kumar and Dr Yogita Gharde) have undertaken the task of compiling, editing and presenting these articles in a systematic manner. It is hoped that this volume will be useful to scientists, teachers, students, administrators and policy makers who are concerned with weed management. The financial assistance received from Research and Development Fund of National Bank for Agriculture and Rural Development (NABARD) towards this publication is gratefully acknowledged.

1 March, 2017

Dr. N.T. Yaduraju
President, ISWS

Dr. A.R. Sharma
Organizing Secretary

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We are pleased to present the e-Proceedings containing the keynote lecture, presidential lecture, plenary lectures, lead lectures, and papers for rapid fire presentations and poster presentations submitted by the weed scientists for presentation at Biennial Conference on "Doubling Farmers' Income by 2022: The Role of Weed Science" being held at MPUA&T, Udaipur from 1-3 March, 2017. A large number of papers were received covering a wide range of themes from all over India and a few from abroad. These papers were thoroughly reviewed for both technical content and editorial quality.

The articles included in this proceeding clearly highlight the role of weed science in contributing to agricultural productivity. In general, papers covered the main theme of the Conference well, the Publication Committee observed that number of papers submitted on sub-theme "Weed management in major crops and diversified cropping systems" just accounted for half of the total papers submitted. Papers on other relevant sub-themes such as non-chemical weed management; herbicide residues and their mitigation; weed management for higher input-use efficiency; weed dynamics under climate change and herbicide resistance weeds/crops; and emerging problem weeds and their management are less. We hope that some of these neglected research areas/gaps would be addressed adequately in due course. Only a small number of papers on emerging challenges like climate change and herbicide resistance in weeds were received indicating that efforts in these areas are yet to be intensified.

We thank Dr. N.T. Yaduraju, President, ISWS and Dr. A.R. Sharma, Secretary, ISWS and Organizing Secretary of this Biennial Conference for giving us this opportunity and providing their guidance and inputs for bringing out this proceeding. We also thank all the authors for contributing research articles for presentation at this Conference. Special assistance provided by Mr. Anoop Rathore, Mr. Subhash C. Singhariya and Mr. V.C. Tyagi of Directorate of Weed Research, Jabalpur in editing the proceedings is gratefully acknowledged. We appreciate the efforts made by Mr. Gyanendra Pratap Singh in processing, and formatting of articles, and bringing out the proceedings.

1 March, 2017

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Contents

Keynote address

Doubling Farmers Income by 2022: A Reality Check

Dr. Mruthyunjaya

Doubling farmers' income by 2022: A reality check

Mruthyunjaya

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1. Backdrop

In pursuance of the Honourable PMs historic announcement to doubling the income of farmers, the Finance Minister made the proposal for doubling farmers' income by 2022 during the budget of 2016. It may be noted that one of the first major initiatives of the newly constituted NITI Aayog was to constitute a Task Force on Agriculture (decision to constitute the Task Force taken in the meeting of the First Governing Council of the Aayog on 8th February 2015) to recommend strategies for re-invigorating agriculture in all its aspects by reviewing the status of farming and farmers in India and make recommendations for their wellbeing. The Task force observed that the most appropriate measure of farmers well being is the level of farm income which has seen low to high growth during the last three decades but the growth in farm income after 2011-12 has plummeted to around 1% and this is an important reason for sudden rise in agrarian distress in recent years (NITI Aayog, 2015). The PM's announcement followed up with FMs budget proposal is most probably prompted by the rising distress of farmers and its wider implications on food security and the economy as a whole as reflected by the findings and recommendations of this Task Force which among others suggested rising productivity in agriculture, giving remunerative prices to farmers, bringing second green revolution in rainfed areas in general and eastern India in particular, helping small and marginal farmers by reforming tenancy laws and providing quick relief to farmers in times of natural disasters. Shri Arjun Ram Meghawal Union Minister of State for Finance, expressed in a NABARD Seminar on 12th July 2016 that the intention of doubling farmers income is "The farmers have given us food security and we intend to provide income security as a gift for their hard work under difficult conditions"(NABARD, 2016).

2. Major Policy Announcements on Agriculture in the Past and their Outcomes

Ad-hoc measures to manage food deficit

Since independence, India is engaged in ushering a more equitable agrarian system and battling with frequent food crises and providing adequate food to its growing population. The country inherited the remembrance of worst food crisis of Bengal Famine of 1943 when 4 million people are reported to have been died out of starvation. Grow More Food Campaign was launched by GoI in 1948 as a program of crop production, field demonstration and contact with farmers. The Government introduced rationing of food grains, introduction of public distribution system, also tried with "Miss a meal" movement without importing food for a while, and suggested 'Eat Forest Products during "Vanamahostav" time. Having not being able to get enough food the public revolted against the Government telling that "Give us bread or leave office". In 1950, the Food Army of Socialist Party of India asked people to give "Ek Ghanta Deshko" to build canals, irrigation tanks, compost pits to increase food production. In 1951, The Socialist Party again said "Hungry and naked India demands bread, clothing and houses and a Government that cannot end black marketing and corruption has no right to exist". Since the General Election was around the corner in 1951, the Government announced "Import a meal" by seeking barter help of food from food surplus countries and also by asking people "Help by giving up one meal a week". Food shortages continued, if not famine like situations and there was an acute shortage of food in 1965-66 and 1966-67 and India imported 10 million tons of food grains. The Government was seriously concerned and actively engaged in planning to formulate a strong strategy towards improving food production in the country. Fortunately, by this time India had developed an impressive agricultural research system, with Indian Council of Agricultural research as the apex institution and state agricultural universities dealing with agricultural research and education at the state level. Establishment of AICRPs in major agricultural commodities located in different agro-ecological regions helped to launch HYV programmes in the country.

Transition to HYV strategy

With good monsoons in 1967-68, India with the active role of the Government marched towards pursuing new policies like attaining self sufficiency in food, strategies, programs like HYV program, supportive policies like massive irrigation projects, investment in fertilizer factories, revamping of cooperative societies, Community Development Programs, National Extension Programs, etc. institutions coupled with hard work of farmers could able to increase production in general and attain near self sufficiency in food grains. Indian agricultural transformation was remarkable and it increased food production more than 5 times from about 50 million tonnes in 1950-51 to 264 million tonnes in 2013-14. During this journey, it passed through emerging challenges of reaching the limit of area growth, flattening yields owing to natural resource degradation, increasing costs and falling profitability, rising demand for exports, fast dietary changes, diversified demand and significant trend towards agricultural diversification, concerns of nutritional security, price shocks, and climate change. Several studies during the period analysed the food situation and prospects and suggested suitable policy and program interventions to address changing demands of the time. Realizing the need for reforms in economic policies in agriculture, India formulated a National Agricultural Policy in 2000 (DAC, 2000) to actualize over the next two decades the vast untapped growth potential of Indian agriculture to attain a long term growth rate in excess of 4% per annum, strengthen rural infrastructure to support faster agricultural development, promote value addition, accelerate the growth of agro business, create employment in rural areas, secure a fair standard of living for the farmers and agricultural workers and their families, discourage migration to urban areas, and face challenges arising out of economic liberalization and globalization.

Continuation of fluctuating agricultural growth and farmers' fortune

The pace of reforms in agriculture sector was slow since Government with complacency on green revolution agricultural growth had preoccupation with the external sector, industry and services and neglected agriculture in investment (Vyas, 2016). But with rising farmers' distress, came out with a more comprehensive National Policy for Farmers in 2007 (DAC, 2007) with primary focus on farmers to improve the economic viability of farming through substantially improving net income of farmers with emphasis on increased productivity, profitability, institutional support and improvement of land, water and other support services apart from provision of appropriate price policy and risk mitigation measures. But India failed to maintain and sustain the targeted tempo of growth in production and farmer income. India also faced serious deficits in oilseeds and pulses ending up with huge imports by spending scarce foreign exchange. Nutritional insecurity particularly of women and children became a critical development issue. Raising productivity on a sustainable basis was also threatened by natural resource (land and water) depletion and degradation besides continuing problems of decreasing farm size, input delivery and institutional problems, monsoon and market failures, adverse climate change implications etc.

3. Paradigm Shift in Agricultural Development Strategy

Special drives

To overcome persisting and emerging problems, India went for special drives/missions/crash programs (Oilseeds: 1986; Pulses: 1990-91) to increase their production though we are still grappling with deficits particularly with pulses. During 1999, the Government came with a slogan to double food production in next 10 years (by 2009) with a regionally differentiated strategy based on agro-climatic planning to ensure food and nutritional security. The focus was on: 1) On-farm Water Management in Eastern India (additional 10 lakh tonnes of foodgrains per year), 2) Technology Mission on Horticulture in NE Region, 3) Special Program for Increasing Production and Productivity of Wheat and Pulses in the Hills and Plateaus of Central India and 4) Technology Mission on Cotton. The other mega programs/schemes included National Horticultural Mission, National Food Security Mission, Bringing Green Revolution in Eastern India, Rastriya Krishi Vikas Yojana, Mahatma Gandhi Rural Employment Guarantee Act (MGNREGA), National Mission on Sustainable Agriculture, Sub-Mission on Agricultural Mechanization, Doubling of Agricultural Credit over 2004-07, National Agricultural Insurance Scheme, increase of MSP of Wheat and Paddy, Decentralized Procurement, National Watershed Development Project, Rainfed Area Development Programme, etc.

Outcome of special drives

There were reported improvements in the efficiency (quality) of implementation of some of these special programs/ measures/initiatives/programs/missions and were useful but in general failed to make sizeable impact. For instance, even the national mission announced by then PM of doubling food production during 2000 could able to increase food production by only 15% by 2009. Against the target of long term 4% growth rate in agriculture, growth trends in agriculture averaged to 2.59% during 1970-71 to 1986-87, 2.79% during 1986-87 to 2000-01 and 3.97% during 2000-01 to 2012-13 (NAAS, 2016). The long term growth however has been still around 2.5%. As regards growth in farmers income, farm income per cultivator increased by 2.74% a year from 1983-84 to 1993-94, dropped to below 2% in the next decade (sudden rise in farmers suicides and increase in farmers distress), increased to 7.3% during 2004-05 to 2011-12 (a sudden drop in the farmers suicides during this period indicating decrease in farmers distress) and again dropped to around 1% post 2011-12 and this is an important reason for sudden rise in agrarian distress in the recent years (Ramesh Chand et al., 2015). Also there is disparity in per worker income in the agriculture and non-agricultural sectors as a result of much higher decline in the share of agriculture in national income compared to the decline in the share of agricultural workforce in the total workforce of the country (Ramesh Chand, 2008). It should be admitted that Government interventions bring short term improvements in productivity and income but they do not sustain on account of uncertainties of prices (output and input) and markets coupled with adverse impact on policy action and climate change, take over before long and farm households sink back to crisis/distress. In the past decade farm gate prices have been systematically subdued by Rs.10 lakh crore due to Government actions like export ban on rice, wheat, onions, potato, etc. Also imports of maize and edible oils have hurt farmers (NABARD, 2015).

Overall, it is broadly concluded that decent growth in farmers' income requires high growth in output, favourable prices for farm produce and some cultivators moving away from agriculture (Ramesh Chand et al., 2015). If this does not happen, there will be raising agrarian crisis and farmers may abandon farming (Narayanamoorthy, 2006).Retaining farmers and youth in farming is critical for ensuring food security of the nation particularly after India enacted National Food Security Act in 2013. NSSO (2005) Situation Assessment Survey 2003 reported that an estimated 27% of farmers did not like farming because it was not profitable. It also reported that in all 40% of farmers felt that given a choice they would take up some other career. Studies have also shown either abandoning farming or conversion of farm land for non-food crops/non-agricultural purposes have serious implications on food security (Shinoj, 2015; Govindaprasad and Manikandan, 2016). Thus even special drives could not relive farmers from distress and impending threat to food security and something new, innovative solution was sought.

4. Doubling of Farmers' Income by 2022: Debate, Problems, Prospects and Way Forward

The Debate

Soon after the announcement, a debate followed whether it is at all possible to double farmers' income by 2022. The debate started with whether it is real income (at constant prices) or nominal income (current prices). The announcement however was silent on this issue. Settling to real income as the right concept to be considered, several scholars argued that it is not possible to double real income by 2022 on account of: low and unrealizable MSP, non-remunerative price in the market, low share of farmers in final price, poor penetration of crop insurance, high and increasing input cost, absence of market infrastructure and past record of modest growth compared to 12% needed for doubling in nominal terms (20 to 30% in real terms) (Satyasai, 2016). The proposed strategy to double farmers income by PM also emphasized i) big focus on irrigation with large budgets with the aim of "per drop, more crop" (Pradhan Mantri Krishi Sinchayi Yojana) ; 2) provision of quality seeds and nutrients based on soil health of each field (soil health card, neem coated urea, promotion of traditional farming practices through Paramparagat Krishi Vikas Yojana); 3) large investments in warehousing and cold chains to prevent post-harvest crop losses; 4) promotion of value addition through food processing; 5) creation of national farm market (NAM) and removing distortions (Pradhan Mantri Gram Sadak Yojana, e-NAM); 6) introduction of new crop insurance scheme to mitigate risks at affordable cost and 7) promotion of ancillary activities like poultry, beekeeping and fisheries.

Government agencies/departments have started planning and strategizing for doubling farmers' income by 2022.For example, NABARD (2015) has strategized income enhancement through 3 options: 1. increasing the gross income, 2) reducing the costs, and 3. stabilizing prices.

1. Enhancing farmers income: a) Production growth, b) higher prices and c) diversify farm/non-farm earnings (product: higher value crops; process: precision farming; time of operation: delinking from seasonality)
2. Reduce costs: a) reduce purchased inputs; b) exploit complementarities
3. Stabilize income: a) coping mechanisms; b) insurance; c) expand irrigation cover

The Ministry of Agriculture, GoI is also gearing up to initiate actions to fulfil the objective of doubling farmers' income. Among several initiatives, it has entrusted National Institute of Agricultural Economics and Policy Research of ICAR to estimate and publish farmers' income at all India level and state level to help in monitoring the level of income and taking the corrective actions to move the economy towards achieving the objective. If we carefully see the core strategies suggested in the past including that of DAC and NABARD, except for some change in formulation and some details, they all boil down to emphasis on agricultural diversification, water management, critical input (seed, fertilizer, credit, extension) supply and optimal use, post harvest management, infrastructure and market value chain development, favourable price support, effective insurance, promotion of rural non-farm enterprises, etc. The moot question is whether such emphasis and increasing investments plan after plan have resulted in desired impact on improving farmers' real income.

Problems and prospects

In fact, it is surprising that estimates of farm income are not prepared and published in the country. One of the basic questions raised was about the availability of farmers' income time series credible data. It is reported that a proper series of farm income is now constructed (from 1983-84 to 2011-12) which truly measures the income accruing to farmers from agricultural production (Ramesh Chand et al., 2015). The results indicate that: 1) Farmers' income between 1983-84 to 2011-12 multiplied 20 times at nominal prices and increased by only three times in real terms in the last thirty years; 2) Growth in farm income post 2011-12 has plummeted to around 1% indicating sudden rise in agrarian distress; 3) low growth in farm income is associated with an increase in farmers' distress (suicides); 4) About 53% of farm households in India will be living in poverty if they do not have earnings from non-farm sources (Farmers having land holding below 0.63 hectares will not earn enough income from agriculture even to keep his family out of poverty); 5) One rupee invested in farming yields a net income (net of even hired labour) of Rs. 1.70 to farmers indicating no squeeze in profitability in farming and 6) growth rate in real farm income of a cultivator is determined by growth in output; the rate of increase in input cost; changes in wage rates, the number of hired labours and days of labour employment in a year; growth in prices of agricultural commodities at the farm level and the level of inflation.

Using different data series but somewhat comparable with data used by Ramesh Chand et al. (2015), Chandrashekar and Mehrotra (2016) estimated that during 2003 to 2013: 1) average monthly total income of agricultural households increased by three times in nominal terms but at the all India level it increased by a factor of 1.34 (only in Odisha it doubled); 2) among the four components of total farm income (income from wages, net income from cultivation, net income from animal farming and net income from non-farm business), only net income from animal farming increased by 3.21 times, 2) found evidence of doubling of income of households with over 10 hectares of land; 2) in addition to cultivation (livestock) there are other sources of income that can contribute to doubling of income of agricultural households, 3) households with less than 1 hectare of land had average monthly income lower than monthly consumption expenditure; 4) channel funds to small and marginal farmers and rework the mix of short-term and long-term credit in order to incentivise flow of long-term credit relative to short-term credit and 5) measures to remove constraints to income growth from non-farm business at the household level.

Thus the available evidences with limitations of data indicate that doubling of farmers' income in by 2022 is a formidable task, if not impossible. Further, even if farm income is doubled, will it be adequate to sustain farm family and attract youth to agriculture. Once we consider consumption expenditure, farmers have hardly any surplus left and marginal and small farmers have more serious deficit. It is found that farmers' expenditure on health and education is substantial enough to topple his balance sheet (Satyasai, 2015).

Way forward (Roadmap)

It is found that there is casualization of workers in the country and greater focus on development of skill and entrepreneurship among rural youth will help in promotion of self or regular employment and thereby providing a decent-level of income to rural households (NAAS, 2016). The benefits provided under "Skill India" and MUDRA should be used to make them employable remuneratively in non-farm business activities within and outside rural areas (NAAS, 2016; Satyasai, 2016). Without skills, if people migrate to unorganized sector outside agriculture, they will neither have decent living nor have social security (Roy, 2016). The other suggestions include, 1) doubling of public investment in building infrastructure in agriculture; 2) removing all restrictions on leasing land and computerization of all land records; 3) speedy implementation of APMC Act in different states; 4) active involvement of private sector particularly in product market, agro-processing and delivery of inputs; 5) emphasis on agricultural marketing reforms especially strengthening legal framework for contract farming and direct procurement of farm produce by processing industry, retail chain, aggregator, etc.,6) greater focus on term loan for increasing household investment and modern value chain development; 7) Extension of Jan-Dhan-Yojana, Aadhar and Mobile(JAM), implementation of tenancy reforms along with PMFBY and modernization of land records would help farmers manage risk and extend benefits of other schemes directly to farmers; 8) strengthening capital and entrepreneurship development for dairy, meat, etc., 9)promoting mass awareness among farmers about opportunities available for commercialization and diversification, better technologies, facilities, markets, insurance, climate change and 9) assurance of quality of farm inputs and timely delivery at farmers' door steps (NAAS, 2016; Satyasai, 2016; Vyas, 2016).

The Government as usual is planning to gear up to implementing the direction. Since doubling has to be state specific, states are also gearing up. One of the steps taken by the Centre includes discussions during *kharif* and *rabi* campaigns with the states and other stakeholders to initiate actions. A Task Force is formed in MoA to come out with detailed plan and making it operative to doubling farmers' income by 2022. Some states have prepared details of targets for each sub-sector and also needed activities and investments. For example, the Madhya Pradesh Governments' road map has delineated sub-sector's interventions (and targets) and financial resources required. The document presented projected contributions of different components to the income increase as follows:

a) Reduction in input cost (15%)
b) Increase in productivity (30%)
c) Increase in area under cultivation (14%)
d) Agricultural Diversification (20%)
e) Reduction in post-harvest loss (6%)
f) Remunerative prices (15%)

As can be seen, only two components of increase in productivity and increase in agricultural diversification constitute 50% of contributions to increased income highlighting their significance to increasing farmers' income. The roadmap discussed in the national seminar at NABARD to double farmers' income by 2022 included the following:

1. Synergy in implementation of several farmers income enhancement flagship programs
2. Reduction of wastage/loss by processing, creating storage, cold chain logistics and market infrastructure
3. Increase in yield
4. Leverage water resource
5. Special focus on dryland areas
6. Reducing cost through smart nutrient management, low input agriculture (low external inputs, organic), using Farming System Approach
7. Income enhancement through diversification
8. Proper skilling and professionalization
9. Intensifying dairy farming
10. Stabilizing income and risk management
11. Climate change and sustainable agriculture
12. Focus on Eastern India
13. Focus on small holder problems
14. Adjusting to global market trends
15. Computing and publishing state-wise farmers' income on annual basis, make data public on regular basis to help the states to monitor the progress and compete with each other to reach the target by 2022

By and large, almost similar recommendations emerged during the Round Table meeting of Indian Council of Food and Agriculture, Delhi on 30th April, 2016. Forty recommendations were made in 5 parts, namely, improving productivity, water and agri. input policies, Integrated Farming System, Better market price realization and special policies such as land leasing permissible, agriculture particularly post-harvest activities to be brought under concurrent list in view of globalization and the role of the Centre becoming prominent, all "Gram Panchayats" to serve as agri-business hubs and creation of special agricultural zones (SAZs) with emphasis on export and industrial use crops.

CONCLUSION

In view of increasing farmers' distress, doubling of farmers' income by 2022 seen in retrospect is a challenging if not impossible target given by the PM to channelize the energy of the nation in a particular direction. But prospects for doubling are also visible in terms of several proven examples, ideas and strategies, enough/sufficient resources, potential found for enhancing if not for doubling farmer income. What is lacking and hence immediately required is clarity of objectives of interventions, appropriate organizational design to implement, system-wise scaling up of the operation of success stories/examples/interventions, synergy and coordination among all the science and development players and programs, commitment of various functionaries, regular monitoring of progress, midcourse corrections and substantially improving the culture and ethos of implementation. Can we expect a change in Indian mindset, synergy between technology and policy and across programs/investments, faithful implementation of programs and accelerate pace of progress to utilize the opportunity and exploit the possibility to doubling farmers' income in next 5 years? Implementation of programs is a big question/puzzle/ challenge to all of us! Prof. Vyas (2016) says that a policy or a programme is as good as its implementation!

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Plenary lectures

Enhancing farmers' income through smart weed management

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Weeds are a perennial problem with the farmers. They are omnipresent and reduce yield and quality of crops substantially. Farmers spend a lot of resources to reduce their impact, many a times quite unsuccessfully. The data collected from Directorate of Weed Research (DWR), Jabalpur show that with the traditional weed control methods, farmers are losing close to 15-20% crop yield and there is a tremendous scope for enhancing crop yield by adopting recommended weed control practices. Ever since the Prime Minister has given a call for doubling farmers income by 2022, all branches of agriculture are deliberating on their role in achieving this target. In this paper, we will discuss on how weed science can contribute in fulfilling this mission.

Weed control is one of the costliest practices in crop production. It has been estimated that on an average the weed control costs around Rs. 6000/ha in *kharif* crops and around Rs 4000/ha for *rabi*, which comes to the tune of 33% and 22%, respectively of the total cost of cultivation of *kharif* and *rabi* crops. There are two ways of increasing the farmer's income; one is by decreasing the cost of weed control and the other by increasing the productivity. Of course, the third one is by realizing the higher market value which is not within the scope of this paper.

Efficient and effective methods of weed control are the need of the hour as they invariably ensure higher crop productivity. There are opportunities for employing methods, which are not only efficient but are also cost-effective. Such an approach would eventually increase the net returns of the farmers. Large majority of the farmers follow manual and mechanical methods to manage the weeds, which are labor-intensive and are often inefficient. The rural landscape in India has changed dramatically in the recent past. The increasing migration of rural population and employment opportunities under several social security schemes have led to serious shortage of labour in agriculture. Even the population of draught animals is on the decline. Data compiled by DWR, Jabalpur of the research carried out at AICRP on Weed Control have shown that weed control through herbicides on an average has given significantly more yield over farmer's practice, with nearly one-third saving in the cost on weed control. The technology however has not yet been adopted by the farmers for a variety of reasons.

Untimely weeding and the poor crop stand are believed to be the two major factors responsible for the dominance of weeds. It is to be understood that there is no substitute for timely weeding. Keeping the crop weed free or with minimal weed interference during the critical period of weed competition (CPWC) is of paramount importance. Weed competition during this period causes irreparable loss in crop growth ultimately resulting in lower crop yield. This is the most important reason for lower productivity of crops cutting across different agro-ecological regions of the country. The next factor is the inability of majority of the farmers in raising a good crop. As Prof. John Fryer has said in his book '***Good crop is the best weed killer'***. Many farmers face serious weed problem for their inability to raise a good and healthy crop. The recommended cultivation practices starting with selection of crop cultivar, timely planting, optimum seed rate, timely application of fertilizers and irrigation, management of insect-pests and diseases *etc*. are instrumental in establishing a good crop.

The following sections attempts to analyze how each weed control method could be practiced in an ideal way so as to get maximum productivity of crops with relatively lower investment.

Preventive methods

Prevention is better than control; and the most cost-effective measure. With less or no extra investment they can employ to minimize infestation and competition by weeds substantially. But sadly, it is seldom appreciated by the farmers and the extension personnel alike. Some of these methods include use of weed-free crop seed and FYM, use of clean farm machinery, control of weeds along bunds and irrigation canals, preventing weeds from setting seeds, etc. Everyone concerned must be reminded of the old adage *one year seeding is seven years weeding!* Good control of weeds in nursery will ensure transplanting of crop plants free of weed seedlings in the main field. Every effort must be made to prevent the introduction of new weeds in to the crop fields. One should be particularly wary of invasive weeds, perennial weeds and parasitic weeds as they are known for their competitive ability, elasticity and resistant to weed management strategies. Periodical scouting of the field for new introductions and their eradication, if found, therefore assumes significance.

Cultural methods

All production practices followed in raising the crop affect infestation and competition by weeds either directly or indirectly. The practices which encourage crop growth also encourage weed growth. But research has shown that it is possible to manipulate some of the agronomic practices which would have greater impact on crop growth than on weeds. Some of them are the time-tested practices such as crop rotation, summer tillage, stale seed bed preparation, green manuring, mixed/intercropping, intercultural operations, etc. Very often such practices require no or less additional investments. It is known that weeds siphon off large quantities of costly inputs such as fertilizers and water. There is good scope for minimizing the loss of nutrients by resorting to placement of fertilizers nearer to the crop rather than broadcasting. Similarly, the water use efficiency could be enhanced by adopting suitable methods such as, irrigation in the alternate ridges or basin application in wide spaced vegetable, plantation and fruit crops or more desirably through drip irrigation. Similarly, intercropping with fast copy forming crop suppress weed growth. It has been shown that an investment closes to Rs. 2000/ha could be saved by resorting to zero or minimum cultivation. As a bonus, the technology has been found to decrease the incidence of some of the weeds (for example *Phalaris minor* and *Chenopodium album* in wheat) as well.

The effect of the some of the agronomic practices referred above may not be large enough, but they chip in small ways and will have substantial effect when followed collectively. They need to be selected and integrated wisely taking in to account the socio-economic condition of the farmers.

Chemical methods

Herbicides offer convenient, easy, flexible and an efficient option of weed control available. Due to the fact, the labour is scarce and expensive, chemical weed control is gaining wider acceptability with the farmers. A wide range of herbicides are available to suit all crops and cropping systems to control a diverse spectrum of weeds. They could be applied at planting and during early stages of crop growth and also under adverse soil and weather conditions. There are two ways how the farmers could increase their income through use of herbicides; Firstly, by increasing the herbicide efficacy and secondly by minimizing the crop injury. How this could be achieved is discussed in the following sections.

Increasing herbicide efficiency

Selection of herbicide: Crop is infested with a wide-spectrum of weeds which vary with crop, cropping system, soil, climatic and management conditions. The choice of an herbicide depends on weed flora, time of application, crop rotation and whether the crop is grown sole or intercropped. For any given situation, if there are many herbicides available, it is quite natural to go for a herbicide which is relatively cheaper. Selection also depends on what would be the ideal time of application- either before or after crop emergence. There are a good number of herbicides available for application both as pre- and post-emergence in most cereals. However, the availability of herbicides that could be applied post-emergence in pulses and oilseeds are relatively less.

Herbicide dose: The major consideration is soil type and growing conditions. Light soil with low organic matter content requires lower dose than the heavy soils with higher organic matter content. The pre-emergence herbicides perform better when applied to soil with sufficient soil moisture. Hence there is good scope for reducing the herbicide dose in irrigated crops. With post-emergence herbicides, the time of application is more critical. They perform better when applied early. Young and fast growing weeds are more sensitive to herbicide treatment. Ensure optimum soil moisture for maximum effect, stressed plants exhibit resistance to herbicides.

Herbicide application: Unlike other pesticides, the application plays an important role in determining herbicide efficacy. Calibration of the sprayer is a must so as to apply the herbicide at the recommended dose over a given area. Choosing the right kind of sprayer, nozzle and the application pressure are critical in ensuring uniform application. In India, farmers give least attention to application of herbicides. Inappropriate application not only lowers weed control efficiency but may also result in crop injury. More care is required while using spray booms. It is common to see patches of weeds not controlled or patches of crop plants showing phytotoxicity symptoms as result of incorrect alignment of nozzles and faulty height of spray boom. Both these conditions result in poor crop growth and yield.

Use of adjuvants: Most of the herbicides are formulated for ready use by farmers. However, there is scope for improving the efficacy of herbicides by use of adjuvants. Adjuvants increase retention of spray on the foliage and better spreading of droplets thereby increasing the absorption and translocation of the herbicide. For instance, it is well documented that addition of ammonium sulfate enhances the efficacy of glyphosate against many perennial weeds.

Herbicide mixtures: Crop fields are infested with broad-spectrum of weeds. Selective herbicides are known to be effective against a few of them. With continuous use of the same herbicide, the population of weeds which are less susceptible would increase over time. It is therefore ideal to use a mixture of two or more herbicides. Herbicide industry has responded to this concern and has commercialized quite a many 'Ready-mix' herbicides, which are quite popular with farmers. Use of such mixtures provides good control of diverse weeds, sustainably for a number of years. Herbicide mixtures are also known to delay the development of herbicide resistant (HR) weeds. Any attempt to delay development of HR in weeds is worth pursuing as managing them later is highly challenging. Alternative herbicides recommended for managing HR weeds would normally be very expensive. It is also a good idea not to use the same herbicide or herbicides belonging to the same group year after year. It is recommended to follow herbicide rotation meaning alternative use of herbicide(s) belonging to different groups.

Time of application: As has been discussed earlier, targeting the weed at their early growth stage is beneficial. This may entail the use of lower dose of herbicides. More importantly, better weed control could be realized by exploiting the soil and weather conditions which are favorable for increased herbicide activity. A well-prepared seedbed with sufficient soil moisture enhances the efficacy of the pre-emergence herbicides. By and large, higher levels of temperature, relative humidity and solar radiation, enhances the activity of many herbicides applied post-emergence. Greater herbicide efficacy could be achieved by coinciding herbicide application with such weather parameters. Rainfall however has the maximum impact. Herbicide application is to be avoided, if rain is expected within the next two-four hours of application. The interval, however, may vary from herbicide to herbicide. Paraquat, for instance is known to control weeds effectively even if it rains within 15 to 30 minutes of spraying.

There has been contrasting reports with regard to what time of the day the herbicide be applied for better weed control. Early morning hours are generally considered ideal for herbicide spray as there is less wind. Heavy wind encourages spray drift. Spraying paraquat towards the end of daylight hours on a cloudy day is reported to boost the efficacy. These usually result in longer lasting weed control. A group of weed scientists from several universities from USA have observed that glyphosate application made at 5AM resulted in 16% control of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) as compared to 56% when applied at 11 AM. There are opportunities for increasing the efficacy by timing the herbicide application.

In conclusion, it may be stated that there is enormous scope for enhancing the framers income by lowering the cost on weed control and by achieving higher productivity. Timely weeding and raising a healthy crop are critical in our fight against the onslaught of weeds. A number of preventive and cultural methods and minor changes in agronomic practices have a very significant bearing on weed competition. Several of these involve no or insignificant additional expenditure. The impact of these practices may not appear significant when followed individually, but will have substantial effect when more than one are integrated and followed collectively. Herbicides are a labour-saving technology. The labour so saved could be employed in non-farm or secondary farming activities to enhance the income further. By virtue of their merit, herbicides will be an important component of IWM. With judicious use and clever integration with other methods of weed management, herbicides will enable farmers to achieve better weed control at reduced cost and very often with enhanced productivity of crops. However, IWM being a knowledge intensive activity requires the support and patronage of weed scientists and extension personnel. Farmers need to be sensitized in popularizing the benefits of the technology.

Classical biological control of weeds: India as both a beneficiary and a benefactor

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Biological control, especially the classical approach, has always been pro-poor and pro-environment. Resource-deprived small and marginal farmers benefit immensely through the classical biological control (CBC) strategy. A solitary CBC agent, or a select group of agents, could be considered a success in biological control, if an agri-environ weed is kept under control, even without the farmer realising this happening in and around his farm.

India's role as both a beneficiary and a benefactor in the global exchange of weed biocontrol agents could be appreciated through the most recent edition of the book entitled "Biological Control of Weeds: A World Catalogue of Agents and Their Target Weeds" (Winston *et al*. 2014).

Since the 18th century, 19 insects have been imported into India for evaluation and/or release against 8 terrestrial weeds. At least 14 countries have either directly or indirectly participated in the supply/transfer of these weed insects, though the candidate insects originally originated from only Brazil, Colombia, Mexico, South America (specific country name/s not available), Trinidad, USA or Yugoslavia (undivided). In the aquatic environment, 4 insects and 1 mite have so far been imported, with at least 5 countries participating in the movement of these agents into India. In addition, at least 4 species of fish were introduced to tackle small, submersed weeds.

Out of all the field-released arthropods, 8 could not be established on their respective targets. By and large, host shifts or major non-target attacks have not been reported in India, though a necessitated, thorough relook at *Zygogramma bicolorata*, the only established biocontrol agent for parthenium weed, resulted in an unanticipated deadlock in the the CBC programme of weeds for more than a decade.

In 2005, India became the eighth country in the world to field-release a host-specific plant pathogen for CBC of a weed. The isolates of the rust fungus, *Puccinia spegazzinii*, a host-specific pathogen of *Mikania micrantha* (mile-a-minute weed), came from Trinidad and Peru. Though the fungus could not be established on the weed here, several other nations in the Asia–Pacific region followed our example; India, thus, became a trendsetter.

As a benefactor, India is now helping United Kingdom-based CABI to zero in on the best biocontrol agents for *Hedychium gardnerianum* (Kahili ginger), a plant native to the Himalayas, in New Zealand and Hawaii. Several insects, including a stem-mining fly and hispine beetles, have been identified as potential biocontrol agents, in a project funded by New Zealand's Landcare Research and the Hawaii Invasive Species Council.

India has also helped CABI, which is collaborating with the Galapagos National Park Directorate, in identifying suitable biocontrol agents for an invasive blackberry (*Rubus niveus*) affecting the Galapagos Islands. Since India is part of the native range of this species, surveys for natural enemies, especially for rust fungi, were undertaken in Himachal Pradesh and the Nilgiris.

In the last century, several insects were sourced from India for controlling weeds such as *Xanthium strumarium* (in Australia and Fiji), *Cyperus rotundus* (in Cook Islands, Mauritius and Tonga), *Hydrilla verticillata* (in USA) and *Caesalpinia decapetala* (in South Africa).

CBC attempts have been made against only a handful of exotic weeds out of the more than 170 invasive alien plant species recognised in the country. The last arthropod to have been introduced was the gall fly, *Cecidochares connexa*, against *Chromolaena odorata* (Siam weed) in 2005. It is imperative to take up calculated measures to find CBC solutions to weeds that are difficult to control through conventional methods.

We now have the option, wherever possible, to base our future considerations on weed biological control on the World Catalogue, which has three clear categories of CBC agents: (a) Exotic organisms intentionally introduced; (b) native organisms intentionally redistributed; and (c) previously used or potential agents found in exotic ranges where their deliberate release is not recorded. For those weeds that have never been targeted by biocontrol agents, the process should start from scratch. On the bright side, the recent advances in molecular biology enable faster and precise identification of both the target weed and the best candidate organism, and more or less accurate determination of the host range of the candidate. Other advancements in science should also be exploited in CBC of weeds, like the use of unmanned aerial vehicles or drones for the release and spread of arthropods or microbial propagules over a sizeable area. Finally, CBC is here to stay, and India has a major role to play in this field for the benefit of agriculture and environment around the world.

Increasing input resources use efficiency through appropriate weed management in Indian agriculture

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Indian agriculture plays a major role in the country's economy with 60% of India's population depending on agriculture sector. The central concern of Indian agriculture is low productivity, evident in modest average crop yields. India may need at least 20 million tons of additional food every year to meet the minimum food and nutritional demands of the growing population which is expected to be 1.7 billion by 2050. Thus the greatest challenge for Indian agriculture is to produce more with minimal input resources without causing imbalance to environment and in a sustainable manner. One of the approaches to face the challenge is production of crops with increased input resource use efficiency by managing impediments such as weeds, which are adaptable to all adverse environments and compete with the crops for utilization of land, labor, light, nutrients and water resources (Yaduraju and Rao 2013). In this presentation, an effort is made to give an overall picture of resources used in Indian agriculture, extent of competition by weeds for resources with crops and extent of losses caused by weeds and appropriate weed management strategies for enhancing input resources use efficiency of crops for attaining increased crop productivity and production to meet the present and future demands of Indian population.

METHODOLOGY

A review of available literature was made on input resources being used in Indian agriculture, the extent of losses caused by weeds in the inputs used in agro-ecosystems and the weed management strategies suggested for managing weeds and enhancing input resources use efficiency of crops for attaining increased crop productivity and production. In addition to the review, related experimental findings in Bhoosamrudhi program of Karnataka are incorporated. A few suggestions were enlisted for further enhancement of inputs use efficiency through appropriate weed management in Indian agriculture.

RESULTS

In India, weeds are one of the major biological constraints that limit crop productivity causing yield losses ranging from 10 to 100%, while competing with crops for natural and applied input resources. The weeds caused losses in inputs such as land, labor, monetary, nutrients, water and energy resources were reported to vary with the crop grown, amount and quality of inputs applied, geographic region, crop and weed management practices adopted. Utilization of weed smothering ability of component crops coupled with adoption of best weed management in inter cropping systems was reported to increase land use efficiency by Ã 47%. The NPK content of the weeds was reported to be higher as compared to the crop plants resulting in reduced nutrient use efficiency. Adoption of improved weed management in different crops was reported to increase nutrient use efficiency, which varied with varying associated factors. Technological adoption of micro-irrigation systems in different crops was reported to cause not only minimized weed problems, enhanced inputs use efficiency but also reduced expenditure on weed management. It is possible to increase in irrigated area by saving water through best weed management and utilize saved water for bringing more area under irrigation. In rice, improved weed management adoption was reported to cause reduced input use, increased energy output and energy use efficiency. Achievement of a mean 54% higher grain energy yield with a 104% increase in economic returns, 35% lower total water input, and a 43% lower global warming potential index was observed (Ladha et al., 2015) in a study conducted at different countries in South Asia, when integrated weed management was a component of best management practices, conservation agriculture and crop diversification.

CONCLUSION

The future weed management strategies and technologies of India should target at agricultural transformation aimed at an eco-efficient revolution with increases in the efficiency of scarce resources used to meet the food demands of increasing population while minimizing many negative environmental impacts associated with current food systems.

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Emerging challenges and opportunities in weed science research and education

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Weeds by virtue of its dynamic nature have become a constant problem in agricultural production. The extent of weed infestation in the field depends on the agronomic practices used (*i.e.*, crop rotation, type of tillage, method and timing of fertlization, row spacing, and herbicides), soil type, and environmental conditions. Herbicide use for weed control in agricultural crops has made agricultural production simple and economical and resulted in increased farm size. On the other hand, with the availability of selective herbicides for weed control, weed management is no longer an integral component of cropping systems. Although herbicide-based agricultural systems have benefitted the farming community in many ways, continuous use and heavy reliance on herbicides have created the problem of herbicide-resistant weeds, shifts in weed flora, and off-site movement of herbicides in agro-ecosystems. Therefore, the new challenge for weed scientists is to develop innovative, economical, and sustainable weed management systems that can be integrated into existing and future cropping systems to bring a more diverse approach to weed management. Due to diversity and plasticity of weed communities, weed management programs are now considered as a continuous process in the agricultural system.

New challenges, like herbicide resistance, force weed researchers to develop cutting edge technologies in weed science. As with any science, the dynamic nature of weed science will continue to present future researchers with challenges that require innovative solutions, which may once again revolutionize agriculture as it first did with the introduction of herbicides not so long ago.

Studies on the mechanism of herbicide resistance have revealed that plants employ and may evolve a fascinating biological arsenal as a defense. The unraveling of the complexities in metabolic-based resistance is a challenge that has the potential to cause a paradigm shift in our understanding and management of resistant weeds. Basic and fundamental research on the mechanistic and genetic basis of resistance must contribute to missing links of a genetic basis to the evolutionary path to herbicide-resistant plants at different scales: genotypic, population, and ecosystem levels. Future research must focus on questions about standing genetic variations versus novel resistance mutations, fitness benefits, and costs under herbicide selection and links between metabolic resistance and general detoxification pathways involved in stress-response dynamics. In India, global trading is also resulting in weed spread and alarming a new situation in the wake of climate change. Therefore, advanced knowledge in weed science will provide new tools for handling such complex emerging problems related to weed management.

Emerging problems in weed science

Some of the emerging problems in weed science are briefly given below.

- The appearance of herbicide-resistant weeds, including multiple herbicide-resistant species like the *Amaranthus* complex in corn and soybeans and grass weeds in cereals and cereal-based rotations.
- The increase in weediness/plasticity of the major weed species, *e.g.* season long germination and increased metabolic capacity.
- Crop-related weed species, for example, weedy rice in direct-seeded rice, cruciferous weeds in rapeseed, and Johnsongrass and shattercane in sorghum.
- Gene flow from herbicide-resistant (HR) crops to weedy relatives. For example, weedy rice has developed resistance to herbicides used in herbicide-resistant rice in the USA.
- Potential difficulties are controlling HR volunteer crops in rotation, for example, corn in soybeans and oilseed rape/canola in sugar beets.
- Weed shifts are driven by a change from hand weeding to chemical control; triggered by labour shortage and increasing labour costs. The limited spectrum of registered herbicides will subsequently also increase the risk of herbicide resistance.
- An increase in surface-germinating weeds (small-seeded dicots and grasses) due to increased adoption of conservation tillage (e.g., no-till) practices.
- Climate change has led to altered distribution, for example, the appearance of waterfern (*Marsilea* sp.) under wetter conditions in rice in India.
- The water scarcity is driving the move to direct-seeded rice, promoting grass weeds, including weedy rice.
- Increasing problems of parasitic weeds (e.g., *Striga*, *Orobanche*) under continuous cultivation of host crops (e.g., corn, sorghum, rice, sunflower, legumes, and vegetables) combined with low soil fertility.
- General weed problems in specialty crops/vegetables due to the disappearance of old herbicides and the lack of new herbicide molecules.

Opportunities

- There is a need to develop interdisciplinary programs in weed science to learn more about the complexity of weeds in farming systems and discover and implement new solutions. New curricula in weed science should be focused on the concept of the role of genetics, molecular biology, and biochemistry in weed science.
- There is a critical lack of knowledge of weed biology (including biochemical, molecular biological, and genetic aspects), weed ecology, local and global

distribution, and population dynamics of weed species for the development of knowledge based weed management programs.

- There is a need to include economics of crop losses due to weeds and economics of weed control methods in the weed science curriculum.
- Graduates in weed science should have more hands on experience. Crop protection and seed industry should provide training and scholarships to students.
- The intake of students in weed science is decreasing. Reasons need to be identified, and steps need to be taken to solve this issue.
- More investment in weed research funding for long term studies is needed. Private companies should consider funding students' projects.
- There is a need for weed surveys and mapping to understand changes in species composition and geographic distribution. Weed prescription maps and decision making tools should be developed for each region. Knowledge of drone (unmanned aerial vehicles, UAV) should be imparted to weed scientists so that they can use this technology in developing decision making tools.
- The potential utility of field robots and nanoherbicides for weed control should be explored. Their benefits and risks need to be evaluated.
- Develop weed thresholds as part of precision weed control. Need to collect current data on crop yield loss due to weeds to attract funding from different agencies.
- There is need to develop long term management strategies in addition to short term control solutions on the basis of modeling studies.
- Improve knowledge about the mechanisms of the development, spread and stability of herbicide resistance.
- Develop more diversified weed control methods, for example, develop integrated weed management (IWM) systems that include agronomic practices including cover crops, tillage, row spacing, and crop density for sustainable weed management.
- Develop precision weed control systems to optimize the use of herbicides and lower the risk of herbicide resistance development
- More research based on farmers' needs – farmers to be integrated into weed control related research. In other words, there is a need to emphasize on farmers' participatoiry research. Students' research should be conductyed on farmers' fields.

Future directions

1. There is a necessity to increase the life of existing commercial herbicides, effectively by reducing selection pressures on weeds and therefore, preserving the genes for susceptibility. To acheive this implies the need for:

- New and better strategies for the use of herbicides (*i.e.* use of full rates, mixtures, rotations and emphasis on early season weed management).
- More emphasis on the development and use of non chemical means of managing weeds and integration of these methods with chemical weed control methods.
- Smarter use of products, increasing efficiency and effectiveness, through the development and adoption of precision application technology to maximize delivery to the target, and minimize wastage and environmental impact.
- A change in attitude, approach and ultimately behaviours from the control of weeds today to the management of weed populations on a sustainable long term basis.

2. Intensify efforts to find alternative and better ways to manage weeds, such as:

- The invention of new herbicides that can control both susceptible and resistant weed populations.
- The development of new herbicide tolerance traits and the extension of existing traits to different crops, to provide enhanced utility from existing chemical solutions.
- The development of weed seed stimulants and desiccators to explore the germination and dormancy mechanisms of weed seeds for reducing weed seed bank in the soil.
- The development and commercialization of entirely new non chemical technologies (*e.g.* bio control methods, RNAi – RNA interference).
- More holistic research and development on the best practices for sustainably managing weed populations over multiple seasons.

3. Exploration of weeds as a source of useful genetic materials for breeding into crop plants – flood, drought, salt and temperature stress tolerance.
4. Breeding weed-tolerant crops (vigour) and allelopathic crops that suppress/kill weeds.
5. The ecological role of weeds in cropping systems relative to threshold levels for weed management. More focused research on weed ecology in reducing weed seed banks in the soil.

Anticipatory research in weed science to mitigate climate change impact

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Scientists agree that the planet's temperature has risen by 0.5ºC since 1900 and will continue to increase at a faster rate. Because of change in land use pattern, the terrestrial biosphere of 21[th] century would probably be further impoverished in species richness. The biosphere will be generally more weedy. Altered precipitation, evaporation and temperature patterns due to climate change have resulted in weed flora shifts in northern coastal districts of Tamilnadu state, India. In particular, there has been a preponderance of invasive alien species such as *Leptochloa chinensis* and *Marsilea quadrifolia* in wetlands, *Trianthema portulacastrum* in uplands and *Eichhornia crassipes* in aquatic systems. Alteration in the precipitation and evaporation pattern coupled with frequent inundation and drought, increasing temperature regimes and sea-level rises that are regarded as consequences of global warming, would alter the nature of vegetation and agriculture in Asia. Increasing temperature regimes are observed to favour invasive potential of alien weeds in monsoon Asia. Under upland conditions, increasing temperature above 35ºC favoured the germination and establishment of *T.portulacastrum*, an invasive weed originated in Tropical Africa. Germination of noxious carrot grass *Parthenium hysterophorus* L. is observed to be triggered by a combination of higher temperature and moderate available soil moisture. Similarly, the rate of increase in root biomass of invasive alien weed *Prosopis juliflora* under increasing temperatures is observed to be higher, increasing it's persistence potential and invasive behaviour. Research undertaken at Annamalai University in India is providing some alternative solutions to manage these problematic weeds. Innovative use of fish culture and poultry rearing in rice fields was shown to compliment weed control through 400 on-farm experiments, with biomass reductions of invasive alien species ranging from 31-38%, in these districts. Similarly, using goats for off-season grazing reduced the biomass of weeds in upland crops. For example, biomass of the dominant *T.portulacastrum* declined by 23-29% in 500 on-farm participatory experiments. The invasive weed *E. crassipes* in aquatic systems was controlled in seasonal waterbodies within a season, by innovative and integrated use of insect agent (*Neochetina eichhorniae*) and plant product of *coleus amboinicus* Utility modes for consuming the extensive biomass of *E.Crassipes* have also been explored. Results indicate that tempo mediated extraction of Nanofibers offers an innovative tag of utility for management of this weed.

The role of changing climate in triggering the invasive behaviour of certain weed species resulting in a shift in the floristic composition of weeds is becoming obvious. Such a scenario warrants the need for multiple options to address a particular weed problem rather than relying upon unified approach. Accordingly, exploring the feasibility of engaging a systems approach of integrated farming, indigenous knowledge base and weed utility offers good weed solutions that reinforces sustainability.

Herbicide tolerant crops in India: Where do we stand?

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With a rapidly growing global human population, the demand for food, feed, clothing, energy and shelter is expected to increase in future. Given the multitude of social and environmental challenges, improving global agricultural productivity and efficiency is critical. In addition to enhancing the crop productivity, adopting optimal crop production regimens to realize the potential yields of the crop by reducing the losses to crop yields is also a significant strategy. From this context weed management assumes great importance. Weeds affect crop growth and yield more than any other pest. Weeds directly compete with crops for space, nutrients and water from the soil, thus considerably reducing input efficiency and negatively impacting the yield, if not removed in time. Weed management is needed and is a top priority during the initial stages of crop growth. The labour cost is highest among all the costs for agricultural production and with diversification of agriculture and urbanization, the available labour force is shrinking. Globally farmers have graduated from manual weed control to pre-emergence herbicides and then to post-emergence herbicides. Although the Indian Crop Protection market has been traditionally dominated by insecticides with over 70 % share, herbicides are a segment growing rapidly. In India too, use of post-emergence herbicides is growing in the crops where herbicide consumption is high e.g. wheat, rice, soybean, plantations and even vegetables. Alternate new technologies using latest biotech approaches like herbicides tolerant crops with broad spectrum non-selective non residual herbicides are expected to provide better and more cost effective solutions.

Advent of biotechnology in agriculture has paved the way for new techniques like gene insertion technology; Molecular assisted breeding, cell biology *etc*, which can play a significant role in developing products and technologies leading to increased yield and better performance. Genetically modified Herbicide Tolerant (HT) crops offer farmers a choice of flexible and convenient way of weed management. Apart from, HT crops also form an important component of Integrated Weed Management. Globally, HT crops are growing since 1996, which has seen greater adoption by farmers due to their ability to provide desired weed control, flexibility to control weeds at later stages of crop growth, reduced soil compaction, use of low toxicity compounds etc. HT traits still account for highest acreage under GM crops globally followed by the stacked traits of HT and IR, clearly demonstrating the farmers choice (James, ISAAA report on Global status of GM crops 2016). The global experience of HT crops have illustrated that following are the major benefits:

- Offer greater economic and effective season long weed control choice adding to the existing options of manual weed control and selective pre- and post-emergence herbicides.
- Offers flexibility to farmers for over the top application (wider application window) and better weed control with outstanding crop safety.
- Herbicides recommended and used for the herbicide tolerant crops are more environmental friendly as they are non-residual in nature.
- Herbicide tolerant crops help adoption of conservation tillage which helps in preventing soil erosion and reduces turnaround time between harvests to planting of next crop.

In India, there has been multiple HT crops have been developed and field tested for evaluating the efficacy as well as for generating the necessary biosafety data to seek approvals for commercial release. A snap shot of the products being evaluated will be discussed, with greater emphasis on some of the challenges which are being faced by the technology providers. In India, Bt Cotton has ushered in a very positive revolution, and demonstrated the potential of Biotech crops. The current Bollgard II technology was approved in 2006 and since then no other GM crop or trait has been approved for commercial release owing to different set of factors. There is a very robust pipeline of products for different traits in different crops, being developed by both Public and private sectors labs, waiting to be evaluated. This includes many herbicide tolerant crops as well. Over the years, multiple consultations have been conducted under different platforms to discuss the relevance and need of herbicide tolerant crops for Indian agriculture. All these consultations, have recommended the need of this technology to address the challenges faced by Indian farmers, on efficient weed management. In addition to available technologies such as Glyphosate resistant, Glufosinate resistant crops, many academic institutes in India are also involved in research to develop alternate modes of action to develop HT crops. This presentation will try to provide status of research and development of HT crops globally in general and more specifically in India.

Recent trends and development of nanotechnology application in weed management

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Presently thousands of herbicide formulations are available in the market to combat weed plants under diverse situation. In 2002 global herbicide sales were nearly US$28 billion, constituting 47 per cent of the total agrochemicals used worldwide. It would reach $31.5 billion by 2020, registering CAGR of 5.4% from 2014 to 2020. Asia-Pacific is the dominant market in terms of consumption of herbicides (around two fifth of market share). With respect to India the consumption has increased rapidly from 4100 metric tonnes (MT) in 1988-89 to 11,000 MT in 2001-02 and it is likely to further increase in future. It is estimated that the herbicide market would grow at over 10 % per annum (NRCWS).

Although herbicides will continue to be the dominant technology in weed management programs, several problems have arisen from reliance on herbicides including herbicide movement to non-target areas, environmental contamination, and development of herbicide-resistant weeds. Continuous exposure of plant community having mild susceptibility to an herbicide in one season and different herbicide in another season develops resistance to all the chemicals in due course and become uncontrollable through chemicals.

The performance of herbicides in tropical environments can sometimes be erratic and inefficient. This is particularly true for soil-applied herbicides where high temperatures, intense rainfall, low soil organic matter and microbial activity results in rapid breakdown and loss through leaching. Further the the irrgation process reduces the herbicide concentration lead to reduced weed control efficiency coupled with leaching and potential ground water pollution. Thus the half-life period for many soil applied herbicides remains very short period of time ranging from few hours to couple of weeks. Whereas some of the herbicide parent material persist in soil for long time and results in residual toxicity problems. Among the herbicides, atrazine is almost a non-volatile and its half-life in neutral condition varies from 4-57 weeks depending on various environmental factors like pH, moisture content, temperature and microbial activity. Although, there are different methods (by activated carbon adsorption, microbes or air stripping) for removal of atrazine residues from aquatic system, there are no established methods for the vast soil phase. Furthermore the herbicides available in the market are designed to control or kill the germinating or growing above ground part of the weed plants. None of the herbicides are inhibiting the viable underground propagating materials.

Recently scientists have started using nanotechnology to deliver the genes to specific sites at cellular levels and rearrange the atoms in the DNA of the same organism to get expression of desired character, thus skipping the time consuming process of transferring the gene from the foreign organisms. In the management aspects, efforts are made to increase the efficiency of applied fertilizer with the help of nano clays and zeolites and restoration of soil fertility by releasing fixed nutrients. Research on smart seeds programmed to germinate under favourable conditions with nanopolymer coating are encouraging. In the controlled environment agriculture and precision farming input requirement of crops are diagnosed based on needs and delivered the required quantities in right time at right place with the help of nanobiosensor and satellite system. Nanoherbicides are being developed to address the problems in perennial weed management and exhausting weed seed bank. Remediation of environmental contamination of the industrial waste and agricultural chemicals like pesticides and herbicide residues are possible through metal nanoparticles. Details of possibilities and concepts of application of nanotechnology in the crop production and results obtained already in these areas are reviewed in this paper.

Hence it is evident that the task is huge and solutions are limited. Amidst this situation, the new science, nanotechnology throws rays of hope for the development of nanoherbicides with highly specific, controlled release and increased efficiency to circumvent the weed competition under different ecosystem of crop production. Nanotechnology is a technology having the potential ability to study, design, create, synthesis, manipulation of functional materials, devices, and systems to fabricate structures with atomic precision by controlling the size of the matter at the scale 1–100 nanometers (one nanometer being equal to 1×10^{-9} of a meter). The properties and effects of nanoscale particles and materials differs signiûcantly from larger particles of the same chemical composition. By controlling structure precisely at nanoscale dimensions, one can control and tailor properties of nanostructures, such as nanocapsules, in a very accurate manner for slow release herbicide to achieve season long weed control. Degrading phenolic compounds responsible for dormancy of weeds with suitable functionalized nanoparticle would be an intelligent solution for the exhausting the weed seed bank. Despite their minuscule size, the Zero Valent Iron (ZVI) nano particle, a chemical reductant holds the potential to cost-effectively address the issue of atrazine residual toxicity. Hence with the advancement of science in nano-scale level, vast scope is ahead for the weed scientist to resolve the problems encountered in weed management without hampering the natural ecosystem.

Weed management in conservation agriculture systems in Vertisols of Central India

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Conservation agriculture – A new paradigm

Conventional agriculture systems are characterized by intensive tillage operations, clean cultivation, fixed cropping, indiscriminate use of irrigation water and chemical fertilizers. Adoption of these practices over the last 4 decades since Green Revolution period has led to declining factor productivity, deteriorating soil health, surface and groundwater pollution, increasing cost of production and lower profitability. It is therefore, now realized that we need to change the system of crop production, which is more sustainable and in accordance with natural ecosystems. Conservation agriculture (CA) is being considered as a new paradigm in resource management for alleviating the problems associated with the so-called modern cultivation practices.

Two major innovations in the latter half of 20th century have lead to a change in our thinking on crop production. These include the availability of new farm machinery and effective herbicides, which suggest that ploughing of the fields is no longer required for sowing, fertilizer placement and weeding. Zero-till based CA has been promoted in US agriculture since 1970s primarily due to large scale erosion problems in rainfed ecosystem. Subsequently, the adoption was triggered with the availability of herbicide-tolerant crops (HTCs) from mid-1990s. These two technologies, i.e. zero tillage and HTCs have revolutionized world agriculture grown hand in hand showing double-digit growth in most years, and presently adopted on 160 and 180 million ha, respectively.

In the present context, CA involves minimum soil disturbance, soil cover with crop residues, and dynamic crop rotations, besides other suitable modifications in water, fertilizer, weed and pest management as well as farm machinery. These systems are adopted on a large scale in USA, Canada, Brazil, Argentina, Australia and other countries of North and South America. In the Asian countries, the adoption rates are low but progressing in recent times. In India, the efforts are being made since mid-1990s, primarily for growing of wheat in the Indo-Gangetic Plains (IGPs). The area of zero-till wheat reached about 3 million ha in the early part of 21st century, which is now stagnant or decreasing due to various operational constraints.

Weed management in CA

Conservation agriculture (CA) requires a total paradigm shift from conventional systems with regard to management of crops, soil, water, nutrients, weeds and farm machinery. Management of weeds is a major issue in agricultural production system, particularly under CA where the infestation is likely to be higher than conventional intensive–tillage system. Understanding ecology, seed bank and dynamics of specific weed flora is essential for developing effective management strategies in divergent situations. Weed control in CA is a greater challenge than in conventional agriculture because there is no weed seed burial by tillage operations. The behaviour of weeds and their interaction with crops under CA is complex and needs to be fully understood. The weed species that germinate in response to light are likely to be more problematic in CA. In addition, perennial weeds become more challenging in this system. In the past, attempts to implement CA have often resulted in a yield penalty because CA failed to control weed interference. However, the recent development of post-emergence broad-spectrum herbicides provides an opportunity to control weeds in CA. Considering the diversity of weed problems, no single method of weed control, *viz*. cultural, mechanical or chemical provides the desired level of weed control. Approaches such as stale seedbed practice, uniform and dense crop establishment, use of cover crops and crop residues as mulch, crop rotations and practices for enhanced crop competitiveness with a combination of pre- and post-emergence herbicides should be integrated to develop sustainable and effective weed management strategies under CA systems.

Research work at DWR

Directorate of Weed Research, Jabalpur took a major initiative and launched a flagship programme in 2012 to experiment and develop technologies related to CA in the Vertisols of central India. These efforts were complimented by Borlaug Institute for South Asia (BISA) at Jabalpur through large scale demonstration at their research farm. After laser leveling of the fields, we started with zero-till wheat, chickpea, mustard and maize (winter), followed by greengram (summer) while retaining the residues of previous crop *in situ*. Sowing of seed and placement of basal fertilizer was done with a specially-designed zero-till seed-cum-fertilizer drill (Happy Seeder) immediately after the harvest of previous crop with combine. Following the success of these crops, the technology was extended to rainy season crops like rice, soybean, maize, and pigeonpea. Simultaneously with the on-station trials, the on-farm trials were also undertaken in the farmers' fields of Jabalpur district from 2012-13. There has been no looking back since then and the adoption of this technology has now spread to several thousand hectares in the Mahakaushal region of Madhya Pradesh.

Impact of adoption of CA technologies at DWR farm has shown wonders as evident from timely sowing of crops (by June-end for rainy season crops, October-end for mustard and chickpea, mid-November for wheat, and March-end for greengram); increase in cropping intensity from <150% in 2012 to 300% in 2016; large savings in diesel cost, machinery repair and irrigation water; increased productivity (>10 t/ha/year) and profitability; apparent improvement in soil health; and development of a Model Farm on 150 acres. Indirectly, this has proved to be a climate resilient technology as it avoided burning of crop residues, puddling for rice transplanting, and ensured C-sequestration through residue recycling and zero-till cultivation. Contrary to the general belief, the weed infestations have reduced considerably under CA compared with the conventional practices. This technology has found rapid acceptance among the farmers of Jabalpur, Katni, Seoni, Narsinghpur and Mandla districts of Madhya Pradesh. Based on the findings, the Government of Madhya Pradesh has now proposed to cover 50 lakh ha under CA over the next 5 years.

Similar success stories of adoption of zero-till cultivation of crops are also available from the non-IGP area of India. Zero-till mustard is grown on a large scale in rice fallows in the Manipur valley. Further, zero-till maize and sorghum are cultivated in coastal Andhra Pradesh after rice harvest, achieving yields of 8-10 t/ha in place of conventional blackgram / greengram which previously yielded only 500 kg/ha. Shaguna Rice Technology (SRT) based on zero-till broad-bed CA has been promoted in the Konkan region of Maharashtra and caught the attention of farmers and policy makers.

There is no doubt that CA holds a great scope for Indian agriculture, and can be rightly termed as the 'Future of Agriculture' or 'Agriculture of Future'. We are willing to share our expertise with all those who are interested to promote this technology in other parts of the country.

Lead lectures

Herbicide resistance management: How far?

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Weeds are great threat to the agricultural soils and crop growth. The weed flora of crops and cropping systems include grasses, broad leaved weeds and sedges. Crop growers adopt different management techniques to manage weeds that include manual or mechanical weeding, cultural operations and chemical methods. Repeated and intensive use of herbicides with similar mechanisms of action in crops/ cropping systems over a period of time leads to development of resistant biotypes within the community which is a worldwide problem and a challenge for both the farming community as well as weed researchers (Guru 2016). Herbicide resistance is defined as the inherited ability of a weed or crop biotype to survive and reproduce following treatment with a dose of herbicide to which the original population was susceptible. The selection pressure of herbicides on weed population is quite high. Over time, it results in changes in both density and diversity of weed communities. Gradually the resistant biotypes develop multiple resistance posing a greater threat to the production systems. At present, there are 459 unique cases (species x site of action) of herbicide resistant weeds globally, with 250 species (145 dicots and 105 monocots). Weeds have evolved resistance to 22 of the 25 known herbicide sites of action and to 160 different herbicides (Heap 2016). Therefore, while it is important to monitor the cases of resistance continuously, emphasis should be laid on development of effective management strategies to control herbicide resistance.

Earliest report of herbicide resistance dates back to 1957 in *Commelina diffusa* against 2,4-D in Hawaii (Hilton, 1957) followed by the report of triazine resistance in common groundsel (*Senecio vulgaris* L.) in 1964. In India, herbicide resistance was reported for the first time in littleseed canary grass (*Phalaris minor* Retz.) against isoproturon during 1992-93 (Malik and Singh 1995). This was the most serious case of herbicide resistance in the world, resulting in total failure of wheat crop under heavy infestation (2000-3000 plants m^{-2}). Over the years, this species has developed multiple resistances to herbicides with different mechanisms of action such as ALS inhibitors, ACCase inhibitors, and premix of herbicides mesosulfuron and idosulfuron (Vencill *et al.* 2011). Resistance due to target site and enhanced metabolism are reported from Haryana while resistance due to enhanced metabolism has also been reported from Uttrakhand, India (Kumar and Guru 2016). Herbicide resistant weeds have been reported in 86 crops in 66 countries (HRAC, 2015). Among the weed flora, the most important herbicide resistant species reported across the globe include *Lolium rigidum*, *Avana fatua*, *Amaranthus retroflexus*, *Chenopodium album*, *Eleusine indica*, *Echinochloa cruss-galli*, and *Phalaris minor* (Gressel, 2002). Resistance of *P. minor* to Isoproturon was observed in different localities of Udham Singh Nagar and Nainital districts of Uttrakhand and adjoining areas of Uttar Pradesh. Treating *P. minor* seeds collected from farmers' field with recommended (1 kg) and double (2 kg) doses of isoproturon revealed that survival of *P. minor* plants has been on the increase from 2007 onwards (Fig. 1) in this region (AICRP Annual Report 2011).

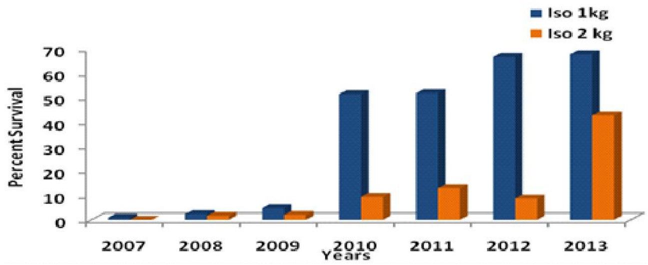

Fig. 1. Survival of *P. minor* at recommended and double doses of isoproturon treatments (mean of all the locations) during 2007 to 2013 (Situation in Uttrakhand and parts of UP).

Factors influencing resistance development

The development of resistance in weeds is a result of a combination of number of factors which include biology of weed species (seed dormancy, germination, mode of pollination, seed production capacity) and weed seed bank in soil, type of herbicide in use and application methods. The weed itself, herbicide and cultivation/crop practices influence the development of herbicide resistance. Over-reliance/ overdependence on herbicide as the only and principal mean of controlling weeds, continuous use of a herbicide as the only and principal mean of controlling weeds, continuous use of a herbicide or herbicides having same mechanism of action, intensive agriculture indulging crop monoculture and zero or minimum tillage have been the major cause of occurrence of herbicide resistance in most weed species. The resistant biotypes may develop cross resistance (Bechie and Tardiff 2012) (resistance to two or more herbicides having the same mode of action) over a period of time. At biochemical level, differential uptake, translocation and metabolism of the herbicide decides the fate of resistance development.

Management of herbicide resistance

Resistance to herbicides is a serious problem worldwide. The cases of resistance are increasing at an alarming rate. Cross and multiple resistances have further complicated the situation. The best solution for minimizing herbicide-resistant weeds or its management is to prevent their development. Prevention is always easier than tackling confirmed resistance. Some important strategies are discussed below related to the herbicide resistance management approach which may provide some needful solutions to this problem. Strategies can be divided in two different parts *viz.*, prevention/delaying resistance and post-evolution of resistance.

1. Prevention/delaying resistance:

Any weed management strategy applied to minimize selection pressure for resistance will block the emergence of resistance. All of the following or combination of some may prevent or at least delay the evolution of resistance in weeds.

a) **Herbicide management:** Screening of alternative herbicides having different modes of action, but same level of activity on target weed and selectivity to crop should be conducted and also should be rotated preferably once in every three years. Two or more herbicides having different modes of action, different degradation pathway, similar persistence and similar target weed specificity should be selected to reduce selection pressure for resistance development. Use of synergists may be employed to augment herbicidal efficacy where metabolic resistance has cropped up in weeds. (Das, 2008)

b) Integrated weed management: It is the simultaneous or sequential use of a range of weed control techniques like chemical to reduce weed population. Herbicide resistant crops serve as an important component in integrated management of weeds since in most cases, glyphosate, control all weeds including resistant ones.

c) Use of herbicides when only necessary: Indiscriminate use of herbicide like pre-emergent application of herbicide must be avoided wherever there is an option for selective post-emergent herbicide. Adoption of herbicide resistant crops can also help in this respect.

d) Control of weed escapes and sanitation of equipment to prevent spread of resistant weeds: Weed escapes must be prevented by adopting optimum dose, time and method of application of herbicides. Dissemination of resistant weed must be prevented by clean tillage and harvest equipment before moving from fields infested with resistant weeds to fields that are not infested. Also rouging for preventing seed production and its contamination in crop harvest.

e) Regular monitoring of field towards cross and multiple-resistance: Before and after herbicide spray, fields should be scout regularly observing the weed flora and destroy the weed patches, if remains after the herbicidal application. Quick responses to weed flora shift should be there to restrict the spread of plants that may have developed resistance.

f) Cultural/ecological approaches: Competitive and high-yielding variety plays a vital role towards combating weed growth and seed production. So using pure and certified seeds prevent dissemination of many weeds such as *Avena ludoviciana*, etc. Suitable combination of stale seed bed and time of sowing could control *Phalaris minor* (Das 2008). Closer row spacing and higher seed rate exert crop plant population effect which may reduce weed growth and enhance crop's competitive ability. Continuous change in the cropping system is very important and beneficial as it maintains soil fertility and also helps to interrupt the life cycle of specific weeds. Therefore, instead of growing the same crop every year, efforts should be made to grow some other crops after every two or three years which allows manipulation of planting time, weed flora shift, cultivation techniques, choice of herbicide with different mode of action, different stage and different way of application. It has been established that rice straw burning stimulates *Phalaris minor* seeds to germinate in large population in wheat and it reduces efficiency of post-emergence herbicides, therefore residue burning should be avoided. Seed production by suspected resistant biotype should be checked to prevent spread of resistance to other areas (Yaduraju 2012).

g) Mechanical and manual approaches: Furrow irrigated raised bed system (FIRBS) is an effective method of non-chemical weed control particularly *Phalaris*. Increased use of herbicide in zero tillage and reduced tillage kills susceptible population and resistant population grows profusely. Deep and inversion tillage reduce herbicide usage and delays resistance build-up. Some other approaches like soil solarisation, harrowing and manual weeding should be adopted.

2. Post-evolution of resistance: To maintain regular check over the herbicide resistant weeds, integrated weed management approaches must be incorporated appropriately.

a) Farmer's awareness and training: They should be imparted training on proper cultural and physical measures, herbicide use (kind, dose, time; rotation, mixture or sequence) and the option of IWM.

b) Monitoring changes in weed population towards resistance if any while using herbicides across the years.

c) **Herbicide management**: The selection pressure for resistance development should be minimized by using lower doses and minimum number of applications/season.

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Innovative approaches for weed management in crops and cropping systems

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Prior to the advent of herbicides, farmers relied on methods such as tillage, manual weeding and diversified crop rotations to control weeds. For nearly 20 years, herbicides have been the preferred method for weed control, and many farmers use more than one herbicide in a single crop. Assessment of the current situation clearly shows that herbicides have not been able to reduce/eliminate weed problems, rather new and difficult-to-control weed species have increased in abundance over time. There is a clear need to explore innovative alternative methods to manage weed populations in the field in order to increase economic returns for farmers and improve sustainability of weed management. Some of the innovative strategies discussed in this paper may address the future needs of weed management research in India.

All weed management decisions need to target the soil weed seed bank, which is the source of future weed infestations. Seed predation can play an important role in determining weed infestations. Crop management practices such as zero till (ZT) can lead to up to 90% seed loss due to predation. Therefore, crop management practices such as ZT and residue retention, which are known to enhance the activity of weed seed decay and predation agents, could cause large reductions in the weed seed bank in the long run. Another approach is to collect weed seed during crop harvest, and then destroy the seeds collected by mechanical methods either during the harvest operation or soon after crop harvest. Farm machines such as Harrington Seed Destructor are particularly effective in this regard and are being used in Australia. However, not all weed species are suitable for harvest weed seed collection. Only those weed species that retain their seeds until harvest are suitable for such mechanical weed management tactics. Local research, with collaboration of agronomists and engineers, should be undertaken to investigate seed dispersal pattern of different weed seeds until crop harvest.

Research has shown that cover crops could play an important role in weed management; however, their level of adoption in India at present is fairly low. Prior to termination, cover crops compete with weeds for resources; release allelo-chemicals into soil which may be detrimental to competing weed species. After termination, weed suppression occurs by physical impedance of weed species with cover crop residue as well as continued leaching of allelo-chemicals into the soil. Cover crops (such as *Sesbania,rapeseed*) could be exploited to suppress weeds and reduce early season herbicide use, and may be a useful part of integrated weed management. Future adoption of cover crops will be dependent upon local research to identify suitable cover crops to fit in cropping systems, on how to maximise weed seed bank depletion during cover cropping and on herbicide strategies that can work effectively in high residue systems in conservation agriculture.

Improvements in planting technology like shredder-spreader have made it possible to sow wheat in heavy residue mulch of up to 8 to 10 t/ha without any adverse effects on crop establishment. Such a heavy mulch has the potential to reduce the establishment of weeds in crops. Crop residues retention, however, limits the choice of herbicides and can intercept 15-80% of the applied herbicides resulting in reduced efficacy. In this context, proper selection of herbicide formulations like granules for application under crop residue retention, or use of higher spray volume may be necessary to increase its efficacy. This indicates need for greater collaboration between agronomists, engineers and chemical industry in future research in this area.

Enhancing crop competitive ability through spatially uniform establishment of healthy and vigorous crop seedlings can cause a large reduction in crop yield loss and weed seed production. In this context, laser land levelling provides uniform soil moisture in the entire field and allows uniform crop establishment and growth leading to a reduced weed infestation. This practice has been quite popular in Punjab and Haryana, and need to be promoted in other parts of the country for enhanced weed control and better efficiencies from other inputs.

The development of multiple herbicide resistance in *Phalaris minor* has been a serious threat to the sustainability of wheat productivity. At present, farmers are often misled by the chemical sellers to use incorrect alternatives which either fail to kill weeds or causes crop damage or both. Proper and regular monitoring of all the existing herbicides through structured herbicide resistance surveys is desirable before the situation comes out of control. This should then be followed by clear advice to the farmers about which herbicides are most likely to work in different areas. The close interaction of scientists and industry to come up with alternate chemistries as well as working out non-chemical alternative is desirable.

In India, ineffective and faulty spray technologies have lead to greater wastage of chemicals. The damaging effects include increased health hazard to human and livestock, reduced herbicide efficacy and crop safety and increased soil toxicity. In a recent study in rice-wheat system at farmers field in Punjab, improved spray technology using multi-boom tractor operated sprayer enhanced weed control by >10% and grain yield by 3-5% compared to conventional spray, indicating the need to create awareness among farmers regarding appropriate spray technologies for enhancing judicious use of herbicides.

Weed management in organic agriculture

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Organic Agriculture has grown out of the conscious efforts by inspired people to create the best possible relationship between the earth and men. Since its beginning the sphere surrounding organic agriculture has become considerably more complex. A major challenge today is certainly its entry into the policy making field, its entry into global market and the transformation of organic products into commodities.During the last two decades, there has also been a significant sensitization of the global community towards environmental preservation and assuring of food quality. Keen promoters of organic farming consider that it can meet both these demands and become the mean for complete development of rural areas. After almost a century of development organic agriculture is now being embraced by the mainstream and shows great promise commercially, socially and environmentally. While there is continuum of thought from earlier days to the present, the modern organic movement is radically different from its original form. It now has environmental sustainability at its core in addition to the founders concerns for healthy soil, healthy food and healthy people.

Organic agriculture is a production system that sustains health of soil, eco-system and people, by relying on ecological process, bio diversity and natural cycles and adapted to local conditions than use of inputs with adverse effects (IFOAM). In our country, concept of organic farming is not new. In traditional India, only organic farming was practiced. Wherein, no chemical fertilizers and pesticides were used and only organic techniques where natural pesticides and organic manures were obtained from plant and animal products were used. During 1950s and 1960s, the ever increasing population of India lead to a food scarcity. The government was forced to import food grains from foreign countries and compelled to increase the food grain production of India to enhance the food security.

To overcome the problem of food scarcity Green Revolution took place under the leadership of Dr. M.S. Swaminathan. During this period, high yielding varieties, chemical fertilizers, synthetic pesticides, mechanization, irrigation projects were introduced in the country, thus, helped in overcoming food crisis, self-sufficiency in food grain, buffer stock of food grains. But, over a period of time, this lead to Stagnation or fall in productivity of crops, decline in soil fertility, salinity problem, lowering of water table, environmental pollution. To overcome these problems farmers realized that the organic farming is the best solution.

How to manage weeds in Organic Agriculture?

Weeds are often recognized as the most serious threat to organic crop production (Penfold *et al.* 1995, Stonehouse *et al.* 1996, Clark *et al.* 1998) and fear of ineffective weed control is often perceived by farmers as one of the major obstacles to conversion from conventional to organic farming (Beveridge and Naylor 1999). Despite this, researchers have so far paid relatively little attention to weed management-related issues in organic agriculture. Furthermore, weed management is often approached from a reductionist perspective, e.g. focusing only on the comparison between types and adjustments of implements for mechanical weed control in a given crop. This conventional approach neglects the systemic (holistic) nature of organic agriculture, which has long been recognized as a pillar for the design of real, effective organic crop production systems (Andrews *et al.* 1990, Lockeretz 2000). Cover crop use is then presented as an important link between soil, crop, pest and weed management in organic systems.

In this respect, a too narrow view of weed management is questionable, because of the likely underestimation of interaction effects among system components and of their carryover across growing seasons, and may also result in information of little practical value to farmers. After a reasoned analysis of the literature on this subject published recently, this paper illustrates how some peculiar features of organic systems suggest the need to undertake an integrated approach to weed management.

Strategies for Successful Weed Management in Organic Farming:

Organic weed management begins with careful planning of the cropping system to minimize weed problems, and seeks to utilize biological and ecological processes in the field and throughout the farm ecosystem to give crops the advantage over weeds. In addition, mechanical and other control measures are usually needed to protect organic crops from the adverse effects of weeds. This is particularly true in vegetables and other annual crops, for which production practices keep natural plant succession at its earliest stages (Bond and Grundy 2001).

Important practices/methods to control weeds in organic farming, *viz*. 1. Prevention 2.Cultural 3.Mechanical 4.Biological 5. Chemical (organically approved) have been discussed.

Patil and Reddy (2014) reported that, in finger millet crop, at 60 DAP the total weed density and weed dry weight was significantly lower in hand weeding twice at 20 and 30 DAP (26.32 and 6.4 g/m^2) treatment and it was on par with stale seed bed technique + inter cultivation twice at 20 and 35 DAP (29.67 and 8.0 g/m^2) and Passing wheel hoe at 20, 30 and 40 DAP + one hand weeding (41.26 and 10.7 g/m^2). Also, significantly higher grain yield was obtained in hand weeding twice at 20 and 30 DAP (5460 kg/ha) as compared to unweeded control (2730 kg/ha) and it was on par with stale seedbed technique + Inter cultivation twice at 20 and 35 DAP (5365 kg/ ha). The trends were similar in the straw yield.

Gnanasoundari and Somasundaram (2014) reported that significantly higher rice grain (4.82 t/ha) and straw yield (7.11 t/ha) was obtained in the treatment rice bran at 2 t/ha on 3 DAT + hand weeding in 35 DAT due to significant reduction in weed dry density and dry weight followed by *Azolla*+ conoweeder incorporation on 20 and 40 DAT as compared to unweeded control which has fetched higher B:C ratio (2.45) (Table 1).

Table 1. Effect of organic weed management practices on Productive tillers, grain and straw yields of rice during *Rabi* 2012 at TNAU, Coimbatore

Treatment	Weed dry weight (g) at 30 DAT	Productive tillers (no./m^2)	Grain yield (t/ha)	Straw yield (t/ha)	B:C ratio
*S. aculeata*as intercrop and incorp on 35 DAT	3.81 (12.54)	160.0	3.86	6.17	1.96
Azolla + manual incorpn. on 20 and 40 DAT	3.21(8.32)	165.0	4.26	6.56	1.97
Azolla + rotary weederincorpn. on 20 and 40 DAT	3.21(8.33)	174.0	4.32	6.40	2.09
Azolla + conoweederincorpn. on 20 and 40 DAT	3.09(7.54)	188.7	4.72	6.90	2.28
Rotary weeder four times on 10, 20, 30 and 40 DAT	3.14(7.87)	168.0	3.87	6.22	2.14
Conoweeder four times on 10, 20, 30 and 40 DAT	3.11(7.70)	182.0	4.28	6.44	2.36
Rice hull solution (50%) on 3 DAT + HW on 35 DAT	6.44(39.51)	143.0	3.60	5.96	1.87
Rice hull solution (50%) on 15 DAT + HW on 35 DAT	7.23(50.30)	130.0	3.42	5.91	1.78
Sunflower dried stalk on 3 DAT + HW on 35 DAT	7.24(50.46)	147.0	3.55	5.87	1.87
Sunflower dried stalk on 15 DAT + HW on 35 DAT	7.20(49.88)	141.0	3.44	5.80	1.81
Rice straw at 3 t/ha on 3 DAT + HW on 35 DAT	3.73(11.93)	154.3	3.66	5.99	1.87
Rice bran at 2 t/ha on 3 DAT + HW on35DAT	2.71(5.34)	192.2	4.82	7.11	2.45
Hand weeding on 15 DAT and on35 DAT	3.18(8.11)	185.0	4.51	6.58	2.20
Unweeded control	8.01(62.25)	105.3	2.58	4.47	1.50
LSD(P=0.05)	0.28	16.66	0.38	0.54	

Zahid Hussain *et al*. (2014) concluded that, weed densities in the intercropping treatments were less than the weed densities in the sole crops.

Anup Das *et al*. (2016) recommended that, mulching with fresh Eupatorium 10 t/ha after earthling up at 30 DAS followed by soybean green manure incorporation in situ + one hand weeding 45 DAS had suppressed the weeds drastically and resulted in higher grain weight per cob in maize.

CONCLUSUION

Despite the serious threat which weeds offer to organic crop production, relatively little attention has so far been paid to research on weed management in organic agriculture, an issue that is often approached from a reductionist perspective. Compared with conventional agriculture, in organic agriculture the effects of cultural practices (eg. fertilization and direct weed control) on crop: weed interactions usually manifest themselves more slowly. It follows that weed management should be tackled in an extended time domain and needs deep integration with the other cultural practices, aiming to optimize the whole cropping system rather than weed control. In this respect, cover crop management is an important issue because of its implications for soil, nutrient, pest and weed management. It is stressed that direct (physical) weed control can only be successful where preventive and cultural weed management is applied to reduce weed emergence (e.g. through appropriate choice of crop sequence, tillage, smotherD cover crops) and improve crop competitive ability (eg. through appropriate choice of crop genotype, sowing/planting pattern and fertilization strategy). Problem of weeds can be minimized by adopting right and integrated organic weed management approach's which, helps in reducing the competition by weeds without any adverse effect on yield, quality of produce and soil/ ecosystem.

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Weed management practices in organic production system- An overview

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The global demand for organic food products is growing at a very rapid rate (FAO 2013). Ever since the environmentalists raised their concern regarding harmful effect of increasing use of chemicals in farming, the consumers are getting conscious and selective about edible products (Willer and Kilcher 2011). This increasing awareness has caused shifts in consumers' tastes and preferences which have led to the domestic as well as global rise in demand for organic products (ICMR 2001). There is a need to develop a holistic approach for weed management. Research into the sustainability of organic farming systems in India has been limited. The research has tended to focus on comparative studies in extensive cropping and livestock systems (Sharma *et. al.* 2015). Limited studies of intensive organic farming systems in India & other countries have been on weed management as compared to conventional practices (Chandra, 2013).

Principles of weed management in NPOP standards

Products used for weed management, prepared at the farm from local plants, animals and microorganisms, shall be allowed. If the ecosystem or the quality of organic products might be jeopardized, the certification programme shall judge if the product is acceptable as per the procedure given to evaluate additional inputs to organic agriculture.The uses of synthetic herbicides are prohibited. The producer shall keep documentary evidences of the need to use the product.

Weed management during different phases under organic farming

A. Preventive strategies: Avoid using crop seeds that are infested with weed seeds, for sowing, avoid adding weeds to the manure pits, clean the farm machinery thoroughly before moving one to another field, keep irrigation channels, fence-lines and un-cropped area clean, seed certification, weed laws and quarantine laws

B. Eradication: It is the complete elimination of all live plant parts and seeds of a weed infestation from an area.

C. Physical strategies:

***Sanitation*:** Use of clean seed, mowing of weeds around the edges of fields, prevention of weed seed mixing with crop seed, application of well rotten FYM can greatly reduce the introduction of weed seeds.

***Summer ploughing*:** The land is ploughed after harvest of rabi crop and left without any crop in summer season. T

***Soil solarization**:* The soil temperature is further raised by 5-10 ^{o}C by covering a pre-soaked fallow field with thin transparent plastic sheet which utilizes solar energy for the desiccation of weeds.

***Stale seed bed**:* Stale seed bed technique comprises of allowing weed to germinate (either after rainfall or through light irrigation) on a prepared fine seed bed, then removing weed seeding though tillage or flame weeding. It provides an opportunity for germination and growth of crop before the next flush of weeds.

D. Cultural strategies: Any tactic that makes the crop more competitive against weed is considered cultural management. Some cultural practices are: use proper *Varieties (*Short statured erect leave varieties permit more light compared to tall and leafy traditional varieties); spray Turmeric solution (take 1 kg turmeric in 4 litre of water and boiled it till half in amount. Mix 2 litre turmeric solution in 100 litre of water and use for spray in one acre as pre-emergence application in wheat crop); *do hand Weeding;* adopt mulching practice (materials such as straw and composted material and plastic mulches like black polyethylene); do crop rotation(it involves alternating different crops in a systematic sequence on the same land for developing a sound long term weed control); grow intercrops; make use of cover crops for suppressing weeds; do green manuring to build up soil organic matter and nutrients and to stimulate biological activity; use cowpea, sesbania, lucerne, berseem as common smother crops to suppress weeds; feed the crop, not the weeds by avoiding pre-plant broadcasting of soluble nutrients which might be utilized by fast-growing weeds than slow-growing crops; use of mechanical tools for weed control; make use of allelochemicals, which posses actual or potential phytotoxicity. Incorporated plant residues can become toxic to weeds by the release of allelopatic chemicals.

CONCLUSION

Weed management in organic farming requires a holistic approach. Weed management in organic production system is based more on ecosystem approach. Adoption of preventive, agronomical, mechanical and biological practices of weed management are well known but the substitute of chemical weed management in intensive crop rotations and high value crops through natural pesticides or indigenous environmental friendly and plant based extracts need the focus of research in different crops & cropping systems.

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Herbicide residue hazards and their mitigation modalities

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The enormous benefits and widespread application of herbicides has undoubtedly increased crop production but has also resulted in unintentional exposure to the ecosystem. As herbicides are chemical in nature and judiciously use of herbicide provide selective and economical weed control but excessive, repeated and indiscriminate use may results in residues, phytotoxicity and adverse effects on succeeding crops, non-targets organisms, environment and ultimately hazard to human. Herbicides use is increasing throughout the globe due to increasing labour cost and wider applicably for quick weed control in various situations. Globally consumption of herbicides is around 44% followed by the insecticides (22%), fungicides (27%) and others (7%). It is estimated that only less than 20% applied pesticides actually reaches the target, the rest is distributed into the ecosystem thereby posing a threat to environment, humans and aquatic life. In India, currently 61 herbicides are registered for use in various crops. In India, herbicide application is more common in wheat crop (44%), followed by rice (31%), plantation crop (10%), soybean (4%), and other crops (11%) (Sondhia 2014).

Herbicide are generally applied at a single dose with single application or sometimes followed by another herbicide/ and or in combinations even it may damage sensitive or succeeding crops. Residue levels exceeding the MRL, due to unnecessarily high application rates, or unnecessarily short pre-harvest intervals (PHIs), are contrary to the concept of good agricultural practices and necessitating use of mitigation measures. Varying degree of herbicide toxicity is not only limited to the residue of parent compounds but also include metabolites which results from chemical transformation under natural conditions. Herbicides can also enter in the body of human and animal through skin, swallowing or breathing. Hence in adverse case scenario a suitable mitigation measure must be followed to avoid any crop injury or damage due to residues.

Herbicide residues in various commodities

Sondhia (2014) demonstrated that residues of sulfosulfuron were significantly higher in surface soil at higher dose compared to sub-surface soil at lower dose up to 150 day at 25-100 g/ha in wheat under field conditions. Terminal residues of pendimethalin were detected in the green field peas (*Pisum sativum* L.), chickpea (*Cicer arietinum* L.), tomato, cauliflower, and radishes applied as pre-emergence herbicide at 750-185 g/ha rates (Sondhia 2013). A pre-harvest interval of 118 days for onion crop after the oxyfluorfen application was suggested (Sondhia 2010). Pendimethalin applied at 0.6-0.9% to tobacco resulted in 0.198 to 0.376 mg/kg residues in tobacco leaves and 0.72 mg/kg residues in leaves treated with 0.5% pendimethalin and 0.04-0.079 mg/kg residues treated with 0.25% pendimethalin (Parmar *et al.* 1998). Disappearances of some of the plants species including weed species is another result of use of herbicides from the agricultural fields. In addition, delays in ûowering and reduced seed production occurred widely on plants sprayed at the seedling stage or at later reproductive periods, with plants sprayed at reproductive stages often exhibiting more sensitivity. High doses or long exposure might lead to deleterious effects on non-target organisms and limit their survival rate. Fenoxaprop and metolachlor were conjugated to earthworm (*Eisenia. Fetida*) at low rates. In a study, indirect effect of herbicides on fishes mortality was more with butachlor, followed by anilofos and oxyfluorfen. Indirect effects of herbicides on human are not common in India. However increasing incidences of acute herbicide self-poisoning by butachlor, fluchloralin, paraquat, 2,4-D, pendimethalin, glyphosate *etc*. are a significant problem in parts of Asia (Sondhia 2014).

Factor affecting herbicide residues

Most residue problems can be associated with the use of long lived soil-residual herbicides. Factors contributing to persistence involve misapplication, environmental condition, soil texture, organic matter content, temperature, rainfall, moisture, water holding capacity and percolation rate. Dry weather for first month after application increase chances of carryover. Some herbicides however do not degrade quickly and can persist in the soil for weeks, months or years following application. High pH (>7) increase carryover of sulfonylureas and triazine group of herbicides. Low pH <6 reduce microbial degradation of sulfonylureas and imidazolines herbicides in soil.

Mitigation strategies for herbicide residues

Hazards from residues of herbicides can be minimized by the application of chemicals at the low dosage. Tillage operations help in bringing deep present herbicide residues to soil surface which would aid in decontamination by volatilization of carbamates, thiocarbamates and dinitroaniline. When herbicide residue is detected or suspected, a tolerant crop should be grown. For example, when carry-over due to imazethapyr is suspected, crops such as canola and flax should be avoided. Herbicide drift can largely eliminated by use of proper nozzle and spraying technique and by using granular, foam, gel and encapsulated materials. Lentil has exhibited sensitivity to sulfosulfuron residues (Sondhia and Singhai 2008) and a higher re-cropping interval is recommended after its application. Typically, ALS-herbicides are detected using root inhibition bioassays, and various susceptible plant species including oriental mustard, corn, red beet have been used.

The use of 5% charcoal filter together with filter pads, or with diatomaceous earth was shown to be effective in removing more than 96% norflurazon residues from the finished wine. Activated charcoal may either be broadcasted or applied as narrow band over the seed at the time of planting. Remediation of *s*-triazine herbicides through electrochemical behaviour on mercury electrodes were demonstrated in the acidity range 2.25 MH_2SO_4 to pH 6.5. The FYM application at 10 t/ha or green manuring with *Sesbania* to the soil found to mitigate the residual toxicity of atrazine, sulfosulfuron and dinitroanilines, pendimethalin, trifluralin fluchloralin in sandy loam soil. Soil can be decontaminated of herbicide residues by crop rotation. Antidotes or plant protectants can be applied to the soil, crop seed or transplants to protect the crop from herbicide injury. Decontamination of herbicide residues by means of controlled irrigation practices alone or in combination with tillage, cropping and use of soil amendments has been achieved with success. Some soil microbes such as bacteria and fungi play an important role in deactivating residues. *Aspergillus flavus* and *Aspergillus terricola* rapidly degraded metolachlor applied at 10 kg/ha up to 92 and 87 % after 20 days in sterile and non-sterile soils, respectively. *Penicillium chrysogenum* and *Aspergillus sps.* were found as potent pyrazosulfuron-ethyl, iodosulfuron and penoxsulam degrading fungi in soil (Sondhia 2016). Use of vegetated ditch with some weed species such as *Dactylis glomerata*, *Convolvulusarvensis*, *Lolium multiflorum*, *Rumex crispus*, *etc*. for mitigation of mesotrione, S-metolachlor and terbuthylazine and control of other mobile herbicides is also increasing. Ditch can immediately reduce runoff concentration of herbicides by at least 50% even in extreme flooding conditions (Otto *et al.* 2015).

CONCLUSIONS

Herbicide must be applied in proper dose and time, based on the physico-chemical properties of herbicides, soil, water, and weather parameters to avoid residue problem. Notwithstanding, to guarantee minimal negative side-effects on crop ecosystems other than the soil-plant systems, herbicides should have no or low toxicity, except for the target weeds. Improved formulations are needed to reduce off-target deposition, improve retention on target, and enhance uptake and translocation. Mitigation strategies of herbicide residue hazard need to be developed to lessen their effect on environment by reducing adverse impacts to less than significant levels. Sensitive crops should be avoided after using a soil residual herbicide. A field bioassay can be performed if suspecting a carryover effect. A critical aspect to mitigation is the implementation of best management practices which is facilitated by effective education and training programs. Though some reports of herbicide poisoning are reported though data on the occurrence of herbicide-related illnesses among defined populations in human, the domain of herbicide illustrates a certain ambiguity in situations in which people are undergoing life-long exposure. Central laws and policies regulate many aspects of herbicides including labeling, registration, and application. However, risks are always present with any herbicide use, but improper use or misapplication can further increase these risks and necessitate use of a suitable remediation measure.

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Remediation strategies for herbicide residues

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Weeds are notorious pests harming the crops however due to their manual control by hand weeding herbicides have not occupied significant share in Indian pesticide market compared to insecticides and fungicides. The herbicide use is increasing by increased urbanization in past few years and so the registration and manufacture in country. Still the use is restricted to large area crop mainly wheat, rice, soybean and orchards. If we considered the herbicide residues these crops are harvested at a longer duration from the treatment time thus most of the time harvested produce is detected with residues below detectable levels. Thus, reliable and accurate analytical methods are essential to protect human health and to support the compliance and enforcement of laws and regulations pertaining to food safety. But the industry sites (soil and water) where the manufacture of these chemicals takes place have higher concentration of these chemicals. Similarly the ultimate "sink" of the applied herbicides in agriculture is also the soil. Besides affecting the soil health the residues can affect the crops in sequence or rotation. Therefore remediation technologies for a clean environment will remain in demand.

Contamination with herbicides can be of two types. (i) Heavily contaminated sources which are generally at the factory site (formulation or manufacture), filling and vacating of spraying equipments which are pin pointed sources. (ii) Normal field soils which get contaminated by repeated or over use of herbicides, however this varies from soil to soil and location conditions. Different methods are suggested for use to remediate the herbicide residues

A. Physical adsorption methods

- Charcoal
- Flyash
- Biochars
- Nanoclays
- Modified clays

B. Bioremediation methods

- Microorganisms
- Bio-stimulation
- Enzymatic methods
- Phytoremediation

C. Combined technologies

- Bio-beds
- Prepared inoculums
- Engineered microbes
- Engineered plants

Mostly herbicides and wastes are being treated by physico-chemical methods which are not so efficient and effective. As a result, residue remains in the soil-water environment causing toxicity to the biota and thereby entering into the food chain. The World Health Organization (WHO) data show that only 2 - 3% of applied chemical pesticides are effectively used for preventing, controlling and killing pests, while the rest remains in the soil. Therefore, the surface soil containing residual pesticides causes toxicity in the surrounding environment.

Soil being the storehouse of multitudes of microbes, in quantity and quality, receives the chemicals in various forms and acts as a scavenger of harmful substances. The efficiency and the competence to handle the chemicals vary with the soil and its physical, chemical and biological characteristics. Among biological approaches, the use of microbes with degradative ability is considered the most efficient and cost-effective option to clean contaminated sites. Microorganisms play an essential role in the bioconversion and total breakdown of such xenobiotics in the environment. Genetic engineering techniques can be used to construct bacteria capable of producing enzymes for pesticide detoxification. Genetically modified microorganisms can provide improved activity which should prove useful in large scale application of microbial degradation to environmental problems. However, it is essential that such microorganisms are thoroughly evaluated for safety before release into environment.

Herbicides vis-à-vis other pesticides: An overview on use and potential hazards

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Agriculture is the soul of Indian economy as it brings home the bread to nearly 60% of the population and supplies food to the remainder. From chronic food scarcity to grain self sufficiency, Indian agriculture has come a long way since independence, despite three fold increase in population. This made Indian agriculture transform from subsistence farming to modern farming. Modern agriculture depends on the four main factors *viz*: seed, water, fertilizers and pesticides. About 35-45% crop production is lost due to diseases, insects and weeds, while 35% crop produce are lost during storage.

Pesticides are the integral part of modern agriculture. The total number of pests attacking major crops has increased significantly since green revolution period. For instance, harmful pests affecting rice has increased from 10 to 17 where as for wheat has increased from 2 to 19. The increased damage to crops from pests and subsequent losses poses a serious threat to food security and further underscores the importance of agrochemicals. Undoubtedly pesticides are said to have contributed to the food security by the way of avoidance of post-harvest losses. The growing popularity of synthetic pesticides in agriculture has over shadowed the traditional methods of plant protection which occur due to insect-pest, diseases and weeds. Pesticides like all other inputs play an important role in increasing agricultural production. However there is a growing awareness about the ill-effect of pesticides on human & animal health, environment, natural resources and sustainability of agriculture production.

Indian pesticide market

Indian Agrochemical Industry is estimated to be US $ 3.8 billion in year 2012. Over the 12th plan period, the segment is expected to grow at 12-13% per annum to reach 7.0 billion. The Indian domestic demand is growing at the rate of 8-9% and export demand at 15-16%.

The per capita consumption of pesticides in India is 0.6 kg/ha which is the lowest in the world. The per capita pesticide consumption in China and USA is 13 kg/ha and 7 kg/ha, respectively. Globally, India is the fourth largest producer of crop protection chemicals, after United States, Japan and China. The crop protection companies in India can be categorized into – multinational and Indian sectors, the latter includes public sector companies and small sector units. According to the Pesticide Monitoring Unit, GOI, there are about 125 technical grade manufacturers, including about 10 multinationals, more than 800 formulators and over 145,000 distributors in India. More than 60 technical grade pesticides are being manufactured indigenously. In India top ten companies control almost 75-80% of the market share. The Indian crop protection market is dominated by Insecticides, which form almost 60% of domestic crop protection chemicals market. Fungicides and Herbicides are the largest growing segments accounting for 18% and 16%, respectively of total crop protection chemicals market.

Pesticide hazard analysis

Toxicity is a measure of the capacity of a substance to cause injury or death, and is related to dose. It is an intrinsic property of the substance. The dose-response relationship is a way of quantifying acute toxicity, and the LD_{50} is a crude estimation of the dose needed to kill 50% of the test animals when they are exposed to the chemical by the oral, dermal or inhalation route.

Three categories for formulated products, *viz*. domestic (where the product is marketed to consumers for use in and around a dwelling), commercial (where the product is to be marketed for general use in the commercial activities) and restricted (where additional limitations respecting the display, distribution, use or operator qualifications must be specified on the label because of safety concerns for humans, plants, animals or the environment) are recommended, based primarily on the WHO Recommended Classification of Pesticides by Hazard. The intent of the RESTRICTED category is to limit the availability of relatively hazardous products to situations where they can be used safely. WHO now uses the Acute Toxicity Hazard Categories from the GHS6 as the starting point for classification and is based on the oral and dermal LD_{50} values (to the rat).

Herbicides v/s other pesticides: contamination and environmental effects

All pesticides including herbicides are toxic, hence, their injudicious and irrational use cause damage to both users and the ecology. As per the WHO classification of pesticides, globally 35% of the 158 insecticides fall under extremely hazardous and highly hazardous categories, compared to only about 4% in case of herbicides. Under slightly hazardous group, the number of herbicides is two times higher as compared to insecticides. The number of herbicides that are unlikely to present acute hazard is as much as 37.1% of the total as compared to 12.6% insecticides. Thus it may be noted that herbicides as a pesticide category are safer or less hazardous than other pesticides especially insecticides.

The other points those can be substantiated in favour of herbicides in comparison to other pesticides are as follow:

Lower pesticide load: With the advent of new herbicides, the application rates have come down drastically. Sulfonylureas for example are applied at very low rates (4-30 g/ha) which lead to low herbicides load in the environment. Many herbicides are tightly bound to soil organic matter with little risk of their horizontal or vertical movement. Further as the Indian agriculture is predominant by marginal and small farmers, there is little chance of a large scale use of a single herbicide and thereby possibility of contamination of surface and ground water.

Lower or no residues in food and environment: The waiting period between application and crop harvest is longer in herbicides in comparison to insecticides and fungicides.

More the interval, more will be the exposure of the herbicide to pressures of degradation or dissipation acting on them. Thus In by default the interval between application and crop harvest is very long which ensures their degradation and dissipation to sub-toxic levels. This is in direct contrast to other pesticides which are quite often used at the later stages of crop growth especially flowering and fruiting stages. Thus there are good chances of findings residues of such pesticides on the crop produce.

The above discussion is not intended to give clear chit to herbicides. Some are distinctly different from other pesticides as discussed below:

- Herbicides are crop specific and different chemicals are used to control the same weed. For example, atrazine in maize and butachlor in rice to control *Echinochloa* sp. This is referred to as selectivity.
- Herbicide dose is of great importance. At higher dose, herbicides may significantly damage the crop because selectivity is dose dependent. Whereas other pesticides at higher doses may not affect the crop.
- Uniform application is critical with herbicides. That is why these are recommended at active ingredient basis and applied after calibration of the sprayers. In contrast other pesticides are applied at recommended concentration
- Cautious application is of great concern as any spray drift reaching the susceptible crop plants grown in the adjoining fields may damage them.
- There is need to educate farmers about the dangers of using herbicides meant for HRCs on non-HRCs while it is not relevant in the case of insecticides. For instance insecticides could be safely used both in Bt-cotton as well as in non-Bt cotton.

Sequential application of herbicides in transplanted rice - weed control, economics and energitics

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Rice (*Oryza sativa* L.) is one of the predominant food crops, a grain of life for more than 70 percent of the Asian population. India is the world's second largest producer (105.3 Mt) covering an area of 44.10 Mha, with the productivity level of 2.38 t/ha (Department of Agriculture and Cooperation 2014). Application of pre emergence herbicides control weeds only in the early stages of crop growth. In order to control the weeds at later stages, application of post emergence herbicides is necessary, hence there is a need to apply herbicides in sequence in order to control weeds effectively.

A field experiment was conducted during *Kharif*, 2015 at College farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, to study the effect of sequential application of herbicides on weeds. The experiment was laid out in a Randomized Block Design with eight (8) treatments replicated thrice. Herbicide treatments were pretilachlor S 30.7% EC 0.5 kg/ha as pre emergence (PE) followed by (*fb)* azimsulfuron 50% DF 35g/ha as post emergence (PoE), pretilachlor S 30.7% EC 0.5 kg/ha as PE *fb* penoxsulam 24% SC 25 g/ha + pyrazosulfuron-ethyl 10% WP 20 g/ha PoE, bensulfuron-methyl + pretilachlor 6.6% G 0.66 kg/ha as PE *fb* pyrazosulfuron-ethyl 10% WP 20 g/ha as PoE, bispyribac sodium 10% SC 25 g/ha as early post emergence (EPoE) *fb* pyrazosulfuron-ethyl 10% WP 20 g/ha as PoE, pendimethalin + penoxsulam 25% SE 600 g + 25 g/ha as PE, pretilachlor S 30.7% EC 0.5 kg/ha as PE *fb* pyrazosulfuron-ethyl 10% WP 20 g/ha as PoE, hand weeding at 20 & 40 DAT and un weeded control. Rice variety MTU-1010 was used for experimentation. A uniform dose of 150: 60: 60 kg of N, P_2O_5 and K_2O ha^{-1} were applied in the form of urea, SSP and muriate of potash respectively.

Lowest density of weeds, weed biomass and higher weed control efficiency was recorded with hand weeding twice at 20 & 40 DAT. Among the herbicides, sequential application of bensulfuron-methyl + pretilachlor 6.6% G at 0.66 kg/ha as PE *fb* pyrazosulfuron-ethyl 10% WP 20 g/ha as PoE and it was statistically on par with hand weeding (20 and 40 DAT). The findings in the present study about sequential application of herbicides are in accordance with Deepthi and Subramanyam (2010). Among the herbicides, highest grain yield (5.6 t/ ha), straw yield (6.29 t/ha) and harvest index (47.14%) were recorded with bensulfuron-methyl + pretilachlor 0.66 kg/ha as PE *fb* pyrazosulfuron-ethyl 20 g/ha as PoE, which was at par with hand weeding twice at 20 and 40 DAT. These results are in conformity with Uma *et al.* (2014). There was reduction in grain yield by 58% due to weed competition reflected in unweeded control. Highest net returns (Rs. 45665/ha) and B:C (2.25) ratio were reported with bensulfuron-methyl + pretilachlor at 0.66 kg/ha as PE *fb* pyrazosulfuron-ethyl at 20 g/ha as PoE (Uma *et al.* 2014). Highest EPg was recorded in bensulfuron-methyl + pretilachlor as PE *fb* pyrazosulfuron-ethyl as PoE (0.14 EPg). Highest EPt was recorded with hand weeding at 20 and 40 DAT (0.28 EPt).These results are in accordance with Tiwari *et al.* (2013).

Table 1. Effect of weed control options on weeds, yield, economics and energetics of transplanted rice

Treatment	Weed density (no./m^2)	Weed biomass (g/m^2)	WCE (%)	Grain yield (kg/ ha)	Straw Yield (kg/ha)	Harvest Index (%)	Net Return (Rs/ha)	B:C ratio	EP_g (kg MJ)
Pretilachlor S 30.7% EC 0.5 kg/ha as PE *fb* azimsulfuron 50% DF 35 g/ha as PoE	4.79(22.0)	3.40(10.67)	85.9	4788	5533	46.40	31597	1.82	0.11
Pretilachlor S 30.7% EC 0.5 kg/ha as PE *fb* penoxsulam 24% SC 25 g/ha + pyrazosulfuron-ethyl 10% WP + 20 g/ha as PoE	4.01(15.66)	2.18(4.00)	94.7	5482	6197	46.94	40765	2.03	0.13
Bensulfuron-methyl + pretilachlor 6.6% G 0.66 kg/ha as PE *fb* pyrazosulfuron-ethyl 10% WP 20 g/ha as PoE	2.64(7.00)	1.68(1.83)	97.5	5610	6290	47.14	45665	2.25	0.14
Bispyribac sodium 10% EC 25 g/ha *fb* pyrazosulfuron-ethyl 10% WP 20 g/ha as PoE	4.14(16.66)	2.26(4.33)	94.2	5305	6100	46.51	41545	2.14	0.12
Pendimethalin + penoxsulam 25% SE 600 g + 25 g/ ha as PE	5.66(31.66)	4.32(17.67)	76.3	4337	5230	43.95	27286	1.73	0.10
Pretilachlor S 30.7% EC 0.5 kg/ha as PE *fb* pyrazosulfuron-ethyl 10% WP 20 g/ ha as PoE	4.37(18.66)	3.04(8.27)	89.6	5117	5817	46.80	38028	2.03	0.12
Hand weeding (20 & 40 DAT)	2.64(7.00)	2.11(3.50)	95.4	5925	6553	47.48	40838	1.89	0.13
Unweeded control	8.05(64.33)	8.74(75.50)	-	2483	3687	40.24	3873	1.11	0.05
LSD (P=0.05)	0.276	0.547	-	332	368	-	2398		0.009

EP_g: Grain Energy Productivity, EP_t: Total Energy Productivity.

From the results it can be recommended that Pre emergence application of bensulfuron-methyl + pretilachlor 6.6% G 0.66 kg/ha followed by post-emergence application of pyrazosulfuron-ethyl 10%WP 20g/ha is the best option for efficient and economic weed control, higher yield and energetics in transplanted rice.

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Weed management in conservation agriculture: Challenges and research needs

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Conservation agriculture (CA) is described as a concept by FAO (2012) for resource-saving agricultural crop production, which is based on enhancing natural and biological processes, above and below the ground. Weeds are the most underestimated crop pests in tropical agriculture both under conventional tillage (CT) and CA systems although they cause higher losses in the yields of crops than other pests and diseases. Crop yield losses due to various pests are: 37% by weeds, 29% by insects, 22% by diseases and 12% by others (Das, 2008). Generally, 20% of the crop yield is lost due to pests, and weeds themselves account for nearly one-third of the total losses due to various pests.

Weed ecology, seed distribution and predation in CA

Weed seed bank is the reservoir of viable weed seeds present in soil causing weed problem in an area. It is dynamic (addition and losses take place constantly) and keeps on changing over times (Baghel *et al.* 2017). Soil bank consists of new seeds, recently shed by weeds (i.e. seed rain) as well as older seeds that are persisting in soil for several years. Generally, 1-9% of the viable seed produced in a year develop seedling, the rest remain viable and germinate in subsequent years, depending on depth of their burial. Tillage affects weed seed survival in soil. Significantly lower density and dry weight of grassy weeds were observed in broad and narrow beds, and conventional tillage compared to minimum tillage. Heavy weed infestation and poor management are obstacles in the wide-scale CA adoption (Buhler *et al.* 1994), while under CT, tillage affects weeds by uprooting, dismembering and burying them deep enough to prevent emergence (Swanton *et al.* 2000). However, it has been experienced that weed problems gradually decrease after a few years of perfect/true CA compared to CT (Sharma *et. al.* 2015), but weed dynamics in the form of emergence of new weeds may take place. Substantial shifts in weed flora, most commonly to perennial weeds, noticed with the CA adoption (Derksen *et al.* 1993). Seed dormancy and germination are important survival mechanisms of weeds. The seed bank in the soil builds up through seed production and dispersal, while it depletes through germination, predation and decay. As tillage is reduced under CA, only the depth of sowing and the type of seeding machine influence vertical weed seed distribution in the soil profile.

The distribution of surface weed seeds through the soil profile associated with the amount of soil disturbance during sowing operation. A large proportion of the weed seed bank will be left on the soil surface after sowing in CA (Chauhan *et al.* 2006). Differential vertical distribution of seeds in the soil has the potential to affect seedling emergence and weed population dynamics, as different soil depths differ in availability of moisture, diurnal temperature fluctuation, light exposure, and activity of predators. Due to minimal soil disturbance in CA, most of the weed seeds remain on the soil surface after crop planting. Such conditions may also be more favorable for granivore fauna, such as ants and other insects. Weed seeds present on the soil surface in CA are most vulnerable to surface-dwelling seed predators and burial makes seeds largely unavailable. Therefore, seed predation could be important in systems where newly produced weed seeds remain on the soil surface, for example, in no-till systems (Baraibar *et al.* 2009). On the other hand, tillage can damage the nests of harvester ants and redistribute the weed seeds stored in superficial chambers (Baraibar *et al.* 2009).

Weed management in conservation agriculture

The crop yield sustainability with same or even higher yield can be achieved with CA as achieved with CT. Yet, weed control in CA poses a greater challenge than in conventional tilled agriculture. A perfect/true CA system is hardly followed in India considering the complexes in existing cropping systems and cultural practices followed by the farmers. As the use of CA has been increasing in recent years due to the economics of crop production and regulatory mandates concerning environmental problems, there is a need to gain understanding on weed management in CA crop production systems. Various approaches, including the use of preventive measures, crop residue as mulches, intercropping, competitive crop cultivars, herbicide-tolerant cultivars, herbicides and IWM are needed to manage weeds in a CA system. Some important considerations for chemical weed management in CA are: economic viability (cost of herbicides and availability in market; availability and access to sprayers; access to clean water; expertise in handling sprayers and herbicides) and ecological sustainability (long term effects of a given herbicide; impact on soil biota; pollution of water bodies; persistence in the soil; resistance by certain weeds to a specific herbicide).

CONCLUSION

A single isolated approach has inherent potential, but cannot be a sole and fool-proof strategy for season-long effective weed management. A suitable integration of the relevant options for weed management in a compatible and mutually-exclusive manner is required to harness better, efficient and longer weed management in crops and cropping systems. We need to choose and hypothesize a set of IWM modules tested at the local, regional and State levels for recommendations.

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Weed management for higher input-use efficiency

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Efficient application of adequate plant nutrients, irrigation and plant protection measures are the essential ingredients for obtaining the maximum yield potential of high yielding varieties of crop plants. These very factors which are indispensable for maximization of crop yields also are congenial for the rank growth of weeds. Weeds are perceived as unwanted intruders into agro-ecosystems that compete for limited resources, reduce crop yields and quality, and force to use of large amounts of human labour and technology to prevent even greater crop losses. They are potentially responsible for 34 percent of crop loss worldwide (Oerke 2006). Weeds compete with crop plants for water, nutrients, and sunlight, thereby reducing crop yields and consequently input-use efficiency. Nutrient and moisture drain by unchecked weed growth assume added significance in the current context of fertilizer crisis involving non availability and higher costs, and change in climatic conditions. While adopting the modern crop production technologies with higher inputs for maximum yield and profit, efficient weed management becomes even more important, otherwise the weeds rather than the crops get benefits from the costly inputs.

Estimates of overall efficiency of applied fertilizer have been reported to be lower than 50% for N, less than 10% for P, and about 40% for K (Baligar *et al.* 2001). Worldwide, nitrogen use efficiency for cereal production is approximately 33% (Raun and Johnson 1998). An adequate supply of plant nutrients during the period of their uptake is essential in order to achieve optimum crop yields. Crop and weed compete for the same resource pool. The presence of weeds throughout the cropping period alters the available nutrient pool in the soil and dry matter with in the plant. A reduced pool of nutrients in the soil results in development of nutrient deficiency symptoms earlier in crops when grown in association with weeds compared to weed free conditions implying more depletion of soil nutrients under weedy conditions. There are few weeds like *Amaranthus* spp., which are nitrophilous in nature accumulate more than 3% N on dry matter basis. Similarly *Anagallis arvensis* and *Achyranthus aspera* contain more than 3.36% phosphorus; and *Chenopodium* and *Portulaca* species are known as potassium lovers and contain more than 4.0% potassium on dry weight basis. *Setaria lutescens* accumulates as high as 585 ppm of zinc in its dry matter. This is about three times more than by cereal crop.

Competition for water in a crop-weed situation increases water stress for the crop due to presence of weeds. Weeds compete for water, reduce water availability, and contribute to crop water stress. Weeds consume water intended for crops, cause water loss by seepage through root channels, transpire water, and cut water flow in irrigation ditches, leading to higher consumption by weeds and more evaporative water loss. For example, the consumptive use of water for *Chenopodium album* has been estimated to be 550 mm against 479 mm for wheat (Shahi 1978). He further noted that the weeds removed moisture evenly from up to 90 cm soil depth, while moisture uptake by wheat was limited to the top 15 cm of soil. In sugarcane, giving irrigation in a weedy situation increased the cane yields by 1-3 t/ha against 10-28 t/ha increase in weed free plots (Saini *et al.* 1993).The transpiration coefficients 'Q' (Amount of water transpired to produce unit quantity of dry matter) of some of the weeds like *Cynodon dactylon* (Q=813), *Digitaria sanguinalis* (Q=696), *Echinochloa colona* (Q=674), *Tephrosia purpurea* (Q=1108) and *Tridax procumbens* (Q=1402) was higher than that of maize (Q=352) and sorghum (Q=394) (Kanitkar *et al*., 1960). Proper weed control increases available soil water for crop reduction. The effect of water stress on crop is a function of the developmental stage at which the stress occurs, duration and severity of stress and weed species present. Under weedy situations, plants develop water stress symptoms (i.e. lower leaf water potential, reduced leaf stomatal conductance, reduced leaf photosynthesis) earlier than when grown in the absence of weeds, suggesting limited water availability under weedy conditions. It is, therefore possible to maintain higher crop productivity and input-use efficiency even under lower levels of nutrient and irrigation by timely and efficiently managing the weed growth.

Due to faster growth, large leaves and climbing devices, weeds compete with crop for solar radiation. The competition for light begins when plants begin to shade each other. Cudney *et al.* (1991) showed that wild oat (*Avena fatua*) reduced light penetration and growth in mixture with wheat by growing taller than wheat. Similarly in soybean, velvetleaf (*Abutilon theophrasti*) intercepted more light than soybean due to its greater height, growth and dry matter allocation to more branches in the upper layers of the canopy (Akey *et al.* 1990).

Continuous use of a particular herbicide for a longer period in the same crop in the same area leads to shift in weed flora. Considering the diversity of weed problem and agro-ecosystems, no single method, whether manual, mechanical or chemical could reach the desired level of efficiency under all situations. Various weed management approaches, such as the use of stale-seedbed practices, mulching, crop rotation, reduced tillage, improved weeding tools, weed-competitive cultivars with high yield potential, appropriate agronomic practices and need-based herbicides, their application timing, rotation, and combinations, etc. need to be integrated to achieve effective, sustainable, and long-term weed control; higher yields and profitability through improved input-use efficiency.

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Biology and management of *Echinochloa* spp. in rice agro-ecosystem

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The genus *Echinochloa* contains about 40–50 species distributed throughout the world primarily in tropical and warm-temperate regions (Michael 2003). Out of these species, *Echinochloa colona* (L.) Link., *Echinochloa crus-galli* (L.) Beauv. and *Echinochloa glabrescens* Munro ex. Hook. f. are dominant *Echinochloa* species in rice agro-ecosystem in India. *Echinochloa crus-pavonis* (H. B. K.) Schult., is also reported to be present in puddle transplanted rice. *E. glabrescens* is recorded to be more dominant than other species in rice under rice – rice cropping system in West Bengal. One of the important characteristics of *Echinochloa* is early maturing and shattering before rice harvesting which results in the seed deposit in the soil and thus enriching the soil seed bank year after year. Infestations of *E. glabrescens* and *E. crusgalli* are severe in rice nursery as well as in the main field of rice, especially where rice-rice cropping system is followed. In rice-rice system, cases have been reported that farmers were compelled to discard their nursery beds because of heavily infestation with *Echinochloa* spp. An attempt has been made in this paper to highlight the biology, ecology, distribution, and management of *Echnochloa* spp. in rice with our experience of working on *Echinochloa* spp. in rice agro-ecosystem.

Biology and ecology

Morphological characteristics and distinguishing features of *E. colona, E. crus-galli, E. glabrescens and E. crus-pavonis* have been studied in West Bengal. *E. glabrescens* is characterized by thin and weak culm, basal leaf sheath greenish; a circular white scar (without hairs) present at the place of ligule; spikelets without or with a very short (upto 2 mm long) awn. *E. crusgalli* is characterized by thick and stout culm; basal leaf sheath purplish; a row of white, erect stiff hairs present at the place of ligule; spikelets with up to 10 mm long awn. *E. crus-pavonis* is characterized by soft, pinkish panicle with crowded spikelets with very long awn.Growth habit, seed dormancy and morphology vary widely among the species of *Echinochloa.* Our experience in the lateritic belt of West Bengal indicated that germination was the highest (83% in *E. glabrescens* and 73% in *E. crus-galli*) for seeds placed on the soil surface, followed by seed burial at 0.5 cm. Emergence in both the species occurred from a maximum depth of 6 cm. Seedling emergence of *E. glabrescens* was the highest in absence of rice residue followed by the treatments in which residue was applied 2 and 4 t /ha (64 and 23% over no residue). Emergence decreased sharply with increasing residue quantity as only 15.6 and 6.6% emergence occurred with residue of 6 and 8 t/ha respectively. Ecophysiological analysis of competition between rice and *E. glabrescens* revealed that about 56.5% yield reduction occurs in summer rice with a density of 80 plants/m^2.

Distribution

E. crus-galli has spread across 61 countries in the world and grows as a weed in 36 crops. *E. crus-galli* has spread widely all around the globe in the last three decades. The species is reported to present in almost all the rice growing states in India. *E. colona* occurs throughout tropical Asia and Africa in rice fields from sea level to 2500 m. It also grows in drier soils, but is shorter and has few tillers, panicles and seeds. Not restricted by soil pH. *E. colona* is now appearing as multi-seasonal annual in many states of India including West Bengal. An extensive survey in the farmer's field was made in different blocks of Birbhum and other adjacent districts to study the level of infestation of the weeds in rice nursery as well as in the main field in the wet and dry season. It revealed that all the three species of *Echinochloa* occurred in the wet and dry season. *E. glabrescens* is more dominant in West Bengal than *E. crusgalli. E. crus-pavonis* is also present in some locations in dry season rice.

Management

Prevention: The important step of management of *Echinochloa* is preventing the weed from entering or establishing within a given area. In the main field, one of the ways of reducing the infestation is to check the entry through rice seedlings from the nursery. As the weed has mimicry with the rice crop, it is very difficult to distinguish in an early stage. But careful observation by the experienced farmer/labour can separate the seedlings at the time of lifting from the nursery. In the case of direct seeding and nursery, sowing of rice seeds free from weed seeds including *Echinochloa* spp. can check the entry of weeds in a rice field.

Cultural: The seed cannot germinate in water deeper than 15 cm, so flooding the rice field to this depth will give the rice seedlings an advantage. Our experience in the lateritic belt of West Bengal indicated that emergence of both the species *E. crusgalli* and *E. glabrescens* occurred even from a flooding depth of 10 cm for 10 and 20 days duration, but further establishment and growth of seedling were checked. Little work has been done on the screening of weed competitive cultivars, but it is an important strategy to reduce yield losses due to competition from *Echinochloa* spp. The cultivar '*Koral*' expressed the highest competitiveness against *E. crus-galli* by gaining higher dry matter and plant height than other cultivars. This cultivar suppressed the weed by 30% (Mennan *et al*. 2012). Mulching with water hyacinth, *Saccharum* and *Indigofera* was effective in suppressing *E. colona* in direct dry sown rice in the Lateritic belt of West Bengal. Rice residue mulch was effective in suppressing *E. glabrescens* both in pot culture and micro-plot experiments.

Manual/Physical: Hand hoeing is an effective method for controlling *Echinochloa* spp., but having mimicry with crop this method proved to be effective only in between rows of rice. Cono weeder and Japanese paddy weeder are also effective in transplanted rice. But availability and higher wages of labour have been a major limitation. Motorized weeder can reduce the labor cost. In Odisha, motorized weeder reduced the weed control cost by US$ 50 and US$ 90/ ha in transplanted and direct-seeded rice, respectively compareeed to hand weeding.

Biological: Biological weed control for *Echinochloa* spp. is not as common as the other methods of weed control. Some pathogenic fungi like *Exserohilum fusiforme*, *Exserohilum monoceras*, *Drechslera monoceras*, *Exserohilum longirostratum*, *Helminthosporium gramineum* and *Curvularia lunata* have been reported to possess a biological activity against *E. crus-galli.*

Allelopathy: Rice plant itself contains a large number of allelochemicals belonging to different classes. But, in India, little information is available on such direction. More than 20 allelochemicals from rice cultivars have been screened against *E. crus-galli*. Co-existence of rice and *E. crus-galli* improves allelopathic expression of rice as momilactone B was released seven times more when *E. crusgalli* was growing along with rice (Kato-Noguchi 2011). Developing rice cultivars with strong allelopathic effect can be effective and economic strategy for the control of *Echinochloa* spp.

Chemical: Herbicides have been playing a very important role in controlling *Echinochloa* spp. Based on series of experiments conducted in West Bengal during last 5-6 years, it was found that pretilachlor + safener at 0.40 kg/ha as pre-emergence, bispyribac sodium 10% SC at 20-40 g/ha, fenoxaprop-p-ethyl 50 g/ha and cyhalofop butyl at 80 g/ha at 15-20 DAS were found effective in controlling weeds in the nursery without any phytotoxic effect on rice seedlings. In transplanted rice, pretilachlor at 0.75 to 1.0 kg/ha as pre-emergence, azim-sulfuron at 35 g /ha, bispyribac sodium at 20-25 g/ha and fenoxaprop-p ethyl at 90 g/ha applied at 2-3 leaf stage were found effective against *E. glabrescens* and *E. crusgalli* with more than 90% weed control efficiency. Cyhalofop butyl at 80 g/ha, bensulfuron-methyl at 60g/ha, penoxsulam at 22.5 g/ha, bensulfuron-methyl+pretilachlor at 60 + 600 g/ha, pretilachlor at 0.75 lit/ha + pyrazosulfuron-ethyl at 25 g/ha at 3 DAT and azimsulfuron + bispyribac- sodium at 35+25 g/ha at 25 DAT both in wet and dry season rice effectively controlled *Echinochloa* spp. Application of pendimethalin or oxadiargyl or pretilachlor + safner as pre-emergence followed by post-emergence application of bispyrabac-sodium or penoxsulam or fenoxaprop with safner have been found very effective in controlling *Echinochloa* spp. and other weeds in direct seeded rice. Herbicides combinations like penoxsulam plus cyhalofop, fenoxaprop plus ethoxysulfuron, bispyribac + azimsulfuron or bispyribac have also been reported to be effective.

Integrated management: Sole dependent on herbicides may lead to evolution of resistance in long run. Integrated use of cultural, mechanical, and biological control measures could help reduce the impact of *Echinochloa* spp. Integrated approach involving closer spacing, pre-emergence herbicide and mulching with water hyacinth, *Indigofera, Saccharum etc.* has been found cost effective in managing *Echinochloa spp*. in direc seeded rice in West Bengal. It is essential to consider integrated weed management approaches for long-term and sustainable management of *Echinochloa* spp. in rice agro-ecosystem.

Utilization: *E. colona* is a good source of nutrients for cattle and is generally collected from the fields and fed to the animal as fodder. In some areas of West Bengal, the seeds are commonly eaten with cultivated rice grains to make rice pudding or *Khir* on Hindu fast – days. The seeds of *E. crusgalli* and *E. glabrscens* are fed to the birds also.

Conclusion and future directions

Integrated approach considering methods of crop establishment, stale seedbed technique, duration, and depth of inundation, competitive crop cultivars including allelopathic potential, tillage practice along with crop residue management, hand/mechanical weeding and good agronomic practices in rice-based system may be effective for developing management strategies of *Echinochloa* spp. Intensive research on eco-physiology and biology, biological control, allelopathy over the locations may lead to the development of management strategies of *Echinochloa* spp. in future. Utilization of seeds by collecting and processing may be one of the future strategies for managing the weed.

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Herbicide tolerant crops: an innovative approach of integrated weed management in crop production

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Crops made resistant to herbicides by biotechnology are being widely adopted in various parts of the world. Over the past few years, several herbicide tolerant crops (HTCs) have become available in many countries for commercial cultivation (Alberto, 2016). From the genesis of commercialization during 1996 to 2016, herbicide tolerant crops have consistently been the dominant traits. In 2014, the stacked double and triple traits occupied a larger area (47.19 million hectares, or 26% of global biotech crop area) than insect resistant varieties (27.23 million hectares) at 15%. Over the past few years, several herbicide resistant crops (HTCs), both transgenic and non-transgenic, have become available in many countries for commercial cultivation (James, 2015). But in India, the technology of herbicide tolerant crops is in initial stage of field evaluation.

Agronomic efficiency of HTCs

Results of field trials conducted at Tamil Nadu Agricultural University (TNAU), Coimbatore, has clearly revealed that application of glyphosate at 2700 g/ha recorded lower weed density, dry weight and higher weed control efficiency in cotton. Similarly from the field experiments at Punjab Agricultural University (PAU), Ludhiana, it is inferred that potassium salt of glyphosate at 900 and 1800 g/ha applied twice as post-emergence gave effective control of weeds (Table 1). Post-emergence application of glyphosate at 900 and 1800 g/ha registered lower weed density, dry weight and higher weed control efficiency in transgenic Hishell and 900 M Gold maize hybrids (Table 2) and post emergence application of glyphosate at 900 and 1800 g a.e/ha registered lower weed density, dry weight and higher weed control efficiency in transgenic 30V92 and 30B11 maize hybrids at TNAU, Coimbatore (Table 3).

Similarly, the field trials carried out at PAU, Ludhiana (Table 2) also clearly revealed that glyphosate at 900 and 1800 g/ha applied at 25 days after sowing recorded effective control of sedges, grasses and broadleaf weeds and significantly reduced weed density and dry matter in transgenic maize hybrids.

Reduced crop injury and environmental safety

Phytotoxicity symptoms were not noticed in cotton with glyphosate at lower doses, *viz*. 900, 1350, 1800 and 2700 g/ha. Regarding transgenic maize hybrids, there was no phytotoxic symptom observed in transgenic maize hybrids due to application of various doses of glyphosate.

In transgenic maize hybrids, POE glyphosate at lower doses like 900 and 1800 g/ha recorded with more number of bacteria, fungi and actinomycetes.

Increased yield and income

Higher yield of herbicide tolerant transgenic cotton recorded with glyphosate at 2700 g/ha over hand weeding twice during winter season (Table 1) as observed at TNAU, Coimbatore and PAU, Ludhiana field trials. Glyphosate at 2700 g/ha recorded with higher gross and net returns and B:C ratio in herbicide tolerant transgenic cotton. Higher grain yield was recorded with POE application of glyphosate at 900, 1800 and 3600 g/ha in Hishell and 900 M Gold transgenic hybrids (Table 2), higher net return and benefit cost ratio was recorded in glyphosate at 1800 g/ha in transgenic 900 M Gold in all the four seasons. POE glyphosate at 900 and 1800 g/ha registered higher grain yield in transgenic 30V92 and 30B11 corn hybrids (Table 3).

Table 1. Glyphosate on weed control and yield in transgenic cotton

Weed management	TNAU, Coimbatore		PAU, Ludhiana	
	Weed Control (%)	Seed cotton yield (t/ha)	Weed Control (%)	Seed cotton yield (t/ha)
Glyphosate 900 g/ha	92.3	2.54	95.9	1.13
Glyphosate 1350 g/ha	93.7	2.71	96.5	1.43
Glyphosate 1800 g/ha	96.6	2.91	97.2	1.35
Glyphosate 2700 g/ha	97.3	3.14	-	-
HW 15 and 30 DAS	85.2	2.50	84.3	1.03

Table 2. Weed control and grain yield in transgenic maize hybrids

Weed management	TNAU, Coimbatore		PAU, Ludhiana	
	WCE (%)	Grain yield (t/ha)	WCE (%)	Grain yield (t/ha)
Hishell POE glyphosate 1800 g/ha	96.69	10.34	95.2	8.50
900 M Gold POE glyphosate 1800 g/ha	95.41	10.46	90.8	8.14
Hishell PE atrazine at 0.5 kg/ha + HW+ IC	91.54	9.23	68.6	7.71
900 M Gold PE atrazine 0.5 kg/ha+ HW+ IC	88.38	8.77	74.4	7.16
Proagro PE atrazine 0.5 kg/ha + HW+ IC	84.84	7.43	69.9	5.98
CoHM 5 PE atrazine 0.5 kg/ha + HW+ IC	82.92	7.08	71.7	7.73

Table 3. WCE and grain yield in transgenic corn hybrids (Coimbatore)

Weed management techniques	Weed Control Efficiency (%)	Grain yield (t/ha)
30V92HR Glyphosate 1800 g/ha	99.53	12.21
30B11HR Glyphosate 1800 g/ha	98.97	11.98
30V92 Pre Emergence atrazine 0.5 kg/ha + HW+ IC	72.57	10.23
30B11 PE atrazine 0.5 kg/ha + HW+ IC	70.33	9.76
BIO9681 PE atrazine 0.5 kg/ha +HW+ IC	68.73	8.00
CoHM5 PE atrazine 0.5 kg/ha +HW+ IC	68.56	7.33

CONCLUSION

Herbicide tolerant crops in general provide broad spectrum of weed control, reduced crop injury and phyto-toxicity, less herbicide carry-over on the succeeding crops, herbicides like glyphosate and glufosinate are environmentally safe with less persistence and residues, new means for weed resistance management, crop and weed management are flexible and simple, better performance in terms of yield and higher profitability in terms of income of Herbicide Tolerant Crops.

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Management of herbicide resistant weeds for sustainable wheat production

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Worldwide herbicide is a key tool of weed management in wheat due to its cost and time effectiveness. However, the sole dependence on herbicides has led to the problem of herbicide resistance evolution in weeds. Globally, 74 herbicide resistant weeds have been reported to infest wheat crop (Heap 2017). In India, after the first case of herbicide resistance detected in Littleseed canarygrass (*Phalaris minor* Retz.) against isoproturon during early nineties new herbicides belonging to ACCase (Clodinafop, fenoxaprop, pinoxaden) and ALS (sulfosulfuron, mesosulfuron) inhibitor groups were introduced for resistance management. However, sole dependence on these groups further led to extension of multiple herbicide resistance in *P. minor* (Chhokar and Sharma, 2008). Many farmers in northern India having infestation of multiple herbicide resistant populations are facing significant wheat yield reductions in the absence of effective alternative herbicides. Further the problem of wheat farmers is being aggravated by the emergence of four new cases of herbicide resistant weeds. Recently the populations of three other weeds namely rabbitfoot grass (*Polypogon monspeliensis* (Linn) Desf.) Toothed dock *(Rumex dentatus* Linn.) and lamb's quarters (*Chenopodium album*) have started defying the control with sulfonylurea herbicides. Another dominant grass weed, wild oat (*Avena ludoviciana* Dur.) has also evolved resistance to Accase inhibitor herbicides (Singh 2016). The increased cases of herbicide resistant weeds are threat to wheat production and productivity. Therefore, alternative herbicides should be identified and integrated with non-chemical methods for effective herbicide resistance management.

METHODOLOGY

Herbicide resistance profile of *P. minor, Polypogon monspeliensis* and *Rumex dentatus* populations was studied for three *Rabi* seasons of 2013-14 to 2016-17 with populations collected from fields having uncontrolled history with different herbicide usage. Through bioassay, quantification of herbicide resistance in different weeds in pots was carried out. Based on the fresh biomass reduction, the 50% growth reduction (GR_{50}) values were determined and based<16> on which effective herbicides were identified. Field trials were also carried out involving various herbicides and tillage options with focus to target the multiple herbicide resistant *P. minor* as well as other weeds.

RESULTS

The bioassay studies have revealed that *P. minor* has evolved multiple herbicide resistance to three modes of action (Photosynthesis at photosystem II site A, ACCase and ALS inhibitor). Some of the resistant (R) populations exhibited GR_{50} values for clodinafop and sulfosulfuron > 20 times greater than that of the most S (susceptible) population. Population having high level of resistance against clodinafop showed cross-resistance to ACCase inhibitor herbicide groups namely fenoxaprop (fop group), tralkoxydim (dim group) and pinoxaden (den group). Likewise, sulfosulfuron resistant populations showed cross-resistance to mesosulfuron and pyroxsulam. The *P. minor* populations resistant to three modes of action (Photosynthesis at photosystem II site A, ACCase and ALS inhibitor) were sensitive to pendimethalin, flufenacet, pyroxasulfone, metribuzin, terbutryn, oxyfluorfen and flumioxazine. Also, the multiple herbicide resistant populations showed sensitivity to, glyphosate and paraquat. *P. monspeliensis* has shown resistance to ALS inhibitor herbicides (Sulfosulfuron, mesosulfuron and pyroxsulam). Another grass weed wild oat (*Avena ludoviciana*) has also evolved resistance to ACCase inhibitor herbicides (Singh 2016). However, these herbicide resistant grass weeds are susceptible to pyroxasulfone and flufenacet. Among broadleaved weeds two weeds have also evolved resistance to ALS inhibitor herbicides. *Rumex dentatus* has shown a very high level of resistance against metsulfuron and resistant population showed cross resistance to iodosulfuron, triasulfuron, florasulam and pyroxsulam but was sensitive to 2,4-D, carfentrazone, metribuzin, pendimethalin and isoproturon. During 2016-17 crop season there is indication that *Chenopodium album* has evolved resistance to metsulfuron at few locations in Karnal (Haryana). The farmers having escape of *Chenopodium album* with metsulfuron managed with 2,4-D. The evolution of herbicide resistance in multiple weeds is an emerging threat to wheat in Indo-Gangetic Plains. Some of the farmers having infestation of herbicide resistant weed populations are facing significant yield reductions due to lack of knowledge as well as unavailability of effective alternative post-emergence herbicides. If timely effective resistance management strategies are not evolved than it may lead to serious consequence of decrease in wheat production. One important aspect for resistance management is early detection of herbicide resistance. Besides bioassay, biotechnological tools can also be employed for large scale screening of weed population for herbicide resistance detection so that alternative herbicides can be used for economic weed control. Tillage also influences the weed flora build up and it has been observed that no-till favours the buildup of *Rumex dentatus* and *Polypogon monspeliensis* but reduces the *P. minor* population. However, no-till seeding also provides the opportunity to restrict the yield reductions due to herbicide resistant multiple weeds populations by integration of pre-seeding application of glyphosate or paraquat in combination with trifluralin or pendimethalin or terbutryn. Moreover, if no-till system with surface residue retention (Conservation Agriculture) is adopted then benefits are more in reducing the weed infestation. For long term effective weed management, the new alternative herbicides in rotations and mixture should be supported with other agronomic practices (adjustment in sowing time and method, choice of cultivar, seed rate, spacing, straw mulching) to impart the competitive edge to crop over weeds.

CONCLUSIONS

The evolution of herbicide resistance in multiple weeds is a major threat to wheat production in India. The impact of herbicide resistant weeds on wheat production and farmers income can be minimized if a range of integrated weed management strategies consisting of alternative herbicide, crop rotation and other agronomic practices such as early sowing of competitive varieties at higher seed rates under conservation agriculture.

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Orobanche and its management in brassicaceous and solanaceous crops

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Inspite of continuous and extensive research by weed scientist, plant breeders and plant protectionists, *Orobanche* is still causing serious problems in large number of crops worldwide. In India, *Orobanche* spp. has emerged as a major threat to rapeseed-mustard production in northern Rajasthan, Haryana, Punjab, north-east Madhya Pradesh and Purvanchal of UP. In Andhra Pardesh, 50% area under tobacco is infested with broomrapes and causing 50% crop losses. In Karnataka state, 90% area under bidi tobacco is infested with this weed with 50-60% yield losses in some areas (Dhanapal *et.al*. 1998). Yield losses due to *Orobanche* spp. in tobacco growing areas of Tamil Nadu, Gujarat and Maharashtra, UP and Bihar is also reported to be very high. Tomato and brinjal crops are also infested with *Orobanche* spp. in Haryana, UP, Bihar, Orissa and Jharkhand. Even *Orobanche* infestation on cauliflower and cabbage was observed in Dadri and Hisar areas of Bhiwani (India).

Orobanche or Broomrape (*Orobanche* spp.) locally known as Margoja, Rukhri, Khumbhi or Gulli is a phanerogamic, obligate, troublesome holo root parasite that lack chlorophyll and obtain carbon, nutrients, and water through haustoria which connect the parasites with the host vascular system. The diversion of these substances to the parasitic weed causes moisture and assimilates starvation, host plant stress and growth inhibition leading to extensive reduction in crop yield and distressed crop quality in infested fields. Depending upon the extent of infestation, environmental factors, soil fertility, and the crops' response damage from *Orobanche* can range from zero to complete crop failure.

Broomrapes are dicotyledonous annual plants (10-60 cms tall, depending upon the species) and recognized by its yellow to straw coloured stems, bearing yellow, white or blue, snap dragon like flowers. The leaves are merely triangular scales and both stem and leaves show absence of chlorophylls. Flowers appear in the axils of leaf and are white and tubular. The fruits are capsular and contain numerous tiny black seeds. Broomrapes reproduce only by dark brown, oval shaped seeds dust sized weighing 3 to 6 µg (Parker and Riches 1993) and very difficult to recognize without a magnifying microscope. Each capsule contains 600-800 seeds and a single plant may produce more than one lakh seeds depending upon species. Seed generally remains viable in soil for 10 to 13 years but the viability can be up to 20 years (Puzilli 1983). The seeds can easily pass unharmed through animal's alimentary tract and infest the host plants (King 1966). Seeds of *Orobanche* generally remain dormant and require a post-harvest ripening period for their germination in response to chemical stimulation (alectrol/orobanchol) from the host plant roots. Following the conditioning phase, germinated seed produces a germ tube or radicle in close proximity to the host plant roots that elongates chemotropically and develops an organ of attachment 'the haustorium', which serves as a bridge between the parasitic weed and host plant to drive water, mineral nutrients and carbohydrates from the host plant. The part of the broomrape seedling swells outside the root of host plant to form a tubercle. Within 1-2 weeks, a shoot bud develops on the tubercle producing a flowering spike which elongates, and emerges outside the surface soil surface soil. Within a period of 15-20 days, the parasitic weed completes its life cycle and shed thousands of seeds per plant.

Compared with non-parasitic weeds, the control of *Orobanche* has been proved to be exceptionally difficult in agricultural crops due to its underground location, close association with host plant roots, complex mechanisms of seed dispersal, germination, and longevity Furthermore, when the plant becomes visible above ground, much of the damage has already been done and control would be futile.

Several means for managing broomrape have been tried over the years, albeit with somewhat limited effectiveness. Crop rotation of mustard with non-host crops like wheat, barley, chickpea *etc*. is the most effective and commonly used management strategy for reducing the weed seed bank in heavily infested areas. The major restriction in adopting crop rotation in long-run is the longer viability of its seeds. In Indian conditions, at Agricultural Research Station, Nepani (Karnataka), sun hemp and green gram proved to be promising trap crops for *Orobanche cernua* control where bidi tobacco is grown in long growing(Kharif and Rabi) seasons (Dhanapal and Struik 2008). An additional cultural means for reducing *Orobanche* seed bank in the soil is the use of 'catch crops' *i.e*., planting an *Orobanche* host crop for inducing parasite seed germination and attachment and that will be destroyed later on by means of light tillage practices or residual soil herbicides. But the use of trap and catch crops to manage this weed is somewhat limited due to (a) enormous amount of *Orobanche* seeds dispersed in the soil and only a small proportion may be exposed to germination stimulants in the rhizosphere (b) feasibility and economics of growing these crops in the existing situations is also a big question mark. Delaying the planting date affects *Orobanche* more than its hosts; the delay should be two weeks only from the date optimal for sowing in an uninfested field. Earlier planting dates are beneficial in certain instances. Late planting of mustard (last week of October-first fortnight of November) is observed to be helpful in reducing the parasitism of *Orobanche* a result of specific weed and host plant differential response to low temperatures (Yadav *et al*. 2005) in Indian conditions. Globally, specific research has been carried out on the development of herbicide tolerant varieties having significant resistance to *Orobanche* infestation in different crops but no such concerted efforts have been put forward to breed such varieties till date in India. Less infestation of the parasitic weed has been observed in raya/mustard grown under flooded irrigation compared to sprinkler irrigation or on conserved moisture as the seeds of *Orobanche* do not survive an extended period of inundation. However it is not true in case of tomato and brinjal grown in Mewat areas of Haryana where water limitation is not a factor. Use of neem cake/vermi-compost/castor cake and increased N fertilization (120 kg/ha) increased/maintained the crop productivity with parasitism of *Orobanche* by sustaining the host plant growth even with depleted fertility status. Hand weeding though useful but it is time consuming, labour intensive, costly affair and virtually impossible. It only limits the seed production but does not compensate the damage in terms of yield losses. Deep tillage during summer months causes seed desiccation and places them below the root zone preventing seed germination to some extent, but again the longer viability (up to 20 years) of weed seeds raises a question mark in long run. Soil solarization has been proven to be the most effective methods in controlling broomrape in open crops fields (Haidar and Sidahmad 2000). But high cost of polyethylene, appropriate machinery and cloud-free sunny days may restrict its use on larger scale.

There are some reports on managing *Orobanche* through biological perpetuation of a fly, *Phytomyza orobanchia* Kalt. Fungi such as *Trichoderma viridae* and *Psuedomonas inflorescence* were tested at farmers' fields and CCS HAU Hisar during 2010-14, but these were found ineffective against *0robanche* in mustard Relative high soil humidity and soil temperatures are required for the development of soil fungi. Extensive research is needed to develop a reliable biological method under Indian conditions.

During the last decades, some potential useful chemical interventions have become available for the control of parasitic weeds but the herbicide must be selective to host and should have high persistence. Soil fumigation with methyl bromide (MB) prior to planting gave effective control of broomrapes but World Health Organization and Agricultural authorities ultimately banned the use of methyl bromide for fumigation purpose because of its negative environmental effects. Ethoxysulfuron and sulfosulfuron herbicides were found selective to tomato without any crop suppression. Low dose of sulfosulfuron at 20 g/ha does not cause any phytotoxicity in brinjal To achieve good parasite control, high herbicide rates at early developmental stages of the parasite are needed: two or three applications of 37.5 g/ha starting two weeks after tomato planting and repeated at two week intervals. The recommended application rates for weed control in potato are a single treatment of 10-40 g/ha only. Study conducted in Nuh area of Mewat (Haryana) revealed post-emergence application of ethoxysulfuron/sulfosulfuron at 25 g/ha at 30 DAS followed by its use at 50 g/ha or sulfosulfuron at 50 g/ha at 30 and 60 DAS, respectively, provides 85-90 % control of Egyptian broom rape in tomato without any adverse effect on crop with yield increase of 46-58% as compared to untreated check. Tomato planted in last week of October needs two sprays of either sulfosulfuron or ethoxysulfuron (25 and 50 g/ha) at 30 and 60 days after transplanting where as in crop transplanted in last week of November need two sprays of sulfosulfuron and ethoxysulfuron at 50 g/ha at 60 and 90 DAT. Pre-emergence use of 25 g/ha ethoxysulfuron followed by post-emergence application at same rate caused although effective in controlling *Orobanche* but causes stunted seedlings even up to 90 DAT resulting in poor yield. No herbicide residues were observed in tomato fruits and soil at harvest. Residual carry over effect of these herbicides applied on tomato was not observed on succeeding sorghum crop planted 2 months after harvest of tomato crop. Studies under taken at Hisar (Haryana) to evaluate the efficacy and to standardize the dose and time of glyphosate application against the parasitic weed *Orobanche* in mustard (*Brassica juncea* L.) from 2006-2010, indicated that glyphosate applied twice at 25 g/ha at 30 DAS followed by 50 g/ha at 55 DAS provided 65-85% control of *Orobanche* even up to harvest (without any crop injury) with yield improvement from 12 to 41% over the traditional farmers' practice in different years of the study (Shoeran *et al*. 2014 and Punia, 2015). Similar findings on the control of *Orobanche* in mustard through herbicide application were also reported by the scientists at Gwalior and Bikaner (DWSR 2009). Care should be taken that the crop should not suffer from any moisture stress at the time of foliar spray, therefore, the fields should be irrigated 2-3 days prior to herbicide application. The proper time and dose of herbicide should also be taken care of to have better efficacy of herbicide application as repetitive/ higher/lower than the recommended dose may lead to adverse impact on mustard crop or may result in development of herbicide-resistant weeds. Use of plant hole application of neem cake at 200 kg/ha at 30 DAT or post emergence application(DCA) of imazethapyr at 30 g/ha at 55 DAT has been suggested to control *Orobanche* in tobacco under western zone of Tamil Nadu in India.

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How widespread is aquatic weeds problem and their management options in India?

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Aquatic plants play an important role in aquatic systems because they provide food and habitat to fish, wildlife and aquatic organisms. Unfortunately, some aquatic plants often become a problem by stopping uses of water and threaten the structure and function of diverse native aquatic ecosystems. A lot of resources are often used to control infestations of aquatic weeds because of their unchecked growth, which interfere with use of water, increase the risk of flooding and result the conditions that threaten public health. Aquatic weeds are well documented to reduce the water availability in aquatic bodies due to excessive evapotranspiration process. In India, the per capita average annual freshwater availability has reduced from 5177 cubic meters from 1951 to about 1869 cubic meters in 2001 and is estimated to further come down to 1341 cubic meters in 2025 and 1140 cubic meters in 2050 (Kumar 2003). Keeping in view the loss of water and deterioration of water quality through weeds, it has become essential to manage weeds to save water for human use.

Aquatic weeds problems in India: Out of about 160 aquatic weeds, the following are of primary concern to India: (1) *Eichhornia crassipes* (2) *Salvinia molesta* (3) *Nymphaea stellata* (4) *Nelumbo nucifera* (5) *Hydrilla verticillata* (6) *Vallisneria spiralis* (7) *Typha angustata* (8) *Chara* spp. (9) *Nitella* spp. (10) *Ipomoea* spp. Among these, *Eichhornia crassipes*, *Salvinia molesta*, *Hydrilla verticillata*, *Alternanthera philoxeroides* and *Pistia stratiotes* are five primary aquatic weeds of the world and qualify the status of worst weeds in India too. It is, however, estimated that 20-25% of the total utilizable water in India is currently infested with water hyacinth (*Eichhornia crassipes*), while in the state of Assam, West Bengal, Orissa and Bihar, it was 40-50%. By the end of 20 centauries, *A. philoxeroides* had become a growing menace in water bodies in India (Sushilkumar 2011). In Kerala, water hyacinth has become one of the most problematic weeds in low land area and water canals where they severely check the flow of water and hamper the water transport. Several irrigation and hydroelectric projects in the country like Nagarjuna Sagar project in Andhra Pradesh, Tungabhadra project in Karnataka and Kakki and Idikki reservoirs in Kerala are suffering with massive growth of aquatic weeds. In several drinking water lakes in Rajasthan, *E. crassipes* is the major weed. Besides water hyacinth, *Trapa*, *Pistia*, *Nymphaea*, *Nymphoides* and *Nelumbo* spp. cover the impounded waters. During 1980s, water hyacinth was a great problem in Pichola lakes at Udaipur which was overcome by the motivation of local people to remove the weed regularly for many years. Now water hyacinth is not a problem in this lake but the lake is severely infested with *H. verticillata*. In Punjab, floating, emerged and submerged aquatic weeds are major problem in many, reservoirs and wet lands. *Typha* spp., *Potamogeton pectinatus*, *Hydrilla verticillata* and water hyacinth have been a big problem in reservoirs and ponds of Punjab. In Tamil Nadu, almost 80% of 39000 tanks are infested with aquatic weeds mainly water hyacinth and

Ipomoea aquatica and water hyacinth are in the first order among water weeds causing menace in Tamil Nadu. The world famous Ootucmund lake was ruined due to infestation of water hyacinth during 1990s. In Gorakhpur (Uttar Pradesh), about 22 sq km Ramgarh lake was filled with dense growth of *Hydrilla*, *Najas*, *Potamogeton*, *Ceratophyllum* and *Chara* spp. Of these, Hydr*illa* and *Najas* spp. infest the lake round the year while others invade it seasonally. The Gujar lake (110 ha) in Varanasi (Uttar Pradesh) has been invaded by aquatic weeds. In West Bengal, *E. crassipes* is the foremost aquatic weed. In the southern part of West Bengal, *Typha* is a noxious weed. Aquatic weeds have played havoc in West Bengal in fishery waters, potable waters and in lowland paddy fields. In Palta and Baranagar water bodies, *Eichhornia* and *Lemna* spp., along with some molluscs, blocked the water pipes. Nesting, growth and foraging success of plant-loving fish are influenced by plant composition and density. Of the 8 lakh ha of freshwater available in India for pisciculture, about 40% is rendered unsuitable for fish production because of invasion by aquatic weeds. Most of the fishery tanks and ponds in and around Bangalore and other cities have been badly invaded by water hyacinth. Some of the weeds like *Eichhornia*, *Azolla*, *Nymphaea*, *Nelumbo*, *Nymphoides*, *Hydrilla*, *Vallisneria*, *Potamogeton*, *Najas*, *Ceratophyllum*, *Typha* and *Utricularia* spp. are problematic weeds in fishery lakes and tanks of Andhra Pradesh, Assam, Haryana, Himachal Pradesh, Jammu & Kashmir, Maharashtra, Tamil Nadu and Uttar Pradesh in India. Some of the well-known fishery lakes like Barwar, Ramgarh and Guiar lake in Uttar Pradesh, Ansupa lake in Orissa, Ootucmund lake in Tamil Nadu, Kollern lake in Andhra Pradesh, Loktak lake in Manipur and the world famous Dal, Nigeen and Walur lakes in Jammu & Kashmir have been largely invaded by the aquatic weeds. Large number of water bodies, both natural and man made in Assam are infested with aquatic macrophytes, making them unfit for fish culture and other economic uses. In Assam in beel fisheries situation, water hyacinth has been considered a major problem by National Bank for Agriculture and Rural Development (NABARD). Fish production was found drastically reduced in beels due to infestation of water hyacinth. Bheema river in Maharashtra had become badly infested with luxurious growth of *Pistia stratiotes*. The river track of about 50 km used to be blocked every year due to rampant growth of *P. stratiotes*. This cause great problem for taking water from rivers for irrigation purposes. Alligator weed has been recorded to extensively invade maize in Palampur, paddy field in Orissa, vegetable crops and maize in Jabalpur (Sushilkumar 2011) and rice field in Karnataka.

Management options for aquatic weeds: Aquatic weeds are being managed by several methods like biological, chemical and physical. Each method has its benefits and drawbacks. In India, rivers and irrigation canals appear to be a potential source for spreading water hyacinth, alligator weed and *P. stratiotes*, which may be brought under the domestic regulation as assessed and discussed by Kristine and Galatowitsch (2004). Manual methods are suitable only for small scale infestation but when management is required in large water bodies, this method become ineffective due to high cost and fast regrowth of aquatic weeds. Although chemical control is effective but has not gained widespread adoption in India due to fear of deteriorating water quality and effect on non-target species. At present, there has been a significant increase in level of nutrients dumped into water from industrial and domestic sources as well as from land through run-off where excessive fertilizers are used. Successful attempts have been made to control water hyacinth in many aquatic bodies in India by use of exotic host specific weevil *Neochetina* spp. from North-East to South, North and West parts of India. In Kerala, the menace of water fern (*Salvinia molesta*) in aquatic bodies and water channels has been reduced drastically through the use of bioagent *Cyrtobagaus salvinae*, but for several other aquatic weeds, suitable bioagents are not available. Some species of herbivorous fishes (*Tilapia* spp. and *Ctenopharyndon idella*) have been utilized to control some submerged weed especially *Hydrilla* spp. with varying degree of success.

CONCLUSIONS

In India, manual removal of aquatic weeds is still widespread instead of using mechanical devices like aquatic weed harvester, which are essentially used in developing countries. It is encouraging to see the growing use of JCB and poklane machines to remove aquatic weeds from aquatic bodies. The removed aquatic biomass is left on the roadside while it can be converted to good quality vermicompost with less expenditure than the agro-waste. The success of bioagent *Neochetina* spp. against water hyacinth is well document from throughout India, but its deliberate and augmentative use is inadequate and need promotion. The integrated use of chemical and biological methods has been demonstrated by the Directorate of Weed Research to reduce the time taken by the bioagent alone, but has not been adopted widely. There is vast scope of introduction of new bioagents against some most problematic weeds like water hyacinth, *Pista stratiotes* and alligator weed. So far, not even a single successful pathogen or mycoherbicide has been employed against any aquatic weed in India in spite of many reports of fungal pathogen infesting many aquatic weeds severely. Use of integrated approaches and converting the removed biomass for vermicompost has been considered a viable option to mitigate the aquatic weed problems.

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Weed risk analysis of potentially invasive plants

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The spread of exotic species into natural communities is threatening native biological diversity and the functioning of ecosystems, and is occurring at an alarming rate (Weber, 2003). The significance of invasive species as a global environmental problem is widely recognized, and article 8(h) of the Biodiversity Convention asks for measures "to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species". As more and more exotic (alien, nonnative) plant, species are introduced and become naturalized in most regions of the world, the likelihood of new invasion events with subsequent negative ecological impacts on the native communities increases rapidly. To prevent new plant invasions, there is an urgent need for the development of early warning systems to determine the likelihood of a given species becoming invasive and of methods to conduct rapid assessments of the status of invaders (Andow 2003). Preventive measures would ideally consist of the prevention of entry of a species, and the restriction of spread once the species is present. It is possible to avoid damage to native ecosystems by exotic species and the associated costs if such harmful species are not used and planted in the first place. However, this step requires knowledge as to whether a particular species will become invasive where it has been introduced but is not yet widespread, or where it is intended for introduction. It is possible to recognise potential harmful species to at least some extent. In fact, sound models that could be applied to predict invasiveness are needed urgently, including quick and easy-to-perform assessment protocols to screen exotic plant species for their potential invasiveness.

METHODOLOGY

Risk assessment protocol

Plant species considered suitable for risk assessment include any exotic species that is not yet present, has a restricted distribution in the risk area, and is planned to be introduced and commercially used on a large scale. The rating system allocates scores to the species for biogeographical, ecological, and experience-linked aspects (Singh and Priyadarshi 2014). The scores of the 12 questions are summed up, and species are classified into "high risk", "intermediate risk", and "low risk".

Validation

We validated the risk assessment scheme by testing a set of well-known invasive plant species. Out of the 47 invasive plant species tested, 36 were recognized as being invasive in the risk assessment, giving an accuracy of 76.6% (Table 1). The species with the highest scores were *Ailanthus altissima*, *Helianthus tuberosus* and *Reynoutria japonica* (Table 2).

The accuracy of correctly predicting non-invasive species (61.6%) was less than the accuracy of correctly predicting invasive species (76.6%). The overall accuracy was closer to 50% than to 100% (Table 1). However, the likelihood-ratio was high (14.8), indicating that the risk assessment has some predictive character.

Table 1. Accuracy and likelihood ratio of the risk assessment

Identified as	Invasive plant species	Non-invasive plant species
Low risk	0 (0%)	119 (61.6%)
Intermediate	11 (23.4%)	64 (33.2%)
High risk	36 (76.6%)	10 (5.2%)
Total number of species	47 (100%)	193 (100%)

Accuracy for identifying invasive species: A_i=76.6%
Accuracy for identifying non-invasive species: A_n=61.6%
Overall accuracy: A_o=64.6%
Likelihood ratio: LR=14.8

Table 2. Invasive plant species and their rating as obtained by the risk assessment.

Species	Sum of scores	Risk class
Ailanthus altissima	39	III (High risk)
Helianthus tuberosus	39	III
Reynoutria japonica	39	III
Reynoutria sachalinensis	39	III
Solidago canadensis	39	III
S. gigantea	39	III
Arundo donax	37	III
Epilobium adenocaulon	36	III
Robinia pseudacacia	36	III
Bidens frondosa	35	III
Cornus sericea	35	III
Heracleum mantegazzianum	35	III
Rudbeckia laciniata	35	III
Crassula helmsii	34	III
Ludwigia grandiflora	34	III
Acer negundo	33	III
Elodea canadensis	33	III
E. densa	33	III
Ludwigia peploides	33	III
Lupinus polyphyllus	33	III
Pinus strobes	33	III
Prunus serotina	33	III
Myriophyllum brasiliense	32	III
Parthenocissus quinquefolia	32	III
Paspalum distichum	32	III
Rubus laciniatus	32	III
Erigeron annuus	31	III
Impatiens glandulifera	31	III
Rhus typhina	31	III
Rumex longifolius	31	III
Oenothera biennis	29	III
Rosa rugosa	29	III
Veronica filiformis	29	III
Lonicera japonica	28	III
Rumex confertus	28	III
Spiraea douglasii	28	III
Amorpha fruticosa	27	II (further evaluatio
Rhododendron ponticum	27	II
Galinsoga ciliata	26	II
Gunnera tinctoria	26	II
Senecio inaequidens	26	II
Vaccinium macrocarpon	26	II
Cyperus eragrostis	25	II
Impatiens parviflora	25	II
Physocarpus opulifolius	25	II
Aster squamatus	24	II
Lysichiton americanum	23	II

1. Climatic match *Does the known geographical distribution of the species include ecoclimatic zones similar with those of the risk area?*	
• No	0
• Yes	2
2. Status of species in Europe *Is the species native to Europe?*	
• Yes	0
• No	2
3. Geographic distribution in Europe *In how many countries does the species occur?*	
• Species occurs in 0 or 1 country	1
• Species occurs in 2–5 countries	2
• Species occurs in >5 countries	3
4. Range size of global distribution *How is the size of the global range (native and introduced)?*	
• Range is small, species is restricted to a small area within one continent	0
• Range is large, extending over more than 15° latitude or longitude in one continent or covers more than one continent	3
5. History as an agricultural weed elsewhere *Is the species reported as a weed from somewhere else?*	
• No	0
• Yes	3
6. Taxonomy *Does the species have weedy congeners?*	
• No	0
• Yes	3
7. Seed viability and reproduction *How many seeds do the species approximately produce?* *If the species is present in the risk area, this question refers to plants within the risk area. If the species is present in Europe, this question refers to plants within the European range. If the species is not present in Europe, this question refers to the native or introduced range of the species.*	
• Few seeds or no viable seeds	1
• Many seeds	3
• Do not know	2
8. Vegetative growth *Allocate species to one of the following. If more than one statement applies, take the one with the highest score.*	
• Species has no vegetative growth that leads to lateral spread	0
• If a tree or shrub, species has the ability to resprout from stumps or stem layering, or stems root if touching the ground	2
• Species has bulbs or corms	1
• Species has well developed rhizomes and/or stolons for lateral spread	4
• Species fragments easily, fragments can be dispersed and produce new plants	4
• Other or do not know	2
9. Dispersal mode *Allocate species to one of the following. If more than one statement applies, take the one with the highest score.*	
• Fruits are fleshy and smaller than 5 cm in diameter	2
• Fruits are fleshy and larger than 10 cm in length or diameter	0
• Fruits are dry and seeds have well developed structures for long-distance dispersal by wind (pappus, hairs, wings)	4
• Fruits are dry and seeds have well-developed structures for long-distance dispersal by animals (spikes, thorns)	4
• Species has mechanisms for self-dispersing	1
• Other or do not know	2
10. Lifeform *What is the lifeform of the species?*	
• Species is a small annual (< 80 cm)	0
• Species is a large annual (>80 cm)	2
• Species is a woody perennial	4
• Species is a small herbaceous perennial (< 80 cm)	2
• Species is a large herbaceous perennial (>80 cm)	4
• Species is a free floating aquatic	4
• Other	2
11. Habitats of species *Allocate species to one of the following. If more than one statement applies, take the one with the highest score.*	
• Riparian habitats	3
• Bogs/swamps	3
• Wet grasslands	3
• Dry (xeromorphic) grasslands	3
• Closed forests	3
• Lakes, lakeshores, and rivers	3
• Other	0
12. Population density *What is the local abundance of the species?* *If the species is present in the risk area, this question refers to plants within the risk area. If the species is present in Europe, this question refers to plant within the European range. If the species is not present in Europe, this question refers to the native or introduced range of the species.*	
• Species occurs as widely scattered individuals	0
• Species forms occasionally patches of high density	2
• Species forms large and dense monocultures	4
• Total score	

Identify risk class score	
3–20	Low risk — Species is unlikely to pose a threat to agriculture/environment
21–27	Intermediate risk — Species requires further evaluation.
28–39	High risk — Species is likely to become a threat to agriculture/environment if naturalized.

DISCUSSION

The objective of a risk assessment for invasive weeds is to decide which species should be listed on quarantine weed lists and to decide which new species infestations should be controlled or removed in order to prevent their spread. Predicting plant invasiveness is, however, limited due to three facts: (1) the high ecological and taxonomic diversity of invasive plants, (2) the lack of ecological data for most plant species, and (3) the variation in invasiveness within the range of a species.

Risk assessment

Answer the following questions and sum up the scores given on the right side. If not otherwise indicated, only one answer applies.

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Opportunities for collaborative research in application of ICTs in weed management

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Knowledge and skills are as important as resources like inputs for the progress of today's agriculture (Saravanan and Bhattacharjee 2014). Achieving food security heavily relies on "Knowledge Resource" in the present day scenario of limiting land and water resources (Saravanan 2011). The ICT in agriculture is an emerging field focusing on the enhancement of agricultural and rural development in India. It involves application of innovative ways to use ICTs in the rural domain. The advancements in ICT can be utilised for providing accurate, timely, relevant information and services to the farmers, thereby facilitating an environment for more remunerative agriculture. Given the development scenario in Indian Agriculture, ICT movement is still evolving.

Decision making on weed control is challenging. The broad-spectrum of weeds found in many fields, and availability of a number of herbicides in the market make the selection of a particular herbicide for a particular field is a difficult task. ICT tools can play a potential role in achieving timely and effective weed management. They contribute to building and strengthening science and technology capacities through the interdisciplinary and participatory building of an ICT knowledge base on major weeds affecting cropping and non-cropping systems. It also helps in establishing collaboration among research and extension personnel, students and farmers in order to get updated technical knowledge and adopt appropriate technologies to propagate best weed management practices.

For effective sharing of the information on weed science, a common ICT platform is the need of the hour in India. Individuals or research groups working on weed science can better exchange or share the research output or information through a common ICT platform. The unique ICT platform can be developed through collaboration among researchers with need based information required by the stakeholder. Those identified researchers are the authorized users of the platform and they can contribute and have the opportunity to upload or get the information from the common platform. This unique platform or otherwise "Weed Research Portal" can be built with the inputs from experts in Weed Science after needful exercise and elaborate deliberations. This can be an effective, powerful and much useful system for the Weed Science in India but only needs strong initiative and firm desire to take it forward.

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Rapid fire presentations

Control of mixed weed flora in wheat with pre- and post-emergence herbicide combinations

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In wheat, adoption of high-yielding varieties with short stature, extensive fertilizer and irrigation use has changed the weed diversity from predominantly broad-leaf weeds to mixed weed flora comprising of grasses and broadleaf weeds. Weed infestation in wheat cause average yield loss of 20-32 % across different wheat growing regions (Chhokar *et al*. 2008). Herbicides are key component of weed management program being followed in developing countries including India. Presence of mixed weed flora and evolution of herbicide resistance warrant use of different herbicide chemistries as tank-mix or pre-mix and their sequential application at different time for pre- and post-emergence weed control (Baghestani *et al*. 2008). Keeping this in view, experiment was conducted to study the weed control with different pre- and post-emergence herbicides used in sequential application or as tank-mix/pre-mix in wheat.

METHODOLOGY

A field experiment was conducted at Agronomy Research Farm, Punjab Agricultural University, Ludhiana during *Rabi* 2015-16. Sowing of wheat cultivar '*HD 2967*' was done in randomized complete block design with four replications comprising 12 weed control treatments including pre- and post-emergence herbicides (Table 1). The pre-emergence herbicides were sprayed at 1 day after sowing (DAS) using 500 L water while post-emergence herbicides were sprayed at 35 DAS with 375 L water/ha using knapsack sprayer. The crop was raised as per local recommendations except weed control treatments. Data on weed biomass was recorded at 60 DAS, and yield attributes and grain yield at crop harvest. The prevailing market prices of inputs and outputs were used for calculating economic returns under different weed control treatments. The comparisons were made at 5 per cent level of significance.

RESULTS

Application of pre-emergence herbicides like pendimethalin 0.75 and 1.0 kg/ha, metribuzin 0.175 and 0.21 kg/ha and tank-mix of metribuzin 0.175 kg/ha with variable dose of pendimethalin (0.75 and 1.0 kg/ha) provided 73-81% control of *Phalaris minor* at 30 DAS. Pendimethalin when used alone or in tank-mix provided 98-100% control of *Rumex dentatus* and *Chenopodium album*. Unsatisfactory control of *Medicago denticulata* was observed with pendimethalin and metribuzin; however, their tank-mix resulted in 77-85% control. Tank-mix of pinoxaden+metsulfuron, pre-mix of sulfosulfuron + metsulfuron, mesosulfuron+iodosulfuron, clodinafop + metsulfuron provided effective control of broadleaf weeds and significantly reduced the weed biomass than unweeded control (Table 1). All the weed control treatments except clodinafop 60 g/ha recorded significantly higher wheat grain yield and yield attributes than unweedeed control. Sequential application of pendimethalin followed by sulfosulfuron recorded the highest WCE (93-96%), wheat grain yield and was at par with all other herbicidal treatments except clodinafop 0.06 kg/ha.

Table 1. Effect of different weed control treatments on weeds and crop yield and yield attributes

Treatment (dose in kg/ha)	Time of application	Weed biomass (g/m^2) at 60 DAS*		Effective tillers ($no./m^2$)	Grain yield (t/ha)	B:C
		Grasses	BLW			
Pendimethalin 0.75	PRE	5.0 (24)	3.1 (9)	341	4.155	1.878
Pendimethalin 1.0	PRE	3.7 (13)	2.6 (6)	350	4.260	1.855
Sulfosulfuron 0.025	POST	4.4 (19)	3.2 (9)	348	4.228	1.870
Metribuzin 0.175	PRE	5.4 (28)	3.4 (10)	348	4.225	1.875
Metribuzin 0.21	PRE	4.4 (18)	3.3 (10)	348	4.269	1.890
Clodinafop 0.06	POST	5.4 (29)	4.5 (19)	301	3.116	1.370
Pendimethalin 0.75 + metribuzin 0.175	PRE	3.4 (11)	3.0 (8)	367	4.396	1.903
Pendimethalin 1.0 + metribuzin 0.175	PRE	3.4 (11)	2.4 (5)	358	4.396	1.941
Pendimethalin 0.75 *fb* sulfosulfuron 0.018	PRE *fb* POST	2.0 (3)	1.0 (0)	372	4.635	2.024
Pendimethalin 1.0 *fb* sulfosulfuron 0.018	PRE *fb* POST	1.6 (2)	1.0 (0)	370	4.638	2.009
Sulfosulfuron+metsulfuron (Pre-mix) 0.03 +0.002	POST	6.1 (37)	1.0 (0)	368	4.443	1.944
Pinoxaden 0.06 + metsulfuron 0.004 (Tank-mix)	POST	4.4 (23)	1.0 (0)	363	4.545	1.991
Mesosulfuron + iodosulfuron (pre-mix) 0.012 +0.0024	POST	5.1 (26)	1.0 (0)	356	4.496	1.955
Clodinafop + metsulfuron (pre-mix) 0.06 + 0.004	POST	4.7 (21)	1.0 (0)	311	4.155	1.805
2 HW	30 and 60 DAS	1.0 (0)	1.0 (0)	372	4.633	1.514
Unweeded control	-	5.7 (32)	4.1 (16)	259	2.672	1.203
LSD (P=0.05)	-	1.1	0.5	3.1	0.5	-

PRE: pre-emergence; POST: post-emergence; *Data is subjected to square root transformation. Figures in parenthesis are means of original values

CONCLUSION

Sequential/tank-mix application of pre- and or post-emergence grass and broad-leaf herbicides could be adopted for broad-spectrum control of weeds in wheat.

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Pre-emergence herbicide, an ancillary apt for annual planning of weed management in system intensification at inceptisol

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The 'System Intensification' using more biological inputs through best management practices of farmers' available resources, is the best alternative methodology for sustainable food, nutrition, ecological and health security (Ghosh *et al.* 2016). Annual planning of weed pest management (APWPM) aims to diminish the weed seed bank in crop field prior to crop planting and to reduce the weed competition in critical crop weed competition period (CCWCP) by using PE herbicides.

METHODOLOGY

Field experiments were conducted at Viswavidyalaya Farm during 2011-2016 on *pre-Kharif Vigna mungo* cultivar (cv.) '*Sarada (WBU108)*' / *Vigna radiate* cv. '*Sonali (B-1)*' – *Kharif* direct seeded puddled / transplanted *Oryza sativa* cv. Satabdi (IET 4786) – *Rabi Solanum tuberosum* cv. Kufri Jyoti / *Allium cepa* cv. Sukhsagar crop sequences in RBD with varied treatments (5-12) and number of replications (3-4) in 4 m x 5 m plots. The crops were grown following system intensification (SI) package of practices and using annual planning for weed management (APWM). For APWPM glyphosate 71% SG + oxyfluorfen 23.5% EC mixture 1000 g/ha was used after pre-*Kharif* crops besides the application of selective pre-emergence (PE) organic herbicides treatment wise in different crops along with hand weeding (HW), post-emergence (POE) herbicides and weedy check as standard. Weed density and biomass at 30 and 50 DAP; biological yields and yield attributes along with population of soil microflora in the rhizosphere soil were also recorded at 5, 10, 15 and 30 DAA and at harvest.

RESULTS

The results (Table 1) revealed that in all crops use of PE herbicides in APWPM showed enhanced productivity in comparison to standard POE herbicides. PE herbicides treatments recorded 30.5 and 10.3% more productivity over POE treated plots and 38.4 and 60.0% over weedy check in black gram and green gram, respectively. In direct-seeded puddled and transplanted paddy, the corresponding figures were 2.74 and 5.14% and 32.7 and 31.0% while in potato and onion these figures were 21.1 & 30.4 % and 42.0 and 49.0% respectively. The soil microflora population (Fig. 1) at harvest revealed an increasing in all PE herbicides used plots though an initial decreasing trends upto 30 DAP.

CONCLUSION

Use of PE herbicides in APWPM under SI cultivation, because of its' optimistic capability, is more appropriate than that of POE herbicides in respect of timely weed management, better WCE, refining soil health and increasing sustainable crop productivity.

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Table 1. WCE and Productivity of Blackgram / Green gram – DR Paddy / TR paddy – Potato/Onion crops grown in sequence following APWPM during 2011-16

Crop	Treatment	Dose (g/ha)	WCE (%) 30 DAS	Yield (t/ha)
Pre-kharif season (Mid March – Mid June)				
Black gram (*Vigna mungo*)	Oxyfluorfen 23.5% EC at 1 DAS	100	73.61	1.19
	Pendimethalin 30 EC at 1 DAS	750	71.67	1.08
	Quizalofop ethyl 5 EC at 20 DAP	50	53.33	0.87
	Hand Weeding	20 DAS	74.33	1.26
	Weedy Check	-	-	0.82
	SEm (±)			0.05
	CD (P=0.05)			0.15
Green gram (*Vigna radiata*)	Oxyfluorfen 23.5% EC at 1 DAS	100	72.22	0.99
	Pendimethalin 30 EC at 1 DAS	750	71.68	0.93
	Quizalofop ethyl 5 EC at 20 DAP	50	56.67	0.87
	Hand Weeding	20 DAS	75.37	0.97
	Weedy Check	-	-	0.60
	LSD (P=0.05)			0.09
Kharif season (First week of July – End October)				
Direct seeded puddled paddy (*Oryza sativa*)	Oxyfluorfen 23.5 EC at 1 DAP	100	58.27	3.23
	Bispyribac sodium 10 SC at 1 DAP	20	56.95	3.19
	CyhalofopbutyI 10 EC at 1 DAP	100	53.30	3.14
	Carfentrazone ethyl 40 DF at 1 DAP	25	54.31	3.18
	Almix 20 WP at 25 DAP	4	66.70	3.11
	Pyrazosulfuron ethyl 10 WP at 20 DAT	30	61.80	3.09
	Hand Weeding Twice	20 & 40 DAS	69.57	3.30
	Weedy Check	-	-	2.40
	LSD (P=0.05)			0.13
Transplanted paddy (*Oryza sativa*)	Bispyribac sodium 10 SC at 1 DAT	20	68.95	4.19
	Butachlor 50 EC at 1 DAT	1250	63.31	4.04
	Triasulfuron 20 WG at 1 DAT	12	67.28	4.06
	Pretilachlor 50 EC at 1 DAT	500	69.62	4.17
	Pretilachlor 30.7 EC at 1 DAT	500	71.31	4.26
	Oxadiargyl 80 WG at 1 DAT	100	68.27	4.23
	Oxyfluorfen 23.5 EC at 1 DAT	100	69.58	4.15
	Flucetosulfuron 10 WG at 1 DAT	20	64.72	4.12
	Almix 20 WP at 25 DAP	4	74.33	3.98
	Pyrazosulfuron ethyl 10 WP at 20 DAT	30	67.80	3.92
	Hand Weeding Twice	20 & 40 DAT	75.31	4.45
	Weedy Check		-	3.17
	LSD (P=0.05)			0.13
Rabi /Winter season (First week of November – End Fenruary)				
Potato (*Solanum tuberosum*)	Oxyfluorfen 23.5 EC at 1 DAP + Earthing up at 25 DAP	100	93.22	31.86
	Pendimethalin 30 EC at 1 DAP + Earthing up at 25 DAP	750	89.32	27. 70
	Paraquat dichloride 24 SL at 1 DAP + Earthing up at 25 DAP	2500	91.68	29. 33
	Metribuzin 70 WP at 1 DAP + Earthing up at 25 DAP	600	95.37	33. 20
	Metribuzin 70 WP at 40 DAP + Earthing up at 25 DAP	600	72.37	25. 20
	Hand Weeding + Earthing up at 25 DAP	15 DAP	92.38	32.58
	Weedy Check + Earthing up at 25 DAP	-	-	21.50
	LSD (P=0.05)			1.06
Onion (*Allium cepa*)	Oxyfluorfen 23.5%EC at 1 DAP + MW at 30 DAP	100	68.73	29.50
	Oryzalin - XL 40 SC at 1 DAP + MW at 30 DAP	6.25 l / ha	60.31	27.67
	Pendimethalin 30 EC at 1 DAP + MW at 30 DAP	750	56.67	26.30
	Quizalofop ethyl 5 EC at 20 DAP + MW at 30 DAP	50	48.60	21.33
	Hand Weeding+ MW at 30 DAP	25 & 50 DAT	71.33	31.56
	Weedy Check+ MW at 30 DAP	-	-	18.67
	LSD (P=0.05)			2.72

Sequential herbicide application and their effect on growth and yield of *Rabi* onion

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Onion (*Allium cepa* L.) is an important export oriented vegetable among the cultivated *Allium* in India. India ranks 1st in area, 2nd in production and 3rd in export in the world. Onion is a condiment crop, which is consumed fresh in salads or added in cooking dishes as a spice. Onion bulb is rich in phosphorus, calcium and carbohydrates. Although India is a leading country in area and production but the productivity is very low as compared to other leading countries in the world due to many factors. One of the main limiting factors is weed infestation. Weeds compete with onion crop for nutrients, soil moisture, space, light and considerably reduce the bulb yield, quality and value of the crop through increased production and harvesting costs. Losses caused by weeds have been estimated to be much higher than those caused by insect pests and diseases. Generally, the bulb yield of onion reduced by 30-60% due to weed infestation. Weed management may involve non-chemical and or chemical methods. The major aim is to manage the weed population to a level below that will cause a reduction in economic return for the farmer. An integration of different control methods, therefore, needs to be addressed in future research. This study was therefore, conducted to compare the effectiveness of different weed control options in onion crop with the objectives to study the effect of sequential herbicide application on growth and yield of onion and growth of weeds.

METHODOLOGY

A field experiment was conducted during *Rabi* season of 2015 at research farm, Division of Agronomy, ICAR-IARI, New Delhi to study the sequential herbicide application and their effect on growth and yield of *Rabi* onion (*Allium cepa* L.). The experiment was conducted in a split-plot design keeping three crop establishment methods (flat and raised beds with residues and without residues) in main plot and six weed control treatments (pre-emergence and post-emergence) in sub-plots (pendimethalin 1.0kg/ha PE, pendi 0.5 kg/ha PE *fb* ethoxy 15 g/ha POE, pendimethalin 0.5 kg/ha PE *fb* quizalofop-ethyl 50 g/ha (POE), pendimethalin 0.5 kg/ha PE *fb* imazethapyr 100 g/ha (POE), weedy check, weed free check. The *Rabi* onion variety *'Pusa Ridhi'* was transplanted dated 15.01.2015 keeping a planting geometry of 15 x 7.5 cm. All the recommended package of practices was followed for raising a healthy crop. The data on growth parameters of the crop was taken according to standard procedures. For recording weed data, weed count was taken using a 50cm ^{2} quadrat, weed fresh weight and dry weight was recorded and presented on area basis.

RESULTS

The onion crop grown on beds have an edge over the flat sowing and incorporation of crop residues showed an additional impact on growth parameters of onion and recorded significantly lesser number of weeds and fresh and dry weight of weeds. Significantly higher leaf area and dry weight of bulbs was observed in crop raised on beds with 2.5 t/ha of crop residues compared to the rest of treatments and this treatment recorded significantly lesser number of weeds, fresh and dry weight of weeds/m^2 which might be due to lesser light and space available for the weeds to grow. It was observed that weed free check caused the greatest reduction in weed density and weed dry matter production. However, the application of pendimethalin 0.5 kg/ha (PE) *fb* quizalofop 0.050 kg/ha as POE, recorded significantly lesser number and fresh and dry weight of weeds/m^{2}and lower weed index (Table 1). The next alternative could be pendimethalin 1.0 kg/ha (PE). The results are in agreement with Dudi *et al.* (2011) as well as Tripathy *et al.* (2013).

Table 1. Sequential herbicide application effect on growth parameters of *Rabi* onion

Treatment	Plant Height (cm) 100 DAT	Leaf Area (cm^2) [5 plants] 100 DAT	Dry Wt. Bulb (g/5 plants] At Harvest	Dry Wt. Stem (g/5 plants] At Harvest	No of weeds/ m^2	Fresh wt of weeds (g/m^2)	Dry wt of weeds (g/m^2)	Weed Index
Crop establishment								
Flat transplanting	35.23	381.43	176.03	14.58	80.0	298.4	70.4	45.70
Raised Bed (without residue)	39.03	431.8	196.67	13.89	62.0	256.8	66.12	34.62
Raised Bed (with Residue)	38.05	439.5	220.56	13.0	54.0	226.4	60.24	32.23
LSD (P=0.05)	NS	10.59	18.41	NS	7.0	29.5	3.91	-
Herbicides								
Pendi 1.0kg/ha PE	40.8	373.7	220.3	14.0	76.0	270.8	68.6	21.60
Pendi 0.5 kg/ha PE *fb* ethoxy15 g/ha POE	35.7	331.4	113.5	12.7	84.0	321.6	85.6	78.61
Pendi 0.5 kg/ha PE *fb* quizalofop-ethyl 50 g/ha (POE)	39.0	426.95	248.5	16.0	44.0	153.6	39.6	10.31
Pendi 0.5 kg/ha PE *fb* imazeth.100 g/ha (POE)	34.2	313.3	124.0	12.3	100.0	349.2	79.6	83.42
Weedy check	42.9	219.5	120.2	10.4	152.0	556.4	138.2	52.64
Weed free check	38.7	456.75	256.2	16.7	00	00	00	00
LSD (P=0.05)	NS	41.23	10.48	2.3	31.18	110.50	22.34	-

CONCLUSION

Application of pendimethalin 0.5 kg/ha (PE) *fb* quizalofop 0.050 kg/ha as POE, recorded significantly lesser number and fresh and dry weight of weeds/m^2 and lower weed index. The next alternative could be pendimethalin 1.0 kg/ha (PE) for better weed management in *Rabi* onion.

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Influence of integrated weed management on green forage yield and quality of oat

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In India, oat (*Avena sativa* L.) is the major cereal forage crop for *Rabi* season which is quick growing, palatable and nutritious for the livestock. Compared to other cereal straws which have similar chemical compositions, oat straw has more digestible organic matter. Being a winter, irrigated and long durational crop, the oat is heavily infested with various species of annual and perennial weeds decline the fodder productivity. Consequently, if a resource (light, water, nutrients or carbon dioxide) changes within the environment, it is more likely that weeds will show a greater growth and reproductive response. However, on the other side due to scarcity of labour, and irrigated condition resulting in to more crop weed competition for nutrient, light, moisture and space thus, causing substantial reduction in green forage yield and quality of oat.

METHODOLOGY

A field experiment was conducted at the farm of Forage Crops Research Project, M.P.K.V., Rahuri during *Rabi* 2011-12 on the loam soil having low in available nitrogen, available phosphorus and very high in potassium with pH 8.4. The trial of nine treatments was laid out in randomized block design with three replications. Oat variety '*RO-19*' (*Phule harita*) with spacing of 30 cm in rows and fertilizer dose of 100:50:40 $N:P_2O_5:K_2O$ kg/ha apart. Treatments consisted of weedy check (control); weed free check; hand weeding (HW) at 3 WAS (weeks after sowing); hand hoeing (HH) at 3 WAS; pendimethalin as pre-emergence (PE) 0.75 kg/ha + 1 HW at 5 WAS; 2,4-D 0.75 kg/ha at 3 WAS + 1 HW at 5 WAS; metsulfuron methyl (MSM) 0.004 kg/ha at 3 WAS + 1 HW at 5 WAS; 2,4-D 0.75 kg/ha at 3 WAS + 1 HH at 5 WAS and MSM 0.004 kg/ha at 3 WAS + 1 HH at 5 WAS.

RESULTS

The major weed species observed included dicot weeds such as *Chenopodium album* and *Parthenium hysterophorus*, and monocot weeds such as *Cyperus rotundus* and *Cynodon dactylon*. The lowest population and dry weight of weeds were recorded in weed free check and was at par with MSM 0.004 kg/ha at 3 WAS+1 HW at 5 WAS, pendimethalin 0.75 kg/ha + 1 HW at 5 WAS and 2,4-D 0.75 kg/ha at 3 WAS + 1 HW at 5 WAS resulting into higher WCE than other treatments. Similar trend was observed with Kumar *et.al.* (2001). Weed free check recorded significantly higher growth and yield attributes compared to other weed control treatments. Amongst weed management treatment, highest green forage (43.30 t/ha) and dry matter (9.26 t/ha) yields were recorded with the application of MSM 0.004 kg/ha at 3 WAS + 1 HW at 5 WAS and pre-emergence pendimethalin 0.75 kg/ha + 1 HW at 5 WAS and also recorded the lowest WI. These results are in conformity with Sharma and Chander (2006). Crude protein and crude fibre yield followed the similar trend of yields and proved to be the most remunerative weed control treatment, recording the highest net monetary returns (17331.8 Rs/ha) and benefit: cost ratio (2.00).

Table 1. Weed dynamics, forage yield, quality and economics as affected by different integrated weed management treatments in oat

Treatment	GFY (t/ha)	DMY (t/ha)	Dry wt. of weeds (kg/ha)	WCE (%)	WI (%)	Crude protein content (%)	Crude protein yield (t/ha)	Net returns (Rs./ha)	B:C ratio
Weedy check (Control)	24.51	4.53	543	0.00	45.45	7.13	0.32	7313.1	1.59
Weed free check	44.93	9.72	0.00	100.0	0.00	7.19	0.70	10706.6	1.42
HW at 3 WAS	37.17	7.37	057	89.32	17.24	7.07	0.52	13128.4	1.79
HH at 3 WAS	32.27	6.12	236	56.20	28.18	7.00	0.42	10587.7	1.70
Pendimethalin 0.75 kg/ha + 1 HW at 5 WAS	41.66	8.70	025	95.44	7.26	7.25	0.63	14970.2	1.82
2,4-D 0.75 kg/ha at 3 WAS + 1 HW at 5 WAS	34.72	6.67	028	94.76	22.67	7.15	0.47	10084.5	1.57
MSM 0.004 kg/ha at 3 WAS + 1 HW at 5 WAS	43.30	9.22	013	97.60	3.60	7.22	0.66	17331.8	2.00
2,4-D 0.75 kg/ha at 3 WAS + 1 HH at 5 WAS	33.49	6.38	046	91.53	25.45	7.15	0.45	9794.6	1.58
MSM 0.004 kg/ha at 3 WAS + 1 HH at 5 WAS	39.21	8.14	043	92.16	12.69	7.25	0.59	14581.7	1.87
LSD (P=0.05)	2.75	0.80	029	4.50	6.00	NS	0.06	2159.49	0.13

CONCLUSION

It can be concluded that application of MSM 0.004 kg/ha at 3 WAS + 1 HW at 5 WAS, can be a better option for weed control in oat alongside pre-emergence application of pendimethalin 0.75 kg/ha + 1 HW at 5 WAS as it ensures higher green forage and dry matter yield which is even at par with weed free check; and it provides higher net returns and B:C ratio.

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Evaluation of post-emergence herbicides on weed control and yield of sesamum

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Sesamum (*Sesamum indicum* L.) is one of the important oilseed crops grown in India. Weeds pose a serious threat to its cultivation because of its initial slow growth and reduce the yield ranging from 55 to 60% (Punia *et al*, 2001). Though, information on use of pre-emergence herbicides like pendimethalin, alachlor etc. is available (Rao and Narayana Rao 1985 and Sukahadia *et al*. 2004) but information pertaining to post-emergence herbicides and their relative performance is scanty. Hence, the present investigation was undertaken.

METHODOLOGY

A field experiment was conducted during *Rabi* 2009-10 and 2010-11 at Regional Agricultural Research Station, Lam, Guntur (A.P.) to evaluate the performance of different post emergence herbicides in sesamum. The experiment consisting of seven treatments (Table 1) was laid out in a randomized block design with three replications. The soil of the experimental plot was clay loam with pH of 8.0, low in available nitrogen, phosphors and high in available potassium. The sesamum variety '*Gowri*' was sown in the experimental field by adopting all the recommended package of practices except weed control. The pre- and post-emergence herbicides were sprayed by using a hand sprayer fitted with flat fan nozzle using a spray volume of 500 l/ha. The data on weed density and dry weight per unit area were recorded at 60 days after sowing and transformed to "x+½ transformation to normalize their distribution. The prevailing input and output costs were taken into consideration for calculating the economics of different treatments.

RESULTS

The dominant weed flora of the experimental plots were *Echinochloa colona*, *Cynodon dactylon*, *Dinebra retroflexa*, *Dactyloctenium aegyptium* (Grasses), *Cyperus rotundus* (Sedge), *Trainthema portulacastrum*, *Digera arvensis*, *Phyllanthus niruri*, *Cleome viscosa*, *Amaranthus viridis*, *Celosia argentea*, and *Parthenium hysterophorus* (BLW). All the weed control treatments significantly reduced the weed density and dry weight over weedy check (Table 1). Among the treatments, pre-emergence application of pendimethalin 750 g/ha significantly reduced the weed growth with 50% WCE over all other post-emergence treatments but significantly inferior to hand weeding which recorded the highest WCE of 75% at 60 DAS (days after sowing). The results are similar to those reported by Punia *et al.* (2001).

No crop injury observed with the herbicides used under the study. Among the herbicidal treatments, pre-emergence application of pendimethalin 750 g/ha recorded higher crop dry weight and was on par with all other treatments at 60 DAS. Seed yield was significantly influenced by the treatments under study. Among the herbicide treatments, significantly maximum seed yield (665 kg/ha) and BCR (1.41) was obtained with the treatment pre-emergence application of pendimethalin 750 g/ha over all other post-emergence herbicides. Though, hand weeding recorded the highest seed yield (796 kg/ha) but has lower BCR (1.20) because of higher cost involved in manual weeding. Season long weed competition in weedy check caused a yield reduction of 58% compared to hand weeding.

Table 1. Effect of different treatments on weed growth, yield and economics in sesamum (pooled data of 2 years)

Treatment	Dose (g/ha)	Time of application (DAS)	At 60DAS			Crop dry weight (g/m^2)	Seed yield (kg/ha)	Cost of cultivation (Rs/ha)	BCR (Rs/R)
			Weed density (no/m^2)	Weed dry weight (g/m2)	Weed control efficiency (%)				
Unwedded check	-	-	17.9 (307.5)	17.9 (324.2)	-	138	336	10000	0.34
Hand weeding		15 and 30	5.2 (29.1)	4.5 (20.0)	75	406	796	14500	1.20
Pendimethalin	750	2	10.6 (114.9)	8.9 (78.5)	50	346	665	11050	1.41
Quizalofop-ethyl	50	20	13.3 (176.9)	11.8 (138.4)	34	344	539	11550	0.87
Quizalofop-p-tefyryl	40	20	14.2 (204.5)	12.8 (157.5)	29	318	524	11500	0.86
Clodinafop propargyl	60	20	13.6 (187.5)	14.1 (199.2)	21	331	505	11050	0.83
Fenoxaprop-ethyl	50	20	12.9 (166.4)	12.6 (160.0)	30	320	517	11500	0.80
LSD(P=0.05)			2.2	2.4		74.1	109		

Note: DAS: Days after sowing. Data transformed to "x+½ transformation, Figures in parentheses are original value

CONCLUSION

It was concluded that pre-emergence application of pendimethalin 750 g/ha was most effective in reducing weed growth and increasing seed yield with profitability in sesamum, wherever, hand weeding is not possible. The next best treatment was post-emergence application of quizalofop-ethyl 50 g/ha at 20 DAS.

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Impact of sustainable weed management practices on weed flora and yield of sweet corn

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Maize is one of the most important food crops in India and is increasingly gaining an important position in crop husbandry because of its higher yield potential and short growth duration. It contributes a lot to the economy of the country. Being a widely spaced crop it gets infested with a variety of weeds and subjected to heavy weed infestation. If weeds are not controlled during critical period of weed-crop competition; there is reduction in the yield of sweet corn from 60-70% depending upon the weed flora and density (Walia *et al.* 2007). Weed infestation pose competition for natural and applied inputs, such as space and nutrients. The development of herbicide-resistant biotypes, environmental sustainability and public health risks are major concern of the herbicide-dominated systems. Use of herbicides in any crop mixture is a risky endeavour and certainly not eco-friendly approach. Therefore, of late, scientists as well as farmers are seeking a broader perspective to weed management than relying primarily on herbicides. So, present study was conducted to identify the suitable sustainable weed management practices.

METHODOLOGY

Field experiment was conducted at NRM farm of College of Horticulture and Forestry, Pasighat, Arunachal Pradesh during *kharif* 2016. The treatments consisted of Maize + soybean (IC), Maize + blackgram (IC), Maize + greengram (IC), Banana pseudo-stem mulch, Grass mulch, Paddy straw mulch, Hand weeding (25-30 and 45-50 DAS) and weedy check. Seeds of sweet corn 'Sugar 75' were sown at 50 x 20 cm spacing with the recommended doses of fertilizers (120 kg N, 60 kg P_2O_5 and 40 kg K_2O per ha) were applied to crop. One row of (soybean/black gram/ green gram) was grown in between two rows of maize as intercrop. The observations were recorded on weeds (density/m^2, dry weight g/m^2, and weed control efficiency %) and crop. The growth and yield parameters of sweet corn were recorded from five randomly selected plants in each plot. The data for different parameters were statistically analyzed by following the standard methods.

RESULTS

The number of cobs/plant of sweet corn was the highest under two hand weeding condition, however, it was statistically at par with sweet corn + soybean inter cropping (Table 1). Number of cobs per hectare (in lakh) of sweet corn was maximum under maize+ soybean intercropping followed by HW twice at 25 DAS and 50 DAS and mulching with paddy straw mulch. All the weed management practices were effective in suppressing total weed density and dry matter as compared to weedy check. Hand weeding twice, maize +soybean, maize+ black gram, maize + green gram inter cropping, mulching with paddy straw, mulching with grass and mulching with banana pseudo-stem was also found effective in reducing weed population to the extent of 62, 61, 60, 52, 46 and 35 percent as compared to weedy check, respectively. In general, weed dry weight was found higher (10.4 g/m^2) under maize + greengram inter cropping among all the treatments except weedy check. Weed control efficiency of various treatments was ranged from 31.1- 66.32%. Among all the treatments, hand weeding twice was recorded maximum WCE compared to other treatments found at par with maize + soybean intercropping. Higher net return (Rs 1.34 lakh) along with BCR (3.4) was recorded with maize + soybean intercrop followed by hand weeding twice.

Table 1. Weed growth, yield attributes, yield and economics as influenced by weed management practices

Treatment	Weed number (m^2)	Weed dry weight (g/ m^2)	WCE (%)	Number of cobs/plant	Length of cob (cm/plant)	No.of cobs/ha (in lakh)	Gross return (Rs. in lakh.)	Net Return (Rs. in lakh.)	B: C Ratio
Maize + soybean (IC)	*5.9 (34)	2.5 (6.1)	59.8	1.2	21.7	0.64	1.9	1.34	3.4
Maize + blackgram (IC)	5.9 (34.7)	2.5 (6.2)	58.8	1.1	22.2	0.53	1.6	1.04	2.8
Maize + greengram (IC)	6.4 (40.3)	2.8 (7.3)	51.7	1.1	21.7	0.6	1.8	1.24	3.2
Banana pseudo-stem mulch	7.6 (57)	3.3 (10.4)	31.1	1	21.5	0.56	1.7	1.1	2.8
Grass mulch	6.9 (47.7)	2.9 (8.2)	46	1.1	21.8	0.61	1.8	1.2	3
Paddy straw mulch	6.5 (41.7)	2.8 (7.4)	51.2	1.1	21.7	0.62	1.9	1.3	3.2
Hand weeding (25-30 and	5.8 (33.7)			1.3	22.3				
45-50 DAS)		2.3 (5.1)	66.32			0.63	1.9	1.3	3.2
Weedy Check	9.4 (87.7)	3.9 (15.2)	0	0.7	14.5	0.4	1.2	0.68	2.3
LSD(P=0.05)	0.49	0.22	7.69	0.53	NS	0.25	-	-	-

*Transformed data ($\sqrt{x + 0.5}$), data in parentheses are original value

CONCLUSION

It can be concluded that hand weeding twice and soybean as intercrop in maize are the recommendable options for sustainable sweet corn production under high rainfall hill ecosystem of North East India.

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Integrated weed management in turmeric

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Turmeric (*Curcuma longa* L.), a herbaceous perennial important spice crop grown in India. Though, India leads in production of turmeric with 78 % of global production, its average productivity is quite low, mainly due to the competition offered by weeds. Due to improper weed management, 30-70% yield losses have been reported. (Krishnamurty and Ayyaswamy 2000). Turmeric is a long duration crop (more than 280 days), therefore pre-emergence application of herbicides alone does not control weeds throughout critical crop weed competition period of the crop and needs an integration of post-emergence application of herbicides or intercultural operation and application of straw mulch in combination with pre-emergence herbicide application. Considering the increase in labour cost and scarcity of labour, manual weed control has become a difficult task. It felt necessity to develop an effective and economically better integrated weed control strategy for realizing higher productivity of turmeric. Keeping in view, the present investigation was conducted to study the bio-efficacy of pre and post emergence herbicides in IWM on weed control and morphological growth of turmeric.

METHODOLOGY

The field experiment was conducted during *Kharif* season of the year 2015-2016 at the research farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola(M.S.) in Randomized Block Design with three replication having fourteen different chemical and Integrated weed management treatments compared with cultural weed management and unweeded check. The different pre-emergence herbicides viz.metribuzin, pendimethalin, atrazine, oxyflurofen etc. were tried in combination with cultural practice. The soil of the experimental field was black and clayey in texture and slightly alkaline in reaction, low in nitrogen, medium in phosphorous and fairly rich in potash. The turmeric variety PDKV Waigaon was planted at the spacing of 45 x 22.5 cm on 23rd June 2015 with recommended dose of fertilizer 200:100:100 kg NPK /ha

RESULTS

The major weed flora during *kharif* season in turmeric crop in the selected area composed of both broad and narrow leaved weeds, however dominance of broad leaved weeds like Xanthium strumarium, Celosia argentea, Tridax procumbens, Phyllanthus niruri, Lagasca mollis, Euphorbia geniculate, Euphorbia hirta, Phyllanthus niruri, Alternanathera triandra, Parthenium hysterophorus, Digera arvensis was observed in entire field.

The data presented in Table 1 indicated that, all the weed control treatments significantly reduced the weed population and weed biomass when compared with unweeded control. The hand weeding (25, 45 and 75 DAP) recorded significantly lower weed count, dry matter accumulation and WCE of 92.85% followed by integrated weed management treatments of metribuzin 0.7 kg/ha PE followed by straw mulch 10 t/ha *fb* one HW which recorded lowest weed population and weed dry weight at harvest and WCE of 57.34%, followed by pendimethalin 1 kg/ha (0-5 DAP) *fb* straw mulch 10 t/ha (10 DAP. Lowest weed index (0.56) was recorded in treatment pendimethalin 1 kg/ha (0-5 DAP) *fb* straw mulch 10 t/ha (10 DAP) *fb* one HW (75 DAP) followed by metribuzin 0.7 kg/ha (0-5 DAP) *fb* straw mulch (10 DAP) *fb* HW (0.74) followed by atrazine 0.75 kg/ha (0-5 DAP) *fb* straw mulch (10 DAP) *fb* HW (2.00). Significantly Highest Plant height was recorded in pendimethalin 1 kg/ha (0-5 DAP) *fb* straw mulch 10 t/ha (10 DAP) *fb* one HW (75 DAP).

Table 1. Weed population, weed dry matter, WCE (%), WI at harvest, yield and economics of turmeric as affected by different weed control treatments

Treatment	Total Weed population (m^2)	Weed Dry Matter (g/m^2)	Weed Control Efficiency (%)	Weed Index (%)	Plant height (cm)	Fresh Rhizome yield (t/ha)	NMR (Rs/ha)	B:C Ratio
Metribuzin 0.7 kg *fb* 2 HW (45 and 75 DAP)	6.71 (44.85)	7.3954.24)	49.82	10.40	53.60	18.69	224004	3.49
Metribuzin 0.7 kg *fb* fenoxaprop + metsulfuron (67+ 4 g) Tank mix 45 DAP	7.06 (49.46)	7.68(58.42)	45.95	24.39	51.12	15.77	177706	3.04
Metribuzin 0.7 kg *fb* straw mulch (10 DAP) *fb* HW (75 DAP)	6.04 (36.11)	6.82(46.11)	57.34	0.74	56.63	20.70	258306	3.89
Pendimethalin 1 kg *fb* 2 HW (45 &75 DAP)	6.28 (38.97)	8.12(65.45)	39.45	19.63	53.27	16.76	195014	3.25
Pendimethalin 1 kg *fb* fenoxaprop + metsulfuron (67+ 4 g) Tank mix 45 DAP	7.18 (51.13)	8.07(64.63)	40.21	24.31	51.64	15.79	182766	3.22
Pendimethalin 1 kg *fb* straw mulch 10 t / ha (10 DAP) *fb* one HW (75 DAP)	6.23 (38.44)	7.28(52.51)	51.42	0.56	62.93	20.74	260822	4.10
Atrazine 0.75 kg *fb* two HW (45 & 75 DAP)	7.28(52.48)	7.99(63.38)	41.37	21.35	53.93	16.40	190686	3.25
Atrazine 0.75 kg *fb* fenoxaprop+ metsulfuron (67+ 4 g) Tank mix 45 DAP	7.66 (58.16)	7.94(62.51)	42.17	17.79	50.33	17.15	205794	3.50
Atrazine 0.75 kg *fb* straw mulch 10 t /ha (10DAP) *fb* one HW (75 DAP)	6.54 (42.35)	7.65(58.16)	46.20	2.00	57.20	20.44	255962	3.93
Oxyfluorfen *fb* two HW (45 & 75 DAP)	7.02(48.99)	7.61(57.39)	46.91	20.92	53.20	16.49	193238	3.30
Oxadiargyl 0.25 kg *fb* two HW (45 & 75 DAP)	7.10 (50.01)	7.66(58.30)	46.06	27.49	51.13	15.12	169592	3.01
Glyphosate *fb 2* HW (45 & 75 DAP)	6.18 (37.75)	7.03(48.91)	54.75	24.76	50.47	15.69	179798	3.14
Hand weeding (25, 45 & 75 DAP)	2.47 (5.60)	2.85 (7.72)	92.85	0.00	52.60	20.86	237627	3.11
Unweeded check.	10.92(118.7)	10.4(108.1)	0.00	61.90	53.80	7.95	55554	1.71
LSD (P=0.05)	0.52	0.48	-	-	6.58	2.90	48792	-

As indicated in Table 1, integrated weed management practices resulted in increase of rhizome yield over the weedy check. Maximum rhizome yield was observed in weed free treatment (20.86 t/ha), while among the IWM treatments application of pendimethalin 1 kg/ha (0-5 DAP) *fb* straw mulch 10 t / ha (10 DAP) *fb* one HW recorded higher rhizome yield (20.74 t/ha) which was closely followed by metribuzin 0.7 kg/ ha *fb* straw mulch (10 DAP) *fb* HW being par with each other. The lowest yield values were recorded with weedy check. (7.95 t/ha). Similar results were also reported by Jadhav and Pawar (2014). Due to higher rhizome yield, highest monetary returns of Rs.260822 was registered under pendimethalin 1 kg/ ha (0-5 DAP) *fb* straw mulch 10 t/ha *fb* one HW with B:C ratio of 4.10 followed by metribuzin 0.7 kg/ha *fb* straw mulch (10 DAP) *fb* HW with NMR of Rs.258306 and B:C ratio of 3.89 highest than the Hand weeding (25, 45 and 75 DAP) (3.11). This might be due to the higher cost of cultivation in this treatment. This results are in conformity with the results of Sachdeva *et al.* (2015).

CONCLUSION

The findings of present investigation conclusively inferred that, integrated use of either Pendimethalin 1 kg/ha or by Metribuzin 0.7 kg/ha (0-5 DAP) *fb* straw mulch 10 t / ha (10 DAP) *fb* one HW (75 DAP) was adjudged very effective for weed control and for attaining the highest productivity and profitability in turmeric.

Bio-herbicidal potential of encapsulated essential oils on some common weed flora and crop seeds

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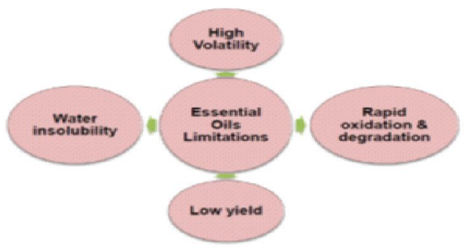
In India, use of synthetic herbicides had brought initial financial rewards to the farmers by effectively controlling the weeds and hence increasing crop production, but with time, several weeds have become resistant to these herbicides. Consequently to control weeds, either concentration of herbicides has to be increased or new more toxic chemicals need to be applied. However heavy reliance on herbicides has led to high infestation pressure of single weed species, herbicide resistance and herbicidal residual influence on the ecosystem. Such a scenario warrants the need for multiple options to address a particular weed problem rather than relying upon unified approach. Among the plant based natural products, Essential Oils (EOs) have been reported as suitable option for controlling weeds (Bouajaj *et al.* 2014). Although EOs has many herbicidal properties yet their use is limited due to their properties which restrict their use or exploration in the development of herbicides, on large scale and natural conditions as illustrated in the above fig. Encapsulation of EOs involving biopolymers has emerged as one of the most promising option for providing a protective layer or coating of single or mixture of polymers over the active ingredients to improve stability, sustainability and ease out the handling.



METHODOLOGY

A Research programme sponsored by Indian National Science Academy under Summer Research Fellowships was carried out in Department of Environmental Sciences , Central University of Punjab, Bathinda, the main objective was to develop immobilized formulations of essential oil by using biodegradable polymers and study the bioherbicidal properties of the developed formulation against common weeds and crop under lab conditions. The leaves of plants (*Calistemon viminalis)* were taken for extraction of essential oils. Then the emulsion of EOs and polymers Gum Arebic and Maltodextrins (GAMD) were prepared. Further the EOs were dissolved in ethanol in concentration range (4% and 8%). For the spay drying process, the Spray Mate II spray dryer (JISL Laboratory Equipment Mumbai) was used with nozzle size 0.7mm, operated at inlet temperature of 170ºC, out let temperature 85ºC, and 20rpm flow rate controlled using a peristaltic pump. After drying the emulsions, powder was stored at 4ºC for further uses. Seeds of weeds were dipped in distilled water for 24h for imbibition. After that 40 seeds were sown in 15cm diameter petri dish lined with two layers of moistened Whatman no 1 filter paper. Immediately after the treatment, petri-dish with its cover was sealed with a piece of para-film to reduce evaporation. A similar set-up, but without EOs served as control. Each set up was arranged in triplicate and kept for one control chamber in 16/8 light/dark condition, 02 week at 25±2 ºC. For bioassay studies, the seeds of two monocots weeds namely *E. crus-galli* L. and *P. minor* and crops rice and wheat were procured from the Department of Agronomy, Punjab Agriculture University, Ludhiana, Punjab.

RESULTS

All the encapsulated treatments were significantly superior in reducing the growth and weight of test weeds taken for study (Table 1). Basal dose at the time of sowing appear more lethal as compared to application at 4 DAS. This indicates the more sensitivity of germinating plumule and redical to encapsulated essential oils. The *Phalaris minor* was found more susceptible to bioherbicides, but pattern of Phytotoxicity remains almost same. Among all the treatments basal application of encapsulates with 8% essential oil was found more lethal and result in maximum phyto-toxicity by registering less shoot length and root length and fresh biomass weight. Further, all the treatments have non-significant effect on crop seeds and registered on par with control treatment with respect of all the parameters under study (Table 1). Thus, proving selectivity of encapsulated essential oils against weed seeds only. These results are corroboratory with the findings of Kobaisy *et al.* 2002.

Table 1. Effect of different treatments on shoot length, root length and fresh weight of test weeds and crop seeds

Treatment	Quantity	*Echinochloa cruss galli*			*Phalaris minor*			Rice			Wheat		
		Shoot length (cm)	Root length (cm)	Fresh weight (µg)	Shoot length (cm)	Root length (cm)	Fresh weight (µg)	Shoot length (cm)	Root length (cm)	Fresh weight (µg)	Shoot length (cm)	Root length (cm)	Fresh weight (µg)
Absolute Control	-	4 [a]	3 [a]	5 [a]	3 [a]	2.5 [a]	3 [a]	3.2 a	3.1 a	4.5 a	3.5 a	2.5 a	3 a
Essential Oil	20 µg /cm2	4 [a]	3.2 [a]	4.5 [a]	2.8 [a]	2.4 [a]	3 [a]	3.2 a	3.2 a	4.5 a	3.8 a	2.4 a	3 a
GAMD	100 µg /cm2	3.5 [a]	3.1 [a]	4.5 [a]	2.8 [a]	2.5 [a]	3.2 [a]	3.5 a	3.1 a	4.5 a	3.8 a	2.5 a	3.2 a
GAMD –Eo Encapsulate (4%) as basal	100 µg /cm2	2 [d]	1.5 [d]	2.8 [d]	1.5 [d]	1.2 [d]	2.1 [d]	3.5a	3.5a	4.3a	3.5 a	2.4 d	3.1 a
GAMD –Eo Encapsulate (8%) as basal	100 µg /cm2	1.2 [e]	1.1 [e]	1.4 [e]	1.2 [e]	1.0 [e]	1.2 [e]	3.2 a	3.6a	4.4 a	3.2 e	2.6 a	3.2 e
GAMD –Eo Encapsulate (4%) at 4 DAS	100 µg /cm2	2.8 [c]	1.8 [c]	3.1 [c]	2.0 [c]	1.5 [c]	2.5 [c]	3.5 a	3.2 a	4.1 a	2.9 a	2.5a	3.3 a
GAMD –Eo Encapsulate (8%) at 4 DAS	100 µg /cm2	2.0 [c]	1.6 [c]	3.2 [c]	2.9 [c]	1.8 [c]	2.2 [c]	3.3 a	3.5a	4.2a	2.9 a	1.8 a	3.2a

CONCLUSION

It can be concluded that the encapsulated EOs of *C. viminalis* has the potent herbicidal properties which can alter the physiological and biochemical process of the weeds. However selectivity of Phytotoxicity is limited to weed seeds only but not crop plants. These bioherbicides should be integrated with synthetic herbicides to reduce herbicidal load on the ecosystem.

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Allelopathic effect of different botanicals against *Parthenium hysterophorus*

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Parthenium hysterophorus L. is an invasive alien species; hazardous to human health, animal, plant and environment. The management of this problematic weed is possible only by repeated application of herbicides. As the management of weeds in present day agriculture mainly depends on synthetic herbicides, but continuous use of these chemicals may cause environmental pollution, besides restricting the choice of succeeding crops through long residual activity. Hence, the use of eco-friendly approach like allelopathy is one of the viable options. Application of allelochemicals, either in pure or crude form, is a potentially valuable and sustainable approach in management of parthenium. Eucalyptus (*Eucalyptus spp.*), *Prosopis juliflora* and Tamarind (*Tamarindus indica* L.) are important tree species, which are widespread in tropics and subtropics. Hence, a laboratory study was carried out to study the allelopathic effect of different botanicals on germination and seedling growth of *Parthenium hysterophorus* seeds.

METHODOLOGY

A laboratory experiment was conducted to study the allelopathic effect of eucalyptus, tamarind, *Prosopis juliflora* on the germination and seedling length of Parthenium. Aqueous leachates of eucalyptus, tamarind and *Prosopis juliflora* (10 and 20%) were prepared by soaking air dried leaf in distilled water (1:10 weight/volume) for 24 hours and filtered in Whatman No.1 filter paper. Calculated quantity of eucalyptus oil was mixed with distilled water to prepare required 0.5 and 1.0% of concentration. Four replicates of each 50 seeds of parthenium were evenly placed on moist germination paper in sterilized petridishes under completely randomized design with three replications. The petridishes were maintained at 25 ^{o}C and 95% humidity with a slow and continuous exposure to 10 ml of aqueous leachates of allelopathic plant products and distilled water (for comparison as control).

RESULTS

The results revealed that maximum reduction of germination percentage was noticed with 20 and 10% eucalyptus fresh leaf leachate (100%), 20% *Prosopis juliflora* leaf leachate (97.25%), 10% *Prosopis juliflora* leaf leachate (94.80%) and 1.0% eucalyptus oil (93.25%) as compared to control (distilled water treatment) (2.93%)(Table 1).The reduction in germination of parthenium seeds might be attributed the release of phenolic acids and volatile oils which functioned as allelopathic agents (Sasikumar *et al.* 2002). The minimum reduction in germination percentage of *Parthenium hysterophorus* was recorded with 10% tamarind fresh leaf leachate (55.25%). Similar results were reported by Sarvanane *et al*. (2015) who observed reduction in germination and seedling length of parthenium due to eucalyptus, tamarind and leucaena fresh leaf leachates.

Table 1. Effect of different botanicals on germination and seedling length of *Parthenium hysterophorus*

Treatment	Concentration (%)	Reduction in germination* (%)	Seedling length (cm)
Eucalyptus fresh leaf leachate	10	100.0	-
Eucalyptus fresh leaf leachate	20	100.0	-
Eucalyptus oil	0.5	88.36	1.5
Eucalyptus oil	1.0	93.25	0.5
Tamarind fresh leaf leachate	10	55.25	3.0
Tamarind fresh leaf leachate	20	82.35	1.6
Prosopis juliflora leaf leachate	10	94.80	0.5
Prosopis juliflora leaf leachate	20	97.25	0.3
Control (Distilled water)	-	2.93	5.7

*Data not analysed

CONCLUSION

It may be concluded that, fresh leaf leachates of both eucalyptus and *Prosopis* were found promising in inhibiting the germination and seedling growth of *Parthenium hysterophorus* under laboratory condition.

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Non-chemical weed management in *Kharif* groundnut under organic farming

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Demand of organically produced groundnut is increasing day by day due to health consciousness. Premium price of organic groundnut tempted farmers for organic cultivation. Weeds are widely reported as a key constraint in organic farming and organic weed management relies on preventive, mechanical, physical, cultural and biological methods, but these tools must be used in an integrated and multi-strand approach. In addition to direct and cultural techniques, timeliness, vigilance and an understanding of farm ecology are also important factors in effective weed management.

METHODOLOGY

The field experiment was conducted on medium black calcareous clayey soil at Organic Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during *Kharif* season of 2014 and 2015 to evaluate non-chemical weed management practices in groundnut. The experimental soil was slightly alkaline in reaction with pH 8.0 and EC 0.61 dS/m. It was medium in available nitrogen (235 kg/ha), low in available phosphorus (23 kg/ha) and high in available potash (385 kg/ha). The experiment comprised pre-sowing treatments (Deep ploughing, stale seedbed and soil solarization) as main plots and post-sowing treatments (Wheat straw mulch 5 t/ha, hand weeding and interculturing at 15, 30 and 45 DAS, weed-free check and weedy check) as sub-plots were laid in a split plot design with four replications. The groundnut variety '*Gujarat Groundnut 20*' was sown in June at spacing of 60 x 10 cm using seed rate of 120 kg/ha. FYM 10 t/ha was incorporated in soil at the time of preparatory tillage. For soil solarization, a light irrigation was applied and then the soil was covered with 25 micron LDPE sheet for 15 days during hot summer (May). Deep ploughing up to 20 cm depth was carried out using mouldboard plough. For stale seedbed, a pre-sowing irrigation was applied to allow weeds to grow. After 7 days germinated weeds were removed by shallow harrowing. The wheat straw mulch 5 t/ha was uniformly distributed on the top soil after sowing. The crop was raised as per the standard package of practices without any chemical input.

RESULTS

The major weed flora noticed were *Echinochloa colona, Dactyloctenium aegyptium, Eluropus villosus, Indigofera glandulosa* and *Brachiaria ramosa* among the monocots; *Ammannia baccifera, Leucas aspera, Digera arvensis, Commelina benghalensis, Eclipta alba, Portulaca oleracea* and *Phyllanthus niruri* among the dicot weeds and *Cyperus rotundus* as sedge weed.

Effect on crop

Significantly highest branches/plant, pods/plant and 100-kernel weight were recorded under stale seedbed, followed by soil solarisation (Table-1), however, plant height and shelling per cent remained unaffected. Whereas, significantly the lowest values of these growth and yield attributes were registered under deep ploughing.

Significantly higher values of plant height, branches/plant, pods/plant, 100-kernel weight and shelling per cent were registered with weed-free, followed by HW and straw mulch. The weedy check recorded significantly the lowest values of these growth and yield attributes.

Table 1. Effect of weed management on growth and yield attributes and crop yield and weed parameters of groundnut (pooled over two years)

Treatment	Plant height (cm)	Branches/ plant	Mature pods/ plant	100-kernel weight (g)	Shelling (%)	Pod yield (t/ha)	Haulm yield (t/ha)	Weed dry weight (kg/ha)	Weed index (%)	Weed control efficiency (%)
Pre-sowing										
Deep ploughing	41.10	4.51	8.39	42.14	63.45	0.917	1.97	921	21.44	47.63
Stale seedbed	44.43	6.75	12.17	50.40	66.94	1.12	2.49	634	19.47	53.91
Soil solarization	43.95	6.01	11.52	48.81	66.46	1.09	2.45	764	21.57	50.44
LSD (P=0.05)	NS	0.39	0.55	1.97	NS	0.07	0.18	43		
Post-sowing										
Straw mulch	42.91	4.93	10.17	45.11	64.33	1.01	2.27	1049	22.67	32.93
HW	45.53	6.74	12.37	50.69	66.67	1.22	2.66	441	6.75	72.32
Weed free	46.79	7.17	12.94	53.22	70.86	1.31	2.83	43	0.00	97.39
Weedy check	37.41	4.19	7.29	39.44	60.61	0.61	1.48	1558	53.87	0.00
LSD (P=0.05)	1.85	0.41	0.52	1.86	3.09	0.06	0.14	53		

The results (Table 1) revealed that stale seedbed produced significantly the highest pod and haulm yields, followed by soil solarisation. The deep ploughing resulted in significantly the lowest pod and haulm yields.

The weed-free check produced significantly the highest pod yield of 1309 kg/ha and haulm yield of 2826 kg/ha. The next best treatments in this regard were HW and straw mulch.

Effect on weeds

The data (Table 1) indicated that the stale seedbed recorded significantly the lowest dry weight of weeds, followed by soil solarisation and deep ploughing having WI of 19.47, 21.57 and 21.44%, and WCE of 53.91, 50.44 and 47.63%, respectively. Similarly, the weed-free registered significantly the lowest dry weight of weeds, followed by HW and straw mulch with WI of 0.00, 6.75 and 22.67% and WCE of 97.39, 72.32 and 32.93%, respectively. The results corroborate the findings of Johnson and Mullinix (1995).

CONCLUSION

Effective control of weeds in *Kharif* groundnut along with higher yield under organic farming could be achieved by stale seedbed and hand weeding at 15, 30 & 45 DAS or wheat straw mulch 5 t/ha.

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Phytotoxicity and dissipation of pre-emergence herbicides applied to beetroot

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Beetroot is an important vegetable crop consumed many-a-time cultivated in more than 5000 ha in Telangana state (DOH, 2013). Weed competition in early crop growth stage in beetroots results in yield reduction up to 42-78% (Kumar *et al*. 2012). At present no recommendation of pre-emergence herbicides to beetroot is included in package of practices. Information on persistence of pendimethalin, oxyfluorfen, alachlor, oxadiargyl and metribuzin applied to beetroot as PE in soil and beetroot tubers is not available. Hence the current experiment is proposed.

METHODOLOGY

A field experiment was conducted during *Rabi* 2015 and 2016 at College farm, PJTSAU, Hyderabad. Pre-emergence herbicides, *viz*. pendimethalin CS, oxyfluorfen, alachlor, oxadiargyl and metribuzin were applied at 580 g/ha, 150 g/ha, 1000 g/ha, 75 g/ha and 500 g/ha, respectively as pre-emergence spray with a hand sprayer fitted with a flat-fan nozzle using a spray volume of 500 L/ha. These herbicides were tested in combination of hand weeding or quizalofop-P-ethyl 50 g/ha at 30 DAS. Hand weeding and unweeded control treatments were also maintained in the experiment to compute efficacy of different herbicides.

For residue analysis, soil samples (0-15 cm) were collected at 0, 5, 15, 30, 45, 60, 90 DAA (days after herbicide application), and at harvest. Beetroot tubers were collected at harvest. Samples were stored at -20^{0}C and brought to room temperature at the time of analysis. Analysis of the pendimethalin, oxyfluorfen, alachlor, oxadiargyl and metribuzin will be carried out employing the standard procedures taking consideration recoveries obtained in different sample matrices.

RESULTS

Severe phytotoxicity was observed with application of pre-emergence herbicide metribuzin at recommended rate resulting in complete failure of germination during both the years. Whereas, pendimethalin, oxyfluorfen application resulted in reduced number of shoots per cluster. But alachlor, oxadiargyl showed equal number of shoots per cluster.

Mean recoveries of the herbicides from soil, studied through fortification with technical standards (2.0 ppm to 0.001 ppm) varied from 86.4-90.8% for metribuzin, 92.6 to 98.9% for pendimethalin and 88.8 to 100.2% for oxyfluorfen, 92.6 to 94.8% for alachlor and 98.6 to 101.8 for oxadiargyl. Dissipation of the all the herbicides was biphasic, with first 50% of the initial detected amount dissipating more rapidly than the remaining soil residue. Among three herbicides, oxyfluorfen was more persistent compared to the other two herbicides and the residues of atrazine persisted for shortest period. Residues of metribuzin, pendimethalin and oxyfluorfen persisted up to 60 DAA. Alachlor and oxadiargyl residues were detected up to 30 DAA. Analysis of soil samples collected at harvest and herbicide residues in beet root samples indicated that residues of pendimethalin, oxyfluorfen, alachlor and oxadiargyl were found below the detection limits.

Table 1. Residues of metribuzin, pendimethalin, oxyfluorfen, alachlor and oxadiargyl in soil samples at different days after application

DAA	Metribuzin	Pendimethalin	Oxyfluorfen	Alachlor	Oxadiargyl
0	0.633	0.577	0.181	0.552	0.093
5	0.521	0.526	0.155	0.299	0.053
15	0.389	0.367	0.113	0.147	0.033
30	0.207	0.156	0.081	0.024	0.021
45	0.103	0.053	0.059	BDL	BDL
60	0.021	0.021	0.031	BDL	BDL
90	BDL	BDL	BDL	BDL	BDL
Harvest (120)	BDL	BDL	BDL	BDL	BDL

CONCLUSION

Alachlor and pendimethalin application resulted in no phytotoxicity and higher bio-efficacy. Alachlor, pendimethalin, oxadiargyl and oxyfluorfen residues in the beetroot tubers at the harvest was below MRL.

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Decontamination of bispyribac-contaminated soil by *Azotobacter chroococcum*

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Bispyribac-sodium, sodium 2,6-bis [(4,6-dimethoxy-2-pyrimidinyl) oxy] benzoate, a member of the pyrimidinyloxybenzoic acid group was introduced by Japan Kumiai Chemical herbicide to manage weeds like *Echinocloa crusgalli*, *Cyperus rotundus*, *Cyperus iria*, *Fimbristylis miliacea* in transplanted as well as direct seeded rice. Bispyribac-sodium is highly soluble in water. The herbicide and its primary degradation product desmethyl bispyribac is medium to highly mobile in soil (Anonymous 2010). It may pose the risk of non-point source of contamination through surface water runoff and leaching towards ground water. Degradation of this product in soil may minimize the risk of water contamination. The photo-chemical degradation of this herbicide and the influence of humic substances in this process was investigated (Choudhury and Barman 2015). But sufficient information was not available on its biodegradation, which may be an important mitigation method for bispyribac-sodiumresidues in soil. In this present experiment, *Azotobacter chroococcum*, a non-pathogenic nitrogen-fixing microbe was attempted for the mitigation of bispyribac-contaminated soil.

METHODOLOGY

An isolate of *Azotobacter chroococcum*, from the Culture Collection Centre, Dept. of Agril. Microbiology, TNAU was tested as the biodegrading agent for the decontamination of bispyribac-contaminated soil. Tolerrance of *Azotobacter* isolate to bispyribac-sodium was studied in *Azotobacter* media containing different levels of sugar, viz. no sugar, 50% sugar, and 100% sugar. Measured volume of bispyribac (100 µg/mL) was added aseptically to autoclaved media and allowed to cool. Media without bispyribac served as control. The flasks were incubated at 30ºC ± 2ºC. Visual observations, viz. opacity and color change of the media were taken after 7 and 15 days of inoculation. For the degradation studies, 25 mg of bispyribac in 5 mL of sterilized water was added to 100 g of sterile soil in 250 mL flask. Twenty one such flasks were incubated with isolated *Azotobacter* isolate in the dark at 30^0C for 40 days in BOD incubator. Three flasks with sterilized soil treated with bispyribac and without the incubation with *Azotobacter* isolate were kept in the dark as a control. Samples were drawn in triplicate at different time intervals, *viz*. 0, 5, 10, 20, 30 and 40 days of incubation. Samples were extracted in suitable solvents and cleaned up by standardized chromatographic techniques for the analysis of the rate of degradation of bispyribac in soil. Samples were analysed on high performance liquid chromatograph equipped with a C-18 reverse phase chromatographic column and a UV-Vis detector. The HPLC determination of analytes was performed using a mobile phase consisting of acetonitrile/water (65:35 v/v) with a ûow rate of 0.8 mL/min and monitored at 248 nm. Total analysis time was 20 min. A separate set of experiment was conducted to study the product formation due to the degradation of bispyribac by *A. chroococcum*. Sterlised soil fortified with bispyribac (100 mg/g) was incubated with *Azotobacter chroococcum.* Degraded products were extracted by partitioning in chloroform from the soil sampled at different time intervals, *viz*. 20, 30 and 40 days of incubation. The solvent was then evaporated under low pressure in the rotary vacuum evaporator to obtain a crude mixture of products. The products were characterized by LC-MS/MS.An API 3200 Qtrap mass spectrometer hyphenated to Shimadzu Ultra Fast Liquid Chromatography was used for the mass characterization of degraded products. Mass spectrometry analysis was performed with electrospray ionization (ESI) in positive (5500 eV) mode for each sample. The nebulizer gas and heater gases were adjusted at 30 psi and 55 psi, respectively. The ion source temperature was set at 500°C. Each sample was injected by infusion technique at the rate of 10 µ/Ls.

RESULTS

A. Choococcum survived and grew in the media containing bispyribac at a very high concentration (100 µg/mL). The herbicide served as a source of nutrients and energy for the microbe. Within 40 days of incubation, it degraded almost three-quarters of the applied bispyribac (Table 1). *A. Choococcum* degraded bispyribac-sodium by releasing extracellular enzymes, which acted upon it, converting into simpler forms enabling the microorganism to derive energy from the herbicide for their growth and maintenance. The degraded products were characterized structurally by the mass spectra found from LC-MS/MS and the structures were further confirmed by the spectra of synthesized molecules and previously reported degraded compounds of bispyribac-sodium. There was no major degradation of bispyribac observed during the incubation without the bacteria under similar condition (pH 7.0 and temperature 30^0C). Metabolites isolated from this biodegradation by *A. Choococcum* were 2-[(4,6-dimethoxy-2-pyrimidinyl)oxy]benzoicacid; 2-[(4,6-dimethoxy-2-pyrimidinyl)oxy]phenol; 4,6-dimethoxy-pyrimidin-2-ol and pyrimidin-2,4-diol. A scheme for the degradation pathways of bispyribac-sodium in soil caused by *Azatobacter* choococcum was proposed.

Table 1. Progressive degradation of bispyribac incubated with *A. chroococcum* in soil

Day of incubation	Bispyribac in soil (%)
0	100
5	65.17 ± 21.25
10	59.24 ± 19.95
20	35.90 ± 14.21
30	29.76 ± 16.34
40	25.66 ± 18.69

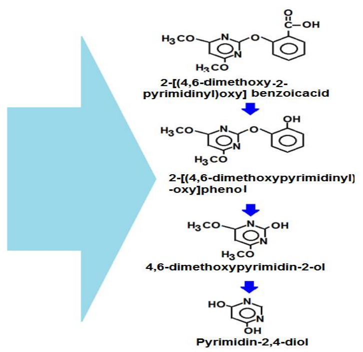

Fig. 1. A plausible scheme for the degradation pathways of bispyribac caused by *A. chroococcum* in soil

CONCLUSION

A. chroococcum isolate, a potent nitrogen-fixing microorganism efficiently degraded bispyribac-sodium in soil. It may be recommended for cleansing the bispyribac-contaminated soil. It may also be a member of a microbial consortium for herbicide degradation. There is a scope for further research to screen out more efficient *Azotobacter* isolates for the purpose of soil decontamination.

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Dissipation kinetics of quizalofop-ethyl in acidic and high organic matter soil

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Among the different group of herbicides used for weed control in field crops, the acetyl-CoA carboxylase (ACCase) or hydroxyphenyl pyruvate dioxygenase (HPPD) inhibitor, quizalofop-ethyl is used frequently by the farmers due to their high efficiency at low rate of application. It is a systemic herbicide belonging to aryloxy phenoxy propionates (FOPs) family. Although it is banned in the European Union, it is registered in USA and India as herbicide (Paranjape *et al.* 2014). Hence an investigation was carried out to study the persistence and degradation behavior of quizalofop-ethyl in soil under laboratory condition.

METHODOLOGY

The surface (0-15 cm) soil samples collected from pesticide free zone was used to conduct the study under controlled laboratory condition. The soil was sandy loam in texture and has pH of 5.2, EC of 0.52 ds/m and OC of 4.35 per cent. The treatments, *viz*. X (50 g/ha) and 2X (100 g/ha) doses of quizalofop-ethyl (5% EC) were imposed by following the standard OECD guidelines for degradation of pesticides in soil. The soil samples were collected at periodical interval and analyzed for quizalofop ethyl residues and the data were subjected to statistical analysis using the kinetics equation to calculate half-life and degradation constant.

RESULTS

After the application of quizalofop-ethyl, the residues were found to vary with the applied concentration from 39.2 to 316.8 µg/kg soil. The residues of quizalofop-ethyl in soil declined sharply to the extent of 54.4 – 62.9% and >85% within the time period of 7 and 15 days after application, respectively (Fig. 1). On day 30, quizalofop-ethyl residues become below detectable limit of 0.01 mg/kg at both the doses of application. The disappearance parameters for quizalofop-ethyl residues were calculated using first order reaction kinetics equation (Fig. 2) and found that its dissipation fit the first order degradation with the R_2 values of >0.95 at both the doses of 50 and 100 g/ha. Increase in concentration of application increased the half-life of quizalofop-ethyl with DT_{50} values of 4.1 and 5.6 days, respectively at 50 and 100 g/ha applied treatments. Similar result was reported by Robert *et al.* (1998) that it rapidly degrades in soil to quizalofop acid by hydrolysis with the DT_{50} value of 20 hrs to 2 days. However, quizalofop acid has a DT_{50} of 60 days and the main metabolite is 4-(6-chloro-2-quinoxalinyloxy) phenol in soil (Paranjape *et al.* 2014).

CONCLUSION

The present study suggests that the persistence of quizalofop ethyl in soil varies with the doses of application

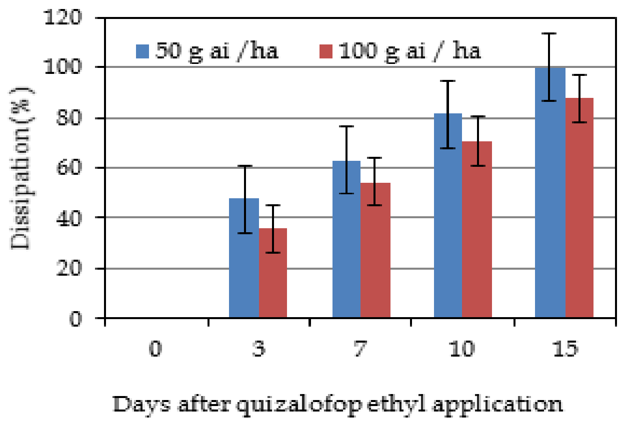

Fig. 1. Quizalofop-ethyl dissipation in soil

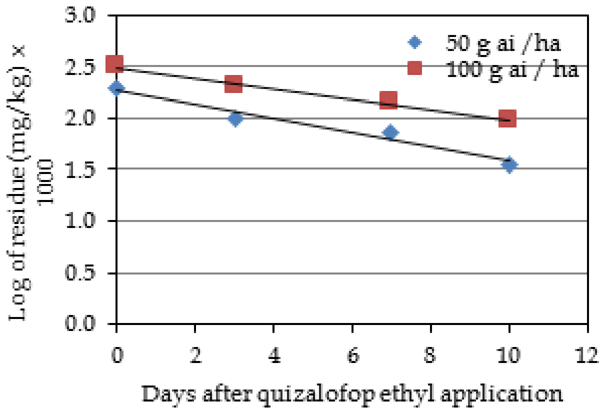

Fig. 2. Dissipation kinetics of quizalofop-ethyl in soil

with the half life of 4 – 6 days in organic matter rich soil (> 4% OC) soil with a pH of 5 and above. Though degraded with shorter half life, it could form persistent metabolite quizalofop acid due to hydrolysis. Hence its monitoring in environment is vital to circumvent the contamination and build up of its residue in soil and crop produce.

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Weed management strategies in maize

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Globally, as per USDA report of January- 2017, maize is grown on 179.69 mha with a production of around 1015.06 mt and having productivity of 5.65 t/ha, whereas India is producing 24.17 mt from 9.19 mha with productivity of 2.63 t/ ha (2014-15). Maize is physiologically different to many other crops as it has 'C_4' photosynthesis. Maize is grown over a wide range of climatic conditions from tropical to temperate. Some harvest data for main producing countries and some developing ones are shown in Table 1.

Many maize farmers have developed successful management practices for weed control but there are instances when weeds become a problem. These include times when herbicide programmes fail because of environmental conditions, weeds become resistant to recommended herbicides or the crop is being grown on leased land where weed control has been poor in the past. The critical time for weed control in maize is between crop emergence and canopy closure. The IWM approach advocates the use of all available weed control options that include:

1. Selection of a well-adapted crop variety or hybrid with good early-season vigor and appropriate disease and pest resistance.
2. Appropriate planting patterns/spacing and optimal plant density, improved timing, placement, and amount of nutrient application.
3. Appropriate crop rotation, tillage practices, and cover crops.
4. Suitable choice of mechanical, biological, and chemical weed control methods.
5. Alternative weed control tools (flaming, steaming, infrared radiation, sand blasting, *etc*.).

Cultural control

Cultural practices play an important role in weed management in maize. Maize is a very competitive crop; so if managed properly, it provides considerable competition against weeds. Weeds that emerge after 4 weeks of maize establishment have less impact on maize yield; therefore, early-season weed control is extremely important to get a competitive maize yield. Row spacing is an important cultural practice affecting weed control because maize in narrow rows will shade soil surface earlier than maize in wider rows. Other approaches may include:

Stale seed beds- The fallow period between two crops is an ideal time to control weeds. A stale seed bed is created when the soil is prepared for planting and then fallowed for a couple of weeks. Weed seeds near the surface germinate and can be controlled effectively with non-selective herbicides such as glyphosate.

False seedbeds- It is also similar to stale seedbeds but the weeds emerging after the fallow are killed by cultivation. This may be a less successful approach than a stale seed bed, as the soil disturbance may stimulate a second germination.

Crop rotation- Diversity in the crop rotation is an important strategy for sustainable weed management. Continuous cropping which favours one plant family, e.g. maize followed by annual ryegrass, can provide an environment that selects for weed species with characteristics similar to those of the main crop, e.g. grassy weeds.

Mechanical control

Tillage turns the soil and buries crop and weed residues and weed seeds. It is still the most commonly used mechanical weeding device between crops in the rotation. Tillage is the most common method of mechanical weed control and it can be divided into two categories: (1) pre-plant tillage and (2) in-row cultivation.

Chemical weed control

Application of herbicides is the most important method of weed control in maize. Herbicides can be applied at different times, such as before the crop is planted (pre-plant), after the crop is planted but before emergence (pre-emergence), and after crop emergence (post-emergence).

Pre-plant - For control of winter annuals and early-spring annual weeds, herbicides applied on emerged weeds are known as "burndown herbicide treatment." Foliar active herbicides, such as glyphosate, 2,4-dichlorophenoxyacetic acid (2,4-D), or dicamba, are the most common herbicides used as burndown before planting maize.

Pre-emergence - Herbicides applied after maize planting, but before emergence and having soil residual activity, are known as pre-emergence herbicides. Soil-applied pre-emergence herbicides may either be broadcast on the field or be applied in bands over the planted crop rows. Pre-emergence herbicides require irrigation or rainfall within 7–10 days of application to activate herbicides and enter the weed germination zone by water infiltration.

Table 1. Maize production in leading and developing countries in 1995 and 2014-15 (USDA)

Country/year	Production (mt)		Area (mha)		Yield (t/ha)	
	1995	2014-15	1995	2014-15	1995	2014-15
World	517.14	1015.06	136.50	179.69	3.79	5.65
USA	187.96	361.09	26.39	33.64	7.12	10.73
China	112.36	215.65	22.85	37.12	4.92	5.81
Brazil	36.27	85.00	13.95	15.75	2.60	5.40
Mexico	18.35	25.48	8.02	7.33	2.29	3.48
Argentina	11.40	29.75	2.52	3.50	4.52	8.50
India	9.53	24.17	5.98	9.19	1.59	2.63
S Africa	4.87	10.63	3.53	3.05	1.38	3.49

Post-emergence - Herbicides applied after maize and weed emergence are known as post-emergence herbicides. They usually have foliar activity on emerged weeds with a good crop safety if applied as directed on the label. Although atrazine effectively controls many broadleaf and some grass weeds, it has been inconsistent for the control of velvetleaf, common cocklebur, and Ipomoea spp. Because most maize growers have a number of broadleaf and grass weed species in their fields, tank-mixing atrazine with other herbicides might be desirable to broaden the weed control spectrum.

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Weed management in potato

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Potato crop encounters severe competition during initial growth stages hampering growth of the crop which results in poor tuber yield. Weeds find a favourable environment due to high dose of fertilizer applied to potato. Thus, a good weed management practice is very essential to check the weed growth during initial phases till earthing up is done which will ensure optimum yield of the crop. Field experiment was planned with the objective to study the performance of weed management practices on growth and yield of potato.

METHODOLOGY

The field experiments were conducted during *Rabi* season of 2012-13, 2013-14 and 2014-15 at the Instructional-cum-Research Farm of Assam Agricultural University, Jorhat with 10 treatments laid out in a randomized block design replicated 4 times. The soil of the experimental site was sandy loam, well drained, acidic (pH 5.4) with high organic carbon (8.1 g/kg), medium available N (282.5 kg/ha), available P_2O_5 (22.8 kg/ha) and K_2O (178.2 kg/ha) content. The tubers of the variety '*Kufri Megha*' were planted on 26th November, 2012, 3rd November in 2013 and 18th November in 2014. The respective harvesting date was 30th March, 12 March and 20 March. A fertilizer dose of 120-100-100 kg/ha N: P_2O_5: K_2O was applied.

RESULTS

The major weed flora comprised *Chenopodium album, Nustertium indicum, Physalis minima, Alternthera sessilis, Polygonum vscossum, Solanum indicum, Sonchus wightianus*, and *Ageratum houstonianum* among broad-leaved; *Cynodon dactylon, Eleusine indica* and *Digitaria setigera* among grasses; and *Cyperus rotundus* as sedges.

Metribuzin 0.750 kg/ha as early post-emergence at 10 day after planting, pretilachlor 0.750 kg/ha pre-emergence and oxadiargyl 90 g/ha pre-emergence recorded lowest weed density and dry weight close to weed free (hand weeding 20, 40, 60 and 80 DAP).

Tuber dry weight, haulm dry weight and tuber yield were also found to be the highest in metribuzin 0.750 kg/ha as early post-emergence followed by pretilachlor 0.750 kg/ha pre-emergence and oxadiargyl 90 g/ha pre-emergence among herbicide treatments. These treatments were close to weed free treatment.

Table 1. Weed density and dry weight in potato due to treatments

Treatment	Weed density at 50 DAP (no. /m^2)			Weed dry wt. at 50 DAP (g/m^2)		
	2012	2013	2014	2012	2013	2014
Weedy	8.40	11.70	10.65	3.23	2.52	9.00
Weed free (W.F.) upto maturity (HW 20, 40, 60, 80 DAP)	4.03	3.17	9.67	1.31	1.50	7.00
HW 30, 50, 75 DAP and W.F. upto maturity	4.82	3.67	10.13	2.44	1.85	8.10
HW 40, 60, 80 DAP and W.F. up to maturity	4.33	4.92	9.60	2.47	1.97	6.75
HW 50 and 75 DAP and W.F. up to maturity	8.48	9.79	8.53	2.45	2.57	7.75
Metribuzin 0.50 kg/ha as pre-em	4.24	8.52	10.30	1.99	1.62	9.35
Metribuzin 0.75 kg/ha as pre-em	4.19	9.25	10.15	1.88	1.52	7.20
Metribuzin 0.75 kg/ha as early post-em	4.07	8.00	8.43	1.47	1.40	6.13
Oxadiargyl 0.090 kg/ha	4.29	9.43	9.45	1.78	1.42	7.03
Preilachlor 0.750 kg/ha pre-em	4.27	8.27	9.03	1.75	1.67	6.58
LSD (P=0.05)	0.33	0.91	1.42	0.28	0.09	1.62

Table 2. Tuber yield, tuber dry weight and haulm dry weight of potato due to treatments

Treatment	Tuber yield (t/ha)			Tuber dry weight (g/m^2)			Haulm dry weight (g/m^2)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
Weedy	12.5	12.1	21.3	257.2	251.4	300.3	118.0	112.2	130.3
Weed free up to maturity (HW 20, 40, 60, 80 DAP)	15.2	15.1	27.0	284.0	279.3	415.3	174.4	168.7	167.5
HW 30, 50, 75 DAP and weed free up to maturity	14.2	14.0	23.7	264.0	258.2	376.8	148.4	143.3	148.5
HW 40, 60, 80 DAP and weed free up to maturity	13.4	13.4	23.7	276.0	259.8	346.3	137.6	131.6	147.8
HW 50 and 75 DAP and weed free up to maturity	13.7	12.5	23.5	275.2	260.1	289.7	130..6	125.4	146.5
Metribuzine 0.50 kg/ha as pre-em	13.2	13.4	23.5	262.0	267.4	310.0	124.4	118.5	123.5
Metribuzine 0.75 kg/ha as pre-em	13.50	13.6	24.0	265.6	270.5	338.0	130.6	121.3	149.8
Metribuzine 0.75 kg/ha as early post-em	14.30	14.0	25.8	262.4	268.9	365.0	124.4	120.0	154.0
Oxadiargyl 0.090 kg/ha	14.40	13.0	24.6	257.6	268.7	331.8	120.0	121.5	138.0
Preilachlor 0.750 kg/ha pre-em	14.50	13.9	25.1	266.4	269.2	344.8	128.0	121.8	151.3
LSD (P=0.05)	1.04	0.88	1.05	4.8	5.8	59.6	2.0	6.0	20.3

Weed management in mango orchards

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Mango (*Mangifera indica* L.) is considered as the king of fruits in India. India is the leading country in the world with about 50% of the world's mango production. In India, it was cultivated in an area of about 2.22 million ha with a total production of 18.51 million tones during 2014-15 (Horticultural Statistics at a Glance, 2015). Uncontrolled growth of weeds in mango orchards causes loss of soil nutrients and moisture, adversely affects growth and yield of tree. This provides shelter to insect-pests, and may pose difficulties in human labour movement for various operations. In orchards like citrus, it was noted that weeds compete with citrus trees for water, light, space and harbor pathogens, rodents and also reduce the efficiency of orchard operations (Futch and Singh, 2007). Hence, keeping growth of weeds under check is very much desirable in mango orchards. Weed management in mango orchards can be accomplished by growing weed suppressive intercrops throughout the cropping seasons, and also by application of herbicides. Therefore, an experiment was conducted to find out the most effective strategy for weed management in a mango orchard.

METHODOLOGY

A field experiment was initiated in the rainy season of 2013 at ICAR-Directorate of Weed Research, Jabalpur to find out the most effective strategy for weed management in a mango orchard. Six treatments comprising intercrops, application of herbicide, along with an unweeded control (Table 1) were evaluated in RBD replicated thrice. The intercrops were sown in rainy, winter and summer seasons in between the interspaces of mango trees. Weed density data were recorded at 60 DAS of intercrops.

RESULTS

During rainy season of 2013 and 2014, the major weed flora recorded in the mango orchard consisted of *Echinochloa colona, Dinebra retroflexa, Cyperus iria, Alternanthera sessilis* and *Oldenlandia corymbosa*. Intercropping *Sesbania* and sunhemp for 60 days in the inter spaces of mango trees could reduce the weed density at 60 DAS by 94.6 and 94.3% during 2013, and 90.8% and 94.3% during 2014, respectively.

In the winter season, the major weed flora infesting the mango orchard was *Medicago denticulata, Chenopodium album, Vicia sativa, Dinebra retroflexa, Sonchus arvensis, Alternanthera sessilis* etc. Application of glyphosate 2.0 kg/ha was most effective in controlling weeds in 2013, however, intercrop of field pea also significantly reduced the weed density compared to unweeded control. Intercrop of field pea was as effective as application of glyphosate in controlling weeds in summer of 2014.

Table 1. Effect of treatments on weed density at 60 DAS in mango orchard

Treatment	Weed density (no. /m^2)					
	2013-14			2014-15		
	Rainy, 2013	Winter, 2013-14	Summer, 2014	Rainy, 2014	Winter, 2014-15	Summer, 2015
Sesbania (R)-pea (W)-cowpea (S)	3.0 (8.5)*	5.8 (33.0)	6.0 (35.3)	4.4 (18.5)	8.3 (72.0)	9.8 (97.0)
Sunhemp (R)-pea (W)-green gram (S)	3.1 (9.0)	5.5 (29.3)	5.9 (34.3)	3.5 (11.5)	9.5 (91.0)	10.7 (114.5)
Soybean (R)-pea (W)-*Sesbania* (S)	8.1 (65.5)	7.1 (49.3)	6.2 (37.3)	8.1 (64.5)	6.9 (48.5)	12.3 (153.0)
Sorghum (R)-pea (W)-sunhemp (S)	6.9 (46.5)	8.1 (65.0)	6.3 (39.3)	10.4 (107.5)	12.7 (162.0)	10.1 (102.5)
Glyphosate 2.0 kg/ha (R-W-S)	4.6 (20.5)	0.7 (0.0)	5.8 (33.0)	7.6 (59.0)	10.6 (121.0)	11.3 (128.5)
Unweeded	12.6 (159.5)	8.9 (84.0)	6.8 (45.7)	14.2 (201.5)	29.0 (874.0)	13.1 (175.5)
LSD (P=0.05)	6.10	0.65	0.77	1.23	10.10	NS

R-Rainy season; W-Winter season; S-Summer season; Weed data subjected to $\sqrt{x + 0.5}$ transformation, *Values in parantheses are original

During summer season, the major weed flora infesting the mango orchard was *Echinochloa colona, Paspaladium* sp., *Cyperus iria, Dinebra retroflexa, Euphorbia geniculata, Alternanthera sessilis*, etc. The intercrops of cowpea and greengram and application of glyphosate were significantly effective in controlling weeds over unweeded control in 2013. During 2014, the effect of different treatments on weed density was non-significant.

CONCLUSION

The results of the two year study revealed that effective weed management in mango orchards can be achieved by growing intercrops of *Sesbania* or sunhemp during rainy season, intercrop of field pea during winter season, and intercrop of cowpea or greengram during summer season.

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Effect of integrated weed management technique comprising of trash mulching against weeds in sugarcane

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Weed problems in sugarcane cultivation is quite different from other field crops because sugarcane is planted with relatively wider row spacing and crop growth is very slow in the initial stages. It takes about 30-45 days to complete germination and another 60-75 days for developing full canopy cover. Thus, the initial 60-120 days period of crop growth is considered as most critical period of weed competition. Therefore the weed management practice adopted should ensure a weed-free field condition for the first 2-4 months period (Tomer *et al*. 2003). Evaluation of new herbicide molecule/products is a continuous process for upscaling of weed management strategies. The sugarcane trash on decomposition release nutrients which improves the fertility of soil. Mulching with sugarcane trash is, therefore, advantageous in respect to weed control over burning of (Singh *et al*. 2008). Keeping these points in view, a field was conducted during 2015-2016 in spring season at the Indian Institute of Sugarcane Research farm, Lucknow (UP) to assess the effect of integrated weed management in sugarcane.

METHODOLOGY

The soil of the experimental site was silty loam with pH 8.6 and organic carbon 0.45%, however available N, P_2O_5 and K_2O were determined to be 231.5, 34.6 and 295.3 kg/ha, respectively. The gross plot size was kept 36 m² (4.5 x 8.0 m) comprising six rows of sugarcane placed at 75 cm distance from each other. The sugarcane variety *'Co Lk 94184'* was planted on 28th May, 2015. Treatments comprised of pre-emergence application of atrazine 2.0 kg/ha and sulfentrazone 0.8 kg/ha and their integration with trash mulching 10 t/ha and 2,4-D 1.0 kg/ha as PO were conducted in randomised block design with three replications.

RESULTS

Predominant weed species in spring planted sugarcane were *Echinochloa colona, Dactyloctenium aegyptium* and *Panicum repens* among grasses; and *Cyperus rotundus* among sedges. Weed dynamics, total weed population and weed dry matter production was significantly affected due to different weed management practices. Lowest population of *Echinichloa colona, Dactyloctenium aegyptium* and *Panicum repens* was recorded with pre-emergence application of atrazine 2.0 kg/ha followed by (*fb*) manual hoeing and layby application of atrazine 1.0 kg/ha *fb* post-emergence (PO) application of 2,4-D 1.0 kg/ha; which was at par with application of either atrazine or sulfentrazone *fb* trash mulching@ 10.0 t/ha. Whereas, manual hoeing being at par with pre-emergence application atrazine *fb* 2,4-D as PO at 60 DOP *fb* manual hoeing at 90 DOP recorded lowest population of *P.repens*. Pre-emergence application of atrazine 2.0 kg/ha *fb* manual hoeing and atrazine + trash mulching *fb* 2, 4-D reduced the emergence of *C. rotundus* (Table 1). Different weed management measure also significantly influenced the total weed population and its dry matter production. Lowest weed population and weed dry biomass production was recorded under manual hoeing thrice, which was comparable to the integrated weed management practices.

Table 1. Weed dynamics, millable cane and cane yield as influenced by integrated weed management in spring season

Treatment	Dose (kg/ha)	Weed density (no./m^2) at 60 DOP: *Echinochloa colona*	*Dactyloctenium aegyptium*	*Panicum repens*	*Cyperus rotundus*	Total weed density	Total weed dry biomass (g/m^2)	Millable cane (000/ha)	Cane yield (t/ha)
Atrazine	2.0	6.3	6.0	4.3	23.3	39.9	155.2	82.5	50.13
Sulfentrazone	0.8	6.7	7.3	11.0	24.0	49.0	184.2	120.3	52.57
Atrazine *fb* hoeing + layby atrazine *fb* 2,4-D	2.0+1.5+1.0	1.3	1.3	5.3	10.7	23.6	99.7	152.1	56.97
Atrazine *fb* 2,4-D *fb* hoeing	2.0 *fb* 1.0	3.3	4.3	2.3	22.0	31.9	93.3	153.1	58.07
Atrazine + trash mulching(10 t/ha) *fb* 2,4-D *fb* hoeing	2.0 *fb* 1.0	2.3	2.3	2.3	17.3	24.2	49.5	149.4	58.73
Sulfentrazone + trash mulching(10 t/ha) *fb* 2,4-D *fb* hoeing	0.8 *fb* 1.0	2.3	1.7	3.0	20.0	27.0	74.1	150.1	57.47
Hand hoeing (3)	-	4.7	2.0	1.3	20.0	28.0	35.9	153.9	59.63
Weedy check (control)	-	15.0	18.3	15.7	42.7	91.7	301.9	56.4	35.07
LSD (P=0.05)		2.7	3.6	3.6	11.9	12.0	40.3	19.8	7.93

Different weed management practices in sugarcane affected significantly the yield and yield attributing characters of sugarcane. Significantly higher millable cane (1,53,900/ha) and cane yield (59.63 t/ha) was recorded with manual hoeing thrice at 30, 60 and 90 DOP, but it was at par with pre-emergence application of either atrazine or sulfentrazone + trash mulching *fb* post-emergence application of 2, 4-D. Lowest millable cane (56,400/ha) and cane yield (35.07 t/ha) was recorded under weedy check. Growing weeds throughout crop season caused 63% and 41% reduction in millable cane and cane yield, respectively. The effect of different weed management practices on juice quality (Pol %) was not observed significantly during period of the study. This may be due to the fact that juice quality is the inherent ability of genotype. However, the un-weeded check has registered the lowest Pol percent.

CONCLUSION

It is concluded that integrated weed control technology comprised of pre-emergence herbicides + trash mulching followed by application of post-emergence herbicides may be adopted to control the weeds effectively and higher sugarcane yield.

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Viable weed management options for sustainable crop production

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Weeds are considered to be most potentials pest causing adverse effect on agricultural productivity and quality. Excessive tillage, use of poor quality seed, weed contaminated seeds, weed shift, monoculture, non-availability of human resource for weeding, inappropriate selection and application of herbicides are key concerns for weed management in prevalent agricultural production systems. Potential weed management options have been summarized in order to ensure sustainability of the present agricultural production systems under changing crop management practices, agro-climatic and socio-economic conditions.

Ecological approaches

Poor seed replacement ratio, non-availability of quality seed and seeds admixture with weed seed, especially wild rice, *Echinochloa*, *Phalaris* etc. has emerged as one of the major issues for continued weed infestation in rice–wheat system. Efforts should be focused to use pure quality seeds for avoiding weed seed bank in soil. Under heavily infested fields with wild rice, *Echinochla* use of stale seedbed technique is appropriate way for reducing the weed infestation. In fact, the fallow period (45-60 days) between wheat harvests till planting direct-seeded rice (DSR) provides opportunity to execute stale seedbed more particularly for management of wild rice and *Echinochloa*. Site specific stale seedbed may significantly reduce weed pressure in intensive weed infested areas.

Optimum crop stand is an effective tool to minimize weed infestation. Alterations in the planting pattern (planting geometry) is a cost effective technique that brings desired change in the crop canopy structure and micro-climate, to enhance crop competitiveness against weeds resulting better weed suppression, improvement in resource use efficiency with maximum crop productivity. Need based closer spacing [Zero till (ZT) system 18.5 cm apart] is viable option for minimizing weed infestation in rice-wheat (RW) system. Conservation agriculture (CA) based practices with residue retention are the potential mean for reducing the weed infestation (Singh *et al.* 2014). ZT combined with residue retention on soil as mulch can be important strategies for weed control in rice and wheat in Eastern Indo-Gangetic plains. Rice establishment either by direct seeding (ZT-DSR) or transplanting (ZT-TPR) rice seedlings manually or mechanically can be rotated after every 2-3 years to keep weeds under control. Fast growing, vigorous and competitive cultivar suited to the situation is the need of the hour for minimizing weed infestation. Development and identification of competitive cultivars are required for varied agro ecosystems. Flooding provide an excellent opportunity to check the severe weed infestation therefore, many weeds can emerge in DSR before flooding, making weed management difficult (Chauhan 2012). Development of rice cultivars capable of anaerobic germination (AG) would greatly facilitate weed management via flooding in DSR, which ultimately provide better opportunity for promotion of DSR. Some of the promising AG cultivars, like *'IR64 AG, IR64 AG I'* are performing better under anaerobic environment and reducing the weed infestation. Further, the development and promotion of AG tolerant lines will be helpful in promotion of DSR.

Rational crop rotation is helpful in changing the cycle of the weed which ultimately reduces the weed infestation. Diversification and intensification of the RW system by growing a short-duration vegetable crop (pea or potato) followed by late sown wheat can also improve weed control without any increase in herbicide use. *Sesbania* sp. is allowed to grow with rice to suppress weeds and is then killed with 2,4-D ethyl ester at 25 to 30 days after sowing. Living mulch/ intercrops like mungbean and cowpea in maize and pigeon pea cropping systems helpful in minimizing the weed infestation significantly. Addition of azolla in rice fields suppresses the weeds like *Eichinochloa crusgalli* and *Cyperus difformis*, and the degree of suppression increased with increase in azolla cover and water depth.

Mechanical approaches

Laser land leveling provides uniform soil moisture in the entire field thus promotes uniform crop stand and growth leading to reduced weed infestation. Reduction in weed population in wheat observed under precisely leveled fields compared to traditionally leveled fields (Jat *et al*. 2009). Inter cultivation operation by appropriate tools is definitely a good option for efficient weed management. Surface application of rice residues at 6 and 7 t/ha significantly reduced population, dry matter production and leaf area index of *Phalaris minor* compared to straw removal and incorporation treatments, in wheat. Retention of crop residue with ZT system is an effective practice for suppressing the weed population in rice-wheat cropping system.

Chemical approaches

Appropriate herbicide selection, need based rotation of herbicides with proper method and time of application are the better technique for effective weed management. Different modes of action may be important in avoiding or delaying the evolution of resistance. Improper herbicide application by spray/ broadcasting, use of lower quantity of water (200-300 liter /ha) with inappropriate nozzle type and herbicide mixture are some of the serious concern lowering herbicidal efficiency and develop herbicidal resistance in present day agriculture. Appropriate technique of herbicidal spray with required water amount and proper nozzle type is required for improvement in herbicidal efficiency and to avoid the herbicide resistance problem.

CONCLUSION

In changing crop management practices, climatic and socio-economic situations, emerging weed management option like use of good quality seeds, appropriate cultural techniques, CA practices combined with residue retention and crop diversification, need based stale seed bed technique, site specific selection of herbicide, appropriate method and time of application, rational use of herbicide, proper technique for herbicide spray, crop and herbicidal rotation appropriate to the situation will provide potential opportunity for sustainable weed management.

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Pre-emergence herbicides can tactically fit into conservation agriculture systems with various benefits

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Conservation agriculture (CA) is an obligatory boulevard for natural resource conservation, reduced emission of greenhouse gases, better resilience to climatic extremes and to realize the dream of doubling farmers' income. The initial feat of CA in India particularly in rice-wheat cropping system (RWCS) is attributed to the development of a new machine called Happy Seeder, which enables zero-till wheat sowing in the combine harvested rice fields in presence of rice residues. Weeds are a major constraint to CA systems. Moreover, CA leads to sole reliance on post-emergence (POE) herbicides and consequently, the rapid development of herbicide resistance. Already, over dependence on POE herbicides has exploded the herbicide resistance in India. *Phalaris minor*, the most ubiquitous weed of wheat, have evolved multiple resistance to different MOAs (C2/7, A/1 and B/2). *Rumex dentatus* and *Polypogon monspeliensis* have also evolved resistance to ALS inhibitor herbicides whereas *Avena ludoviciana* has been confirmed for ACCase inhibitor herbicide resistance. *Chenopodium album* also started defying sulfonylureas. Gladly, these herbicide resistant (HR) weeds are sensitive to PRE herbicides but their single application is insufficient to control all the cohorts. To exacerbate the problem, PRE herbicides are less effective in the CA system. First, lack of mechanical incorporation in zero-tillage allows losses through volatility and photodecomposition of PRE herbicides like dinitroanilines. Second, the crop residue can intercept 15 to 80% of PRE herbicides and reduce herbicide penetration to the soil (Chauhan and Abugho 2012). The proportion of the herbicide trapped in the residue is again vulnerable to volatilization or photodegradation. Therefore, exigent tactics are required for the integration of PRE herbicides in CA systems for better herbicide performance and to evade the POE herbicides.

METHODOLOGY

Field studies were conducted at CCS Haryana Agricultural University, Regional Research Station, Karnal, Haryana, India during winter seasons of 2014-15 and 2015-16 with an objective to integrate rice straw mulch (varied levels) and PRE herbicides for management and mitigation of HR weeds in wheat in RWCS. PRE herbicides (pendimethalin, pyroxasulfone, metribuzin) alone and their mixture combinations were evaluated at different application rates by deliberately placing above/under the mulch and using higher carrier water volumes (500 to 1000 L/ha) or surface flood irrigation (PRE used as early POE, just before first irrigation) to facilitate the penetration of herbicides through mulch. The results presented here come from six field experiments appraising permutations and combinations of chemical and non-chemical tools for control of HR weeds.

RESULTS

The dominant weed species present in the experimental area were *Phalaris minor*, *Rumex dentatus*, *Chenopodium album*, *Melilotus alba*, *Medicago denticulata*, *Coronopus didymus*, *Anagallis arvensis*, *Lathyrus aphaca* and *Vicia sativa*. The results revealed that synergistic integration of zero-tillage + higher cropping density (125 kg/ha) + PRE herbicide mixture (pendimethalin 1.5 + metribuzin 0.210 kg/ha) + 8 t/ha rice straw mulch reduced weed population in wheat close to zero when PRE herbicides were applied beneath the mulch. In wheat sown with turbo happy seeder (ZT + rice residue, 8-9 t/ha), application of pendimethalin/pyroxasulfone + metribuzin on top of the mulch either as PRE with high carrier volume (1000 L/ha) or immediately before the first irrigation (20 DAS) as early POE significantly improved weed control without causing any crop injury. In another trial, PRE herbicides when sprayed on top of the mulch, increased rates didn't improve *P. minor* control. In contrast, if herbicides were applied under mulch, even reduced rates with lower mulch level provided satisfactory control of seeded *P minor*. Amazingly, the application of pendimethalin 1.0 kg/ha beneath 12 t/ha mulch provided 100 % control of *P. minor* which can be attributed to reduced herbicide losses due to photolysis and volatilization, and better soil moisture under the mulch. The differential dissipation of PRE herbicides placed on top or below the mulch was also confirmed through herbicide residue analysis.

CONCLUSION

The efficacy of PRE herbicides in wheat can be improved with high carrier volume (1000 L/ha) or using these as early POE just before first irrigation in CA system. Convincingly, application of PRE herbicides mixture beneath the rice mulch in combination with ZT and higher crop density proved to be a novel stratagem to manage and mitigate HR weeds in wheat. However, momentous efforts are required to attach the spraying system below combine harvester so that herbicides can be secured beneath the rice straw while rice harvesting; and sowing the wheat in ZT immediately with Happy Seeder.

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Reduced tillage and weed management strategies on producivity of maize- sunflower sequential cropping in conservation agricultural system

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Reduced soil tillage systems have a major impact on the weed species composition and the density of weed populations (Malik *et al.* 2014). Weed control programs developed under conventional tillage systems are seldom appropriate for reduced tillage systems also. Therefore, introducing reduced soil tillage systems in the cropping system along with weed control programs will be beneficial on the productivity of the crops. This will lead to long-term yield increase and output stability can be achieved, at the same time stopping and reversing land degradation (Mashingaidze *et al.* 2012). The reduced tillage operations combined with effective weed control methods in conservation agricultural systems are to be identified for higher productivity and profitability of the crops.

METHODOLOGY

Field experiments were conducted during *Rabi* 2015 and *Kharif* 2016 in sunflower - maize cropping system at TNAU, Coimbatore with strip plot design without replication. Sunflower hybrid Co 2 and maize hybrid CO HM 6 were used. The main plot consists of conventional tillage and zero tillage in different combinations with and without residues and sub plot consists of recommended herbicides alone (atrazine 0.5 kg/ha followed by 2,4-D 0.75 kg/ha for maize and pendimethalin 1.0 kg/ha for sunflower) and with hand weeding on 45 DAS and unweeded control. The soil samples were collected from all the treatments before sowing and 60th day after sowing for enumeration of microorganisms and enzymes activities.

RESULTS

Predominant species observed were *Trianthema portulacastrum*, *Digera arvensis* and *Parthenium hysterophorus*, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Chloris barbata* and *Cyperus rotundus*. Lower total weed density and dry weight (29.8/m^2 and 13.85 g/m^2) and weed control efficiency was recorded in zero tillage in ZT-ZT + R system and PE pendimethalin at 1.0 kg/ha + HW on 45 DAS (24.18/m^2 and 12.52 g/m^2) in sunflower. Higher yield and yield attributes (2.21 and 1.99 t/ha) also recorded in the same treatment. Higher net return (Rs. 22918/ha) and B: C ratio of 2.13 was recorded in zero tillage in ZT-ZT+R system and PE pendimethalin at 1.0 kg/ha + HW on 45 DAS in sunflower. Conventional tillage -conventional tillage system recorded lower total weed density and dry weight and higher weed control efficiency (31.46/m^2 and 19.95 g/m^2) and PE atrazine at 0.5 kg/ha + HW on 45 DAS recorded (12.16/m^2 and 9.9 g/m^2). Higher yield and yield attributes of maize were recorded in CT-CT system and in PE atrazine at 0.5 kg/ha + HW on 45 DAS of 5.22 and 5.31 t/ha. Higher net return (Rs.35459 and 36154/ha) and B: C ratio of 2.45 and 2.40 were recorded in conventional tillage and in PE atrazine at 0.5 kg/ha + HW on 45 DAS in maize. Total bacteria, fungi, actinomycetes and phosphobacteria and soil enzymes, *viz*. alkaline phosphatase and dehydrogenase were significantly higher in zero tillage + residue system and pendimethalin at 1.0 kg/ha + HW on 45 DAS in sunflower and conventional tillage system with atrazine at 0.5 kg/ha + HW on 45 DAS in maize.

Table 1. Tillage and weed management practices on yield and economics of Sunflower – Maize sequential cropping under conservation agricultural system

Treatment	Sunflower			Maize		
	Total weed density (no./m^2)	Seed yield (t/ha)	B:C ratio	Total weed density (no./m^2)	Grain yield (t/ha)	B:C ratio
Tillage method						
T_1 (CT-CT)	7.71 (60.24)	1.69	1.80	5.62 (31.46)	5.22	2.45
T_2 (CT-ZT)	6.40 (41.33)	2.01	1.94	5.82 (33.85)	5.09	2.44
T_3 (ZT+R - ZT)	7.03 (49.37)	1.78	1.91	5.74 (32.97)	4.80	2.31
T_4 (ZT – ZT+R)	5.46 (29.80)	2.21	2.13	5.90 (34.81)	5.01	2.34
T_5 (ZT+R – ZT+R)	5.59 (31.20)	1.64	1.79	5.94 (35.22)	4.81	2.37
LSD (P=0.05)	0.57	0.21		0.37	0.51	-
Weed management method						
W_1 Herbicide alone	6.58 (44.14)	1.85	1.45	4.51 (20.14)	5.04	2.3
W_2 Recommended herbicide + HW on 45 DAS	4.91 (24.18)	1.99	1.75	3.50 (12.16)	5.31	2.4
W_3 (Unweeded check)	7.99 (65.56)	0.99	1.05	6.13 (37.27)	3.97	1.6
LSD (P=0.05)	0.87	0.18		0.31	0.45	-

CONCLUSION

Conventional tillage with pendimethalin + HW on 45 DAS and zero tillage with atrazine + HW were the best to get higher productivity in maize - sunflower sequential cropping system.

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Soil microbial dynamics of mustard under peralmillet-mustard conservation agriculture system

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Weeds as one of the groups of pest are the major biological constraint and lack of suitable eco-friendly weed control alternatives has led to increase in reliance on herbicides Generally, herbicides are not harmful when applied at recommended rates but some herbicides may affect non-target organisms including microorganisms. These effects on non target organisms may reduce the performance of important and critical soil functions such as organic matter decomposition, nitrogen fixation and phosphate solubilization which support the soil health, plant growth and in turn crop productivity (Singh *et al.* 2015). Therefore, present investigation was undertaken to study effect of different tillage and weed management practices on soil microbial properties in mustard crop for pearlmillate-mustard cropping system.

METHODOLOGY

Field experiment was conducted during 2012-16 in pearlmillate-mustard cropping system at AICRP-WM, AAU, Anand with different tillage and weed management practices (Table 1). Rhizospheric soils samples were collected randomly from the top layers of the soil (0-15 cm) from each plot at 30 DAS, 60 DAS and at harvest to study soil microbial properties *viz.* diazotrophs and PSM count, dehydrogenase, alkaline and acid phosphatase activity during *Rabi* 2016 using standard methods.

RESULTS

Effect of tillage practices

Tillage methods had no significant effect on soil microbial properties at 30 DAS, 50 DAS and at harvest (Table 1), except total PSM count and alkaline phospahtase activity. Among various tillage practices, slight improvement in microbial properties was observed under zero tillage as compared to conventional tillage due to improvement in organic carbon content. Interestingly, at 30 DAS tillage treatments with incorporation of crop residues showed significant improvement in total PSM number and alkaline-P activity. The increase was due to increase in fungi number which grows on crop residues and soil microbes majorly contributes in soil alkaline-P activity. At harvest, there was notable improvement in soil microbial as well as biochemical status in compare to initial status due to tillage practices particularly zero till.

Effect of weed management practices

Significant difference was recorded due to different weed management practices at 30 and 60 DAS, while the difference became non-significant at harvest for soil microbial and biochemical properties (Table 1). However, significant variations were observed in microbial properties between two herbicide and weedy check, this was mainly due to herbicide effect. Among different weed management practices, maximum microbial properties *i.e.* diazotrophs, PSM, DHA, alkaline-P and acid-P was observed in weedy check and minimum in herbicide treated plots at all three crop stages. Interestingly, W_1 and W_2 at 30 DAS showed non-significant difference, while at 60 DAS it become significant. As, there was IC at 30 DAS and IC always promotes aeration in soil, it involves a bit of rhizosphere soil mixing and this can contributes to enhanced microbial activities. While Bhale *et al.* (2012) reported that IC allows pulverization of soil and better soil aeration which ultimately increase the microbial population in the soil. At harvest, there was notable improvement in soil microbial as well as biochemical status in compare to initial status, although there was initial setback of herbicides at 30 DAS.

Table 1. Effect of different tillage and weed management practices on soil microbial properties in *Rabi* mustard

Treatment	Total diazotrophs (10^3 CFU/g soil) Initial: 84.00			Total PSM (10^3 CFU/g soil) Initial: 69.00			Dehydrogenase (µg TPF/g soil/24 h) Initial: 25.00			Alkaline phosphatase (µg p-NP/g soil/h) Initial: 160.00			Acid phosphatase (µg p-NP/g soil/h) Initial: 64.00		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
Tillage Practices (T)															
T_1 :CT-CT--	84.78	89.11	88.56	71.11	77.44	76.89	23.33	27.00	26.22	158.11	165.56	164.67	64.00	66.44	65.33
T_2 : CT–ZT-ZT	84.89	89.22	88.67	72.22	77.67	76.89	24.33	27.44	26.89	158.22	166.67	165.00	65.44	67.89	67.67
T_3 :ZT–ZT-ZT	85.00	89.33	89.00	73.78	78.22	77.56	25.44	28.67	28.11	160.89	166.11	165.89	65.44	67.00	66.44
T_4 :ZT-ZR+R-ZT	85.11	89.44	89.56	76.33	79.67	80.22	26.56	29.78	29.33	163.33	167.22	167.00	68.22	70.22	68.11
T_5 :ZT+R-ZT+R-ZT	85.33	89.78	89.44	76.67	80.11	79.56	28.00	29.78	29.67	163.67	169.00	168.11	69.11	71.11	69.89
LSD (P=0.05)	NS	NS	NS	3.48	NS	NS	NS	NS	NS	3.89	NS	NS	NS	NS	NS
CV%	3.43	3.44	3.52	4.41	3.98	3.77	12.27	10.03	12.31	2.27	1.99	2.11	5.28	4.89	5.77
WM Practices (W)															
W_1 : Pendi 0.50 kg/ha PE	83.80	87.67	88.53	72.93	77.13	77.87	24.07	26.87	27.27	159.73	164.40	164.40	65.07	66.40	66.40
W_2 : Pendi 0.50 kg/ha PE *fb* IC 30 DAS	83.87	91.40	88.93	72.93	80.40	78.27	24.33	29.87	28.00	159.80	168.47	167.07	65.67	68.73	67.40
W_3 :Unweeded	87.40	89.07	89.67	76.20	78.33	78.53	28.20	28.87	28.87	163.00	167.87	166.93	68.60	70.47	68.67
LSD (P=0.05)	2.46	2.50	NS	2.20	2.38	NS	2.08	2.32	NS	2.54	2.66	NS	2.95	3.04	NS
CV%	3.84	3.71	3.72	3.95	4.01	4.72	10.78	10.78	13.04	2.09	2.11	2.01	5.88	5.88	5.97
Interaction T X W	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

CONCLUSION

The results revealed that tillage and weed management practices did not influence soil microbial properties. The maximum increase in microbial properties was observed in zero tillage+residue system, whereas minimum was in conventional tillage. There were no adverse effects of recommended herbicide use on soil microbial properties at the end.

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Changes of microbiological properties and sequestered carbon in soil under influence of conservation agriculture

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Chhattisgarh state is known as "Rice bowl of India". The state is mono cropped mainly with rice but this cropping system threatening the sustainability of the system. Low levels of soil organic matter, appearance of multiple nutrient deficiencies due to their over mining from soils and poor management of crop residues (CRs), leading to their burning are some of the major reasons for declining productivity in the region. Losses of nutrients due to leaching occurs due to more agricultural practices (Havlin *et al.* 1999). Conservation agriculture (CA) is recognized as agriculture of the future (Pretty *et al.* 2011). CA-based crop management technologies, such as no till with residue retention and judicious crop rotation are gaining more attention in recent years. Residue retention improves soil physical, chemical and biological quality. One problem associated with CA is the more weed emergence due to direct seeding condition which is required to be rectified by taking suitable herbicides combination. Hence in this present study efforts have been made to find out the effect of zero tillage, residue management practices and herbicide application on soil microbial activities which are the indicators of healthier soil.

METHODOLOGY

Field experiments were carried out at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur during 2014-15. The experimental soil was Inceptisol, low in organic carbon, low in available nitrogen, medium in phosphorus and high in potassium with neutral soil reaction. Five treatments comprised of pure conventional and zero tillage and three different combinations of conventional and zero tillage with and without residue retention have been taken under direct seeded and transplanted condition of paddy. These treatments put under main plots, whereas in sub plots two weed management practices have been taken compared with one weedy check. The practices were integrated weed management and purely chemical weed management. The crop rotation of rice-wheat-cowpea was followed in both the years. After completion of crop cycles in every year C-sequestration and study of different microbiological properties like activity of dehydrogenase, microbial biomass carbon and basal soil respiration was done. Viability of different treatments was analysed as per the standard procedure.

RESULTS

At the end of the cycle of four crops (paddy, wheat, cowpea and paddy) in two years it was observed that carbon stock significantly affected by different tillage systems. Maximum C-stock was quantified in fields where zero tillage practice was applied along with addition of residue in both kharif and rabi seasons, followed by zero tillage with residue retention only in *Rabi*. The zero-zero tillage with residue application twice in a year had shown significantly superior over all other tillage treatments (Table 1). Among two weed management methods, significantly higher values of carbon accumulation were found in chemical method of weed management over integrated weed management system. The weedy check showed maximum carbon accumulation.

Table 1. Microbiological properties and accumulation of Carbon content in soil as influenced by different tillage and weed management practices

Treatment	Carbon stock (t/ha)			Microbiological property					
	At sowing of paddy in 1st year	At harvest of paddy in 2nd year	Sequestered carbon content	At sowing of paddy in 1st year			At harvest of paddy in 2nd year		
				DHA	MBC	BSR	DHA	MBC	BSR
Main plot (tillage method)									
CT (transplanted) - CT – CT	10.584	11.566	0.982	30.67	80.15	0.383	34.75	90.20	0.390
CT (transplanted) -CT – ZT	11.172	12.336	1.164	33.44	84.33	0.389	40.03	95.73	0.400
Conventional (DSR) –CT-ZT	10.920	11.917	0.997	32.85	82.23	0.383	34.85	90.37	0.392
Zero tillage (DSR)- ZT+ R-ZT	11.004	12.417	1.413	33.06	83.18	0.389	39.87	94.50	0.397
Zero tillage (DSR) + R-ZT + R-ZT	11.256	12.920	1.664	34.17	85.24	0.395	41.43	98.82	0.401
LSD (P=0.05)	N.S.	N.S.	0.141	N.S.	N.S.	N.S.	4.07	8.06	N.S.
Sub-plot (weed management method)									
Recommended herbicide	10.936	11.999	1.063	32.57	83.08	0.387	37.69	91.22	0.395
Integrated weed management	10.987	11.622	0.635	32.97	82.76	0.389	36.16	90.62	0.394
Unweeded	11.037	13.072	2.035	32.97	83.24	0.390	40.72	98.45	0.399
LSD (P=0.05)	N.S.	1.422	0.108	N.S.	N.S.	N.S.	3.64	7.69	N.S.

DHA: Dehydrogenase enzyme activity in µg TPF/h/g soil, MBC: Microbial carbon content in µg/g soil, BSR: Basal soil respiration rate in mgCO_2/h/100g soil

Different tillage systems significantly affected the microbiological properties like dehydrogenase activity (DHA) and microbial biomass carbon content (MBC) of soil after harvest of paddy (*Kharif* 2015). However, the basal soil respiration rate (BSR) was unaffected by tillage systems (Table 2). Maximum enzymatic activity and microbial biomass carbon was found in soil which had experience of zero tillage with crop residue under direct seeded conditions in both *Kharif* and *Rabi* seasons. This was at par with conventional-zero tillage system under transplanted condition and zero-zero tillage system under direct seeded condition. Among different weed management methods maximum soil dehydrogenase enzyme activity and microbial biomass carbon was measured in unweeded plots, which was found at par with plots received only herbicides for weed control. The basal soil respiration was found unaffected by different weed management methods.

CONCLUSION

Zero-zero tillage with residue application twice in a year under direct seeding was found effective to improve soil quality parameters like carbon accumulation in soil and microbiological properties. Among different weed management methods chemical weed control was found best to improve soil health.

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Effect of weed management in blackgram and its residual effect on succeeding mustard crop

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One of the major causes for poor yields in pulses is attributed to the luxurious growth of weeds in these crops and failure to control them in time. Weed infestation in black gram may reduce yield up to an extent of 45 to 60 percent. Use of herbicides under such conditions is advantageous as the operation is not only economical but also provides timely protection. Imazethapyr and its ready mix combination with imazamox, new herbicides of imidazolinone group have been found promising to control weeds in blackgram. Imazethapyr being highly persistent in soil may cause residual toxicity in succeeding crops. Keeping these in view, herbicides imazethapyr alone or in combination with imazamox and pendimethalin as pre-mixture with imazethapyr were tested under pre- and post-emergence conditions.

METHODOLOGY

A field experiment was undertaken at agronomical research farm of Birsa Agricultural University, Ranchi during *kharif*, 2014 and 2015. The experiment was laid out in randomized block design with sixteen treatments replicated thrice. The treatments comprised of pre- and post-emergence application of imazathepyr 50, 70 and 80 g/ha, pre- and post-emergence application of ready mix imazethapyr 35% + imazamox 35% (Odyssey) 50, 70 and 80 g/ha, pre-emergence application of pendimethalin 1000 g/ha, ready mix imazethapyr 2% + pendimethalin 30% (vallor) 1000 g/ha, hoeing twice and weedy check. The black gram crop variety 'T9' was sown on 16th and 3rd July 2014 and 2015 respectively and was harvested on 22nd and 12thSeptember, 2014 and 2015 respectively. The succeeding mustard crop variety "Shivani" was sown 29th October 2nd November, 2014 and 2015 and harvested on 10th and 28th February, 2015 and 2016 respectively.

RESULTS

Post emergence application of imazethapyr and ready mix of imazethapyr and imazamox irrespective of doses showed mean weed control efficiency of 66.53 and 66.77 percent and 82.65 and 78.93 percent respectively at 30 and 60 DAS but at the same time showed slight phytotoxicity in black gram plants at 15 days after application of herbicides in the form of stunted growth of plants which mitigated after some time. Kumar *et al*. (2015) have also observed that post-emergence use of imazethapyr + imazamox at 60-80 g/ha exhibited 78-83% control of weeds with slight crop suppression. Post emergence application of imazethapyr 35% + imazamox 35% 70 g/ha recorded significantly higher seed (1.12 t/ha) and straw yield (2.33 t/ha), gross return (Rs. 34,583/- ha), net return (Rs. 24,126/-) and B:C ratio (2.31). Pre-emergence application of pendimethalin 1000 g/ha and post emergence application of imazethapyr 80 g/ha applied in blackgram reduced mustard plant density to the extent of 10.58 and 16.17% compared to mean plant density of 35.79 plant/m^2 resulting poor mustard yield.

Table 1. Effect of weed control methods on economics of black gram production (pool of 2014 and 2015)

Treatment	WCE%		Yield (t/ha)		Gross return (Rs/ha)	Net return (Rs/ha)	B:C Ratio
	30 DAS	60 DAS	Seed	Straw			
imazethapyr 50g/ha PRE	63.72	77.29	0.92	1.32	28547	18147	1.74
imazethapyr. 70g/ha PRE	75.57	85.78	0.94	1.48	29051	18637	1.79
imazethapyr 80g/ha PRE	86.89	84.88	1.07	2.17	33225	22804	2.19
imazethapyr. 50g/ha POE	55.44	54.97	0.86	1.26	26508	16108	1.55
imazethapyr 70g/ha POE	64.69	65.87	0.93	1.34	28896	18482	1.77
imazethapyr 80g/ha POE	79.47	79.49	1.00	1.77	31053	20632	1.98
imazethapyr 35% + imazamox 35% 50g/ha PRE	73.13	73.76	0.86	1.28	26570	16140	1.55
imazethapyr 35% + imazamox 35% 70g/ha PRE	84.91	86.61	1.03	2.00	31781	21325	2.04
imazethapyr 35% + imazamox 35%80g/ha PRE	90.16	89.38	1.07	2.91	33191	22721	2.17
imazethapyr 35% + imazamox 35%50g/ha POE	71.68	64.03	0.97	1.71	30009	19579	1.88
imazethapyr 35% + imazamox 35%70g/ha POE	87.29	86.08	1.12	2.33	34583	24126	2.31
imazethapyr 35% + imazamox 35%80g/ha POE	88.98	86.70	1.10	2.50	34124	23655	2.26
pendimethalin.1000g/ha PRE	69.79	83.33	1.10	2.28	33997	23093	2.12
imazethapyr 2%+ pendimethalin 30%1000g/ha	94.07	83.67	0.94	1.51	29040	17941	1.62
hoeing twice	76.36	91.46	0.96	1.58	29726	12676	0.74
weedy check	0.00	0.00	0.66	1.03	20375	8981	0.79
LSD (P=0.05)	17.72	22.57	0.16	0.71	4580	4580	0.42

CONCLUSION

On the basis of two year pooled data it can be inferred that post emergence application of imazethapyr 35% + imazamox 35% 70 g/ha can be practiced in black gram for effective weed control and productivity and profitability without adverse effect on succeeding mustard crop.

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Herbicide resistance in toothed dock population from Haryana

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Phalaris minor was the first weed reported to have attained resistance against urea herbicides in early 1990s in north-western India, which later onattained cross resistance against alternate herbicides also after their continuous use for 10-15 years. This has been one of the most serious cases of herbicide resistance in the world, threatening the productivity of wheat crop in the most productive north-western Indo-Gangetic Plains region (Malik and Singh 1995). Since then, no major problem of resistance in any other weed in India came to notice for a long period. But there is every possibility of evolution of resistance in other weeds as well, so one has to be vigilant and explore the cases of poor efficacy of herbicides in different weeds which may turn into cases of herbicide resistance. Instances of herbicide resistance in toothed dock (*Rumex dentatus* L.) have been reported recently (Heap 2014). For the last 3-4 years, poor efficacy of metsulfuron-methyl herbicide against *Rumex dentatus* population from KVK, Panipat in Haryana has been observed, which was needed to be verified and evaluated for resistance development against different herbicides.

METHODOLOGY

Seeds of toothed dock (*Rumex dentatus*) population from KVK, Panipat, Haryana, India which were not controlled by herbicide metsulfuron-methylwere collected during *Rabi* 2014-15. During *rabi* 2015-16, seeds of this biotype were sown in pots (9" diameter) on December 22, 2015 at CCS Haryana Agricultural University, Regional Research Station, Karnal. After germination of weeds, thinning was done to make the population uniform in all pots. The treatments included graded doses (1/4X, 1/2X, X, 2X and 4X of recommended doses) of herbicides metsulfuron-methyl (1, 2, 4, 8 and 16 g/ha), carfentrazone (5, 10, 20, 40 and 80 g/ha) and 2, 4-D (75, 150, 300, 600 and 1200 g/ha) along with untreated check. The experiment was laid out in completely randomized design with four replications. Spray of herbicides was done on February 5, 2016 (2-4 leaf stage) using flat-fan nozzle using water volume of 500 l/ha. The observations on per cent control of weeds were taken at 30 days after herbicide application.

RESULTS

The bioassay studies indicated that *Rumex dentatus* population from Panipat was not controlled effectively (30%) by metsulfuron-methyl even upto 4X dose of 16 g/ha. However, efficacy of 2, 4-D and carfentrazone was good even at X doses. At X doses, metsulfuron-methyl 4 g/ha provided only 17% control of *Rumex*, while 2,4-D 600 g/ha and carfentrazone 20 g/ha provided satisfactory control (98 and 87%, respectively)of weeds (Fig 1). Carfentrazone and carfentrazone have been found effective against this biotype of *Rumex*, so there is no cause of concern as such. These alternate herbicides may be an effective tool in our hands to avoid further spread of herbicide resistance in *Rumex dentatus*. Continuous use of single herbicide may be discouraged and rotational use of herbicides with proper spray techniques may be advocated in order to avoid and delay the chances of development of resistance/ cross-resistance in *Rumex dentatus* in India.

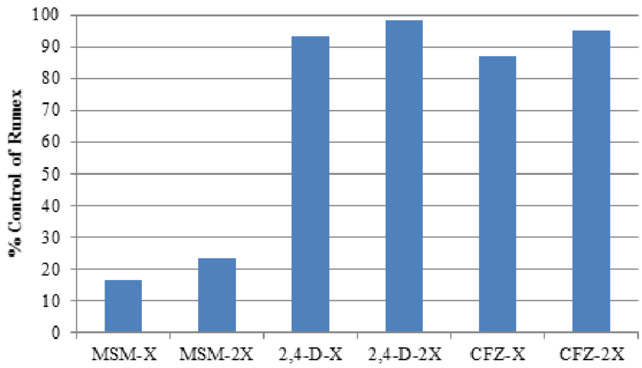

Fig. 1. Efficacy of metsulfuron-methyl (MSM), 2, 4-D and carfentrazone (CFZ) at X and 2X doses against *Rumex dentatus* population from Panipat.

CONCLUSION

Rumex dentatus population from Panipat has shown poor efficacy of metsulfuron-methyl at graded doses, which primarily indicated towards development of herbicide resistance in *Rumex* against metsulfuron-methyl. However, carfentrazone and 2,4-D were found effective, hence could serve as alternate herbicidal options which should be used in rotation for its management and avoid further spread of herbicide resistance.

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New formulation of mesosulfuron-methyl 1% + clodinafop-propargyl 6% to manage resistant weeds in wheat

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Weeds impact production in input-intensive wheat cultivation in India. Little seed canary grass (*Phalaris minor*) and wild oat (*Avena* spp.) are two most troublesome monocot weeds in wheat. *P. minor* alone can cause yield reduction upto 40% (Singh *et al.* 1997). The sole dependence on herbicide of single mode of action contributed to shift towards difficult-to-control weeds and the rapid evolution of cross herbicide resistance. Herbicide rotation and mixtures are widely recommended to manage herbicide resistance (Beckie and Rebound 2009). A new formulation containing mesosulfuron-methyl 1% (ALS- inhibitor) and clodinafop propargyl 6% WG (ACCase-inhibitor) was evaluated to optimize its rate for control two important monocot weeds in wheat to provide an alternate herbicide for delaying evolution of herbicide resistant biotype of P. minor in Eatern Indo-Gangetic plains of India.

METHODOLOGY

Two season field trials were conducted during year *Rabi*, 2014-15 and *Rabi*, 2015-16 to evaluate the effect of different rates of containing mesosulfuron-methyl 1% + clodinafop propargyl 6% WG at Banaras Hindu University, Varanasi The soil at the location was sandy loam in texture. The soil was deficient in Nitrogen and medium in phosphorus and potassium. Three rates of mesosulfuron-methyl 1% clodinafop propargyl 6% WG at 7.5 + 45, 10 + 60 and 12.5 + 75 g/ha compared with clodinafop propargyl 15% WP at 60 g/ha and mesosulfuron-methyl 3% + iodosulfuron-methyl sodium 0.6% WG 12 + 2.4 g/ha applied at 30 days after sowing using plot sprayer fitted with flat-fan nozzle. These were compared with two Hand weeding and untreated treatments in a randomized complete block design replicated three. The crop was grown with recommended package of practices for Wheat in the area. Three places in each treatment were selected at random and marked with pegs. Species wise weed count was recorded using 1 x 1 m^2 quadrate in marked area at 60 days after application. Hand weeding was taken up at 20 and 40 days after sowing. The weed samples were sun dried for four days and then transferred to hot air oven for drying at 60^0 C. Weeds dry weight of each sample was recorded in g/m^2 60 days after application. The crop was harvested at maturity and grain yield was recorded in kg/plot and converted to q/ha.

RESULTS

The dry matter production of *Phalaris minor* and *Avena fatua* was significantly decreased due to mesosulfuron -methyl 3% + iodosulfuron-methyl sodium 0.6% WG 12.5 + 75 g/ha and 10 + 60 g/ha and was lower than clodinafop propargyl 15% WP 60 g/ha and mesosulfuron-methyl 3% + iodosulfuron-methyl sodium 0.6% WG at 12+2.4 g/ha (Table1). The weed control efficiency was also maximum in mesosulfuron-methyl 3% + iodosulfuron-methyl sodium 0.6% WG 12.5 + 75 g/ha closely followed by 10 + 60 g/ha which was comparable to two hand weeding treatments and higher than rest of the herbicide treatments. Consequently, the highest grain yield was recorded due to application of mesosulfuron-methyl 3% + iodosulfuron-methyl sodium 0.6% WG 12.5 + 75 g/ha followed by mesosulfuron-methyl 1% + clodinafop-prpargyl 6% WG 10 + 60 g/ha. Whereas, maximum profit (cost-benefit ratio) was recorded from mesosulfuron-methyl 1% + clodinafop-prpargyl 6% WG 10 + 60 g/ha.

Table 1. Effect of treatments on dry weight, weed control efficiency, and grain yield in wheat (2 year average)

Treatment	Rate (g/ha)	WCE (%)		Grain yield (t/ha)	Additional yield over control	C:B Ratio
		Phalaris minor	*Avena fatua*			
Mesosulfuron- methyl 1% + clodinafop-propargyl 6% WG	7.5 +45	77.0	53.8	2.98	3.1	1:3.4
Mesosulfuron- methyl 1% + clodinafop-prpargyl 6% WG	10 + 60	91.5	87.7	3.97	13.2	1:4.1
Mesosulfuron- methyl 1% + clodinafop-propargyl 6% WG	12.5 + 75	92.4	89.1	4.26	16.0	1:3.41
Clodinafop propargyl 15% WP	60	73.3	43.3	3.19	5.4	1:2.81
Mesosulfuron-methyl 3% + iodosulfuron-methyl 0.6% WG	12 + 2.4	80.7	67.7	3.53	8.8	1:3.82
Weed free (hand weeding)	20 and 40 DAS	94.2	90.8	4.32	16.7	1:2.4
Untreated	-	-	-	2.66	-	-
LSD (P=0.05)	20 + 120	-	-	0.27		

Figures in the parentheses are transformed $\sqrt{x + 0.5}$ values.

CONCLUSIONS

Based on the present study, it can be concluded that for effective control of *Phalaris minor* and *Avena fatua* and higher yield and profit in wheat, mesosulfuron-methyl 1% + clodinafop-propargyl 6% WG at 10+60 g/ha as post-emergence can be promising herbicide formulation over existing herbicides to prevent/ delay evolution of herbicide resistance in the weeds under agro-climatic conditions of Eatern Indo-Gangetic Plains of India.

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Targeting isoproturon resistant D1 protein of *Phalaris minor*: Rational drug design approach

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Isoproturon resistance in *P. minor* was first reported in 1992. Later resistance and cross resistance of clodinafop fenoxaprop (FOP group) traloxydim DIM group was also reported (Chhokar and Sharma 2008). Resistance and cross resistance together makes *P. minor* the most serious grass weed of wheat which has shown resistance to three different drug targets *i.e.* D1 protein of Photo System-II (PS-II), Acetyl CoA carboxylase and acetolactate synthase. Isoproturon herbicide binds at the Q_B site of D1 protein of PS-II located in the thylakoid membrane of chloroplast. In this study computational studies have been performed to identify novel molecules which further require to validate their efficacy *in vivo*.

METHODOLOGY

Homology Modelling and High Throughput Virtual Screening (vHTS): Amino acid sequence of susceptible (AAP47827.1) and resistant D1 proteins (AAP33145.1) of *P. Minor* was retrieved from the NCBI protein sequence database. PDB BLAST was performed to identify the suitable template to model the D1 protein. PS-II herbicides *i.e.* molecules of C1, C2 and C3 class were downloaded from the International Survey of Herbicide Resistant Weeds. Based on 70% structural similarity to the existing C1, C2, and C3 class of herbicides, 33016 structural analogues were downloaded from ZINC database. The vHTS was employed to predict the putative binding affinities of small molecules with D1 protein of PS-II at Q_B binding site. These small molecules were prepared for screening in both rigid and flexible approaches. *De Novo* design of new analogues was performed by LigBuilder, it also consider synthesis ability of the ligands. Protein ligand binding affinity is evaluated by chemscore (empirical scoring function).

Prioritization of leads: Docking was performed for both screened and *de novo* lead molecules at the binding site of D1 protein using AutoDock (Singh et al, 2012). The high ranked molecules of each class were selected on the basis of binding energy, ligand efficiency and inhibition constant from screened and de novo designed molecules. Twenty four leads were selected, thirteen from vHTS and eleven from *De novo* Design.

RESULTS

Modeled structure was evaluated on the basis of their energy scores and root mean square deviation (RMSDs). Modelled proteins were validated by using structural analysis and verification server. The ProSA Z-score was -4.0 which indicate overall quality and measures the deviation from the total energy of the structure. Results clearly suggest that the comparative modelled structure of D1 protein is of good quality, and could be used for further studies.

Virtual High Throughput screening: vHTS for all retrieved 33016 ligands was performed at the ref_lig binding site of modelled D1 protein. 7250 ligands were selected from 33016 ligands on the basis of score either more or equal to ref_lig molecule score. After the first step of screening, selected ligands were set up for three times flexible docking with classes and subclasses of C1, C2 and C3 group of PS-II inhibitors best screened ligands were selected on the basis of defined criteria and ref_lig score.

***De novo* Design:** Molecules were designed considering Lipinski RO5, chemscore, binding affinity, synthesizability, and toxicity parameter for all molecules as well as the molecules were represented with the route of synthesis with cost index. Synthesized ligand (284) belongs to C1, C2 and C3 class.

Docking: The vHTS and *De novo* hits were redocked at the binding site of modelled D1 protein. The best conformation of each hit was selected based on binding energy, ligand efficiency, and inhibition constant. The ref_lig docking scores was set as criteria to select the best hits from each group, thereby thirteen and eleven hits selected from vHTS and *De novo* group. In spite of this, two or more H-bonds and one pi-pi interaction with better binding energy, ligand efficiency and inhibition constant were employed to select the molecule.

CONCLUSION

Herbicide resistance to *P. minor* is one of the major causes of reduced wheat production, in the wheat cropping belts in India. Computational studies were performed to find molecules with high binding affinity at Q_B site of D1 protein and compared to ref_lig (triazine). From the result obtained, vHTS and *De novo* molecules have shown better features in all aspects in comparison to ref_lig. These molecules were selected on the basis of different binding parameters. Moreover, experimental and practical authentication of these molecules could be performed in pots or field for its *in vivo* efficacy.

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Assessment of CP4 EPSPS based glyphosate tolerant maize hybrids for weed control and crop productivity

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Weeds cause considerable yield loss due to competition for resources with maize crop. Season long competition reduced the grain yield of maize in as much as 70 per cent (Malviya and Singh 2007). Chemical method of weed control is the most economical and effective tool get healthy crop stand and good yield. Herbicide resistant maize plants that confer tolerance to glyphosate by production of the glyphosate-tolerant CP4 5-enolpyruvylshikimate-3phosphate synthase (*CP4 EPSPS*) proteins. As an initiative on transgenic maize in India, transgenic stacked maize hybrids evolved by Monsanto India Ltd., NK603 is the gyphosate tolerant technology for the effective weed management system. The plant becomes tolerant to the herbicide while all other weed flora suppressed after application of herbicides. MON 89034 is 2nd Generation Bt corn technology effective against lepidopteron insect pests with a unique and innovative dual mode of action. Keeping in this view field experiment was conducted with the objective to assess the weed control efficiency and maize productivity.

METHODOLOGY

Field experiment was conducted at Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during *Kharif*, 2009 and *Rabi*, 2009-10. Glyphosate was applied as early post emergence application at 900, 1800 and 3600 g/ha in Hishell and 900 M Gold transgenic maize hybrids and these were compared with non-transgenic counterpart hybrids with Pre Emergence application of atrazine at 0.5 kg/ha followed by hand weeding on 40 days after sowing and with and without insect management. Observations on weeds, crop growth parameters such as germination, plant height, yield attributes and yield were recorded.

RESULTS

Broad leaved weeds were predominant (82%), followed by grassy weeds (10%) and sedges (8%). *Trianthema portulacastrum* among the broad-leaved weeds and *Cynodon dactylon* among the grassy weeds were more dominant. Herbicidal treatments significantly influenced the weed population and dry matter production of weeds in both transgenic and non-transgenic hybrids. Weed dry weight is the most important parameter to assess the weed competitiveness for the crop growth and productivity. Sparse weeds with high biomass might be more competitive for crops than dense weeds with lesser dry matter. Considerable reduction in weed dry weight was recorded with the application of glyphosate at 1800 g/ha in transgenic 900 M Gold and 3600 g/ha in transgenic Hishell (0.29 and 1.20) at 40 DAS during *Kharif* 2009 and *Rabi* 2009-10, respectively (Table 1). This might be due to total weed control as achieved by glyphosate. Total weed dry weight was effectively reduced in non-transgenic hybrids with PE application of atrazine at 0.5 kg/ha *fb* HW. The dry weight of weeds exhibited an increasing trend from crop germination to harvest in unweeded checks.

Table 1. Effect of different weed control methods on total weed dry weight and yield of maize

Treatment	Total weed density (no/m^2) at 40 DAS		Grain yield t/ha	
	Kharif 2009	*Rabi* 2009-10	*Kharif* 2009	*Rabi* 2009-10
Transgenic Hishell POE glyphosate 900 g/ha	2.10(2.40)	3.01(7.09)	11.19	8.96
Transgenic Hishell POE glyphosate 1800 g/ha	1.76(1.10)	2.35(3.51)	11.64	9.86
Transgenic Hishell POE glyphosate 3600 g/ha	1.62(0.62)	1.79(1.20)	11.78	10.12
Transgenic 900 M Gold POE glyphosate 900 g/ha	2.23(2.98)	3.26(8.66)	11.30	9.33
Transgenic 900 M Gold POE glyphosate 1800 g/ha	1.51(0.29)	2.29(3.25)	12.01	10.00
Transgenic 900 M Gold POE glyphosate 3600 g/ha	1.53(0.33)	1.82(1.32)	11.68	9.92
Hishell PE atrazine 0.5 kg ha^{-1} + HW + IC	5.06(23.61)	5.39(27.06)	10.52	8.89
Hishell No WC and only IC	10.39(106)	8.25(65.99)	8.05	7.21
900 M Gold PE atrazine 0.5 kg/ha + HW + IC	5.33(26.45)	5.29(26.01)	10.27	9.27
900 M Gold No WC and no IC	9.69(91.92)	9.43(86.89)	7.61	7.19
Proagro PE atrazine 0.5 kg/ha + HW + IC	5.24(25.45)	5.29(26.00)	8.00	6.95
Proagro 4640 No WC and no IC	9.51(88.42)	9.09(80.58)	5.98	5.62
CoHM 5 PE atrazine 0.5 kg/ha + HW + IC	5.35(26.67)	5.34(26.50)	8.04	7.15
CoHM 5 No WC and no IC	10.29(103.95)	9.51(88.50)	6.08	5.73
LSD (P=0.05)	1.42	1.49	1.46	1.69

Among the herbicidal treatments evaluated, post-emergence application of glyphosate at 1800 g/ha in transgenic 900 M Gold maize hybrid resulted in higher grain yield of 12.01 t ha^{-1} during *Kharif*, 2009 and POE application of glyphosate at 3600 g/ha in transgenic Hishell maize hybrid resulted in higher grain yield of 10.12 t/ha during *Rabi*, 2009-10. The findings are in accordance with observation of Tharp *et al.* (1999) who had earlier reported that maize yields of herbicide resistant hybrids were maximum with glyphosate at 0.84 kg ae/ha of glyphosate when applied at fifth leaf stage of maize.

CONCLUSION

Post-emergence application of glyphosate at 1800 and 3600 g/ha in transgenic maize hybrids resulted in lower weed dry weight and higher grain yield compared to non-transgenic counterpart hybrids with existing pre-emergence weed control method.

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Confirmation of multiple herbicide resistance in littleseed canarygrass and possible management with herbicide mixtures and sequences

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Littleseed canary grass (*Phalaris minor*) is one of the most troublesome weed of wheat in rice-wheat cropping system in the Indo-Gangetic plains of India. Presently, its management has become exacting after it evolved multiple herbicide resistance (MHR) to photosystem II, ACCase and ALS inhibitors (Singh 2015). Herbicides are pivotal part of weed management program in wheat crop but with limited herbicides options of new site of action, it may become promising to use herbicide mixtures and/or their sequential application for management and mitigation of herbicide resistance. Therefore, the present study was planned under pot and field conditions to study the herbicide resistance in *P. minor* and its management through herbicide mixtures and their sequential application in wheat.

METHODOLOGY

Fourteen populations of *P. minor* (from seven districts of Haryana) showing differential response to herbicides in field conditions were selected for an herbicide resistance profile study. The population from CCSHAU, Hisar was used as susceptible stock for comparison. Their response to clodinafop (CDF), pinoxaden (PDN), sulfosulfuron (SSN) and mesosulfuron+iodosulfuron (MI) was studied in a pot trial during *rabi* 2014-15 and 2015-16 at CCSHAU, Hisar. Biomass cuts were taken 4 weeks after spraying and fresh weight was measured and expressed as percentage of the control. The field experiment was conducted at resistance affected farmer's field to evaluate the efficacy of herbicide mixtures and their sequential application (treatments' detail in Fig. 1) against resistant *P. minor* and repeated for two years. The experiment was conducted in a randomized block design and each treatment was replicated thrice. Observations on percent control of *P. minor* was recorded 75 days after sowing and grain yield of wheat was recorded at harvest.

RESULTS

The results of the pot experiment revealed that the population Ambala-1 was resistant to all the four herbicides. Population Karnal-1 was resistant to SSN, MI and PDN but it was sensitive to CDF. Majority of the populations were highly resistant to clodinafop and exhibited either a high or medium level of resistance to PDN. Half of the populations tested were resistant to SSN and most of the tested populations were sensitive to MI. The study reinforces the development of MHR in *P. minor* populations at most of the locations in Haryana and this has happened due to the wide adoption of herbicides by the farmers as the sole method of weed control (Singh 2015).

The results of the field experiment revealed that sequential application of pendimethalin 1.5 kg/ha PRE followed by tank mix pinoxaden+metsulfuron 64 g/ha or mesosulfuron+iodosulfuron 14.4 g/ha POE provided excellent control of *P. minor* (Fig. 1) as well as broadleaf weeds. Alone PRE application of pendimethalin+metribuzin was effective against *P. minor* at higher dose of pendimethalin but due to the toxicity of metribuzin on wheat significant reductions in yield was recorded. Management of MHR *P. minor* by pendimethalin had been advocated earlier. With limited herbicides options available, the sequential use of PRE followed by POE herbicides and their mixtures can be an effective strategy to manage MHR *P. minor*.

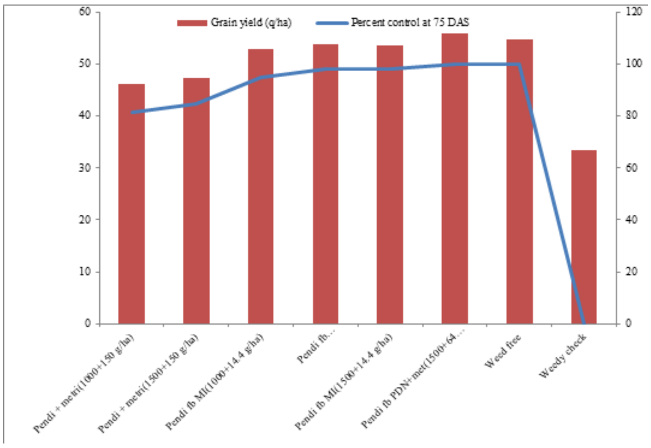

Fig 1. Effect of different herbicide treatments on percent control of *P. minor* and grain yield of wheat

CONCLUSIONS

Dose-response experiments confirmed that *P. minor*, the most ubiquitous weed of wheat in North India, has evolved MHR to the recommended herbicides, CDF, PDN (ACCase inhibitors), SSN and premix of MI (ALS inhibitors). Mixtures and sequential application of herbicides with different MoAs provided promising results and should be exploited as an effective strategy to manage MHR *P. minor*.

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Effectiveness of AM fungi in the management of *striga* in sugarcane under farmers field

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In North Karnataka, severe incidence of *Striga* in sugarcane has created panic among the farmers; conversion of their traditional sorghum and maize fields to sugarcane in view of its remunerative nature is one of the major reasons. Introduction of sugarcane and its monoculture has aggravated the incidence of *Striga asiatica*, since it prefers cane crop. Cane being a long duration crop, it facilitates repeated flushes of *Striga* thereby enriching soil seed bank. The present infestation level is so high, the farmers are loosing fights in controlling this weed. There is decline in the cane yield to the extent of 20-70 per cent, sometimes total crop failure also, threatening cane cultivation. Yet, farmers are not ready to give up sugarcane crop, as it is more remunerative. Unfortunately, *Striga* infestation continues to extend to new areas also, which is of great concern. Recent studies have shown that AM fungal colonization is likely to induce resistance to plant parasitism by converting strigolactones into mycorradicin, which is accumulated in mycorrhized roots and thereby reduces availability of strigolactones for *Striga* to germinate. Our preliminary investigations under pot culture studies carried have revealed that the native AMF isolates from *Striga* suppressive soils of Belguam district have suppressed the *Striga* emergence in sugarcane (Shubha *et al.*, 2015), while standard AMF consortium lowered the induction of *Striga* emergence in sorghum (Jones *et al.* 2014) and therefore formed a basis for the present evaluation of the efficient AMF in *Striga* infested soil under farmers field.

METHODOLOGY

A field experiment was laid out in randomized complete design with factorial concept during *kharif* 2015-2016. There were five main factor and four sub factor consisting of combination of AM fungi and different levels of herbicide. The data on *Striga* parameters, AM fungal mycorrhizal parameters, plant growth poarameters, nutrient uptake, dry matter, chlorophyll content and cane yield were recorded.

RESULTS

The data pertaining to *Striga* emergence at 90 DAP, revealed that application of UASDAMF consortium (native) as well as AMF Consortium STD suppressed the *Striga* emergence significantly (1.33/plot) and 1.83/plot respectively) over UIC (10.83/plot). However, the treatments received single inoculation of UASDAMF5 and UASDAMF9 were also found to reduce the number of *Striga* emergence (9.25/plot and 8.50/plot respectively), which is significantly superior over UIC (10.83/plot).

Applications of herbicidal molecules, at different levels have shown varied responses on *Striga* emergence. At 90 DAP, the treatment received the combination of 100 per cent of atrazine 50 WP 2.5 kg/ha along with 2,4-D sodium salt 80% at 90 DAP recorded least numbers of *Striga* emergence (3.13/plot) over the plots received zero per cent herbicide (10.40/plot)

Table 1. Interactive effect of AM fungi and different levels of herbicides on *Striga* emergence in sugarcane

Treatment	*Striga* per plot														
	60 DAP					90 DAP					120 DAP				
	Herbicide levels					Herbicide levels					Herbicide levels				
AM Fungi	0% RDH	50% RDH	75% RDH	100% RDH	Mean of A	0% RDH	50% RDH	75% RDH	100% RDH	Mean of A	0% RDH	50% RDH	75% RDH	100% RDH	Mean of A
UASDAMF 5	3.00	0.66	0.33	-	1.00	21.66	12.33	2.00	1.00	9.25	11.3	8.66	5.00	3.66	7.16
UASDAMF 9	2.33	2.00	1.00	0.66	1.50	11.33	9.33	8.33	5.00	8.50	9.00	9.00	8.33	7.00	8.33
UASDAMF consortium (native)	1.33	0.33	*	*	0.41	2.66	1.33	1.00	0.33	1.33	1.00	0.33	*	*	0.33
AMF Consortium STD	1.00	0.66	0.33	*	0.50	2.33	2.33	1.66	1.00	1.83	2.00	0.66	0.33	*	0.75
UIC	6.66	0.33	*	*	1.75	14.0	11.00	10.00	8.33	10.83	21.66	10.00	2.33	1.66	8.91
Mean of B	2.80	0.86	0.33	0.13		10.40	7.26	4.60	3.13		9.00	5.73	3.20	2.46	
	S.Em±		LSD (P=0.05)			S.Em±		LSD (P=0.05)			S.Em±		LSD (P=0.05)		
CD of A (AM Fungi)	0.5		1.91			0.55		1.80			0.35		1.14		
CD of B (Herbicides)	0.34		0.99			0.39		1.14			0.29		0.85		
CD of A* B (AM Fungi + Herbicide)	0.88		2.70			0.94		2.85			0.66		2.00		

Note: *No emergence of *Striga* emergence Note: Mean of A-AM Fungi. Mean of B- Herbicide. Mean of A*B- AM Fungi + Herbicide.

Treatment	*Striga* per plot									
	150 DAP Herbicide levels					180 DAP Herbicide levels				
AM Fungi	0% RDH	50% RDH	75% RDH	100% RDH	Mean of A	0% RDH	50% RDH	75% RDH	100% RDH	Mean of A
UASDAMF 5	1.33	*	*	*	0.33	9.00	5.60	3.00	2.00	3.66
UASDAMF 9	0.66	0.33	*	*	0.25	7.60	6.00	1.50	1.00	3.41
UASDAMF consortium (native)	*	*	*	*	*	*	*	*	*	*
AMF Consortium STD	*	*	*	*	*	*	*	*	*	*
UIC	12.33	5.66	2.33	1.66	5.50	12.	6.0	3.66	1.33	5.75
Mean of B	2.86	1.20	0.46	0.33		5.73	3.53	0.73	0.26	
	S.Em±		LSD (P=0.05)			S.Em±		LSD (P=0.05)		
CD of A (AM Fungi)	0.34		1.11			0.25		0.80		
CD of B (Herbicides)	0.14		0.41			0.20		0.55		
CD of A* B (AM Fungi + Herbicide)	0.44		1.37			0.44		1.35		

Among the interactive effects, the treatment received UASDAMF Consortium native plus 100 per cent RDH (atrazine 50 WP 2.5 kg/ha at 3 to 4 DAP; 2,4-D sodium salt 80% at 60 DAP) reduced the population of *Striga* emergence to a greater extent (0.33/plot) over 0, 50, 75 per cent of RDH (2.66, 1.33 1.00 and 0.33/plot respectively). However the results were statistically on par with each other. Among the single inoculation, UASDAMF9 isolate were also effective in reducing the *Striga* emergence at 0, 50, 75 and 100 of RDH (11.33, 9.33, 8.33 and 5.00/plot respectively). Similar trend also recorded in 120, 150, 180, 240, and 320 DAP.

CONCLUSION

Thus, our findings are indicative of the effectiveness of AMF in protecting sugarcane against *Striga*. Hence, the present investigation will be a boon to sugarcane growing farming community of northern Karnataka, wherein devastating losses of yield due to *Striga* infestations are recorded in recent times.

Management of *Orobanche* in tobacco

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Tobacco is an important commercial crop in India. *Orobanche* is a serious crop parasite and a major constraints to tobacco production in India. It debilitates tobacco growth by disrupting physiological and metabolic processes in the host plant thereby causing wilting and a ribbed appearance of leaves (Krishnamurthy *et al*. 1991). The herbicides that are currently in use for broomrape control are glyphosate, and herbicides belonging to the imidazolinones (Eizenberg *et al.* 2006) or sulfonylureas. Glyphosate disrupts the biosynthesis of aromatic amino acids inhibiting the key enzyme 5-enolpyruvylshikimate-3-phosphate (EPSP). Imidazolinones and sulfonylurea herbicides inhibit acetolectate synthase (ALS), also called acetohydroxyacid synthase (AHAS), a key enzyme in the biosynthesis of the brand-chain amino acids isoleucine, leucine and valine. All of them are systemic herbicides absorbed through foliage and roots of plants with rapid translocation to the attached parasite, which acts as a strong sink (Colquhoun *et al*. 2006). No single method is effective in controlling the parasite. The seed bank of the parasite should be minimized in a phased manner by integrating cultural and chemical methods of control. Therefore, an integrated management strategy is the best perspective to control broomrapes in a crop wherever it is problematic.

METHODOLOGY

A field experiment was carried out to know the effective weed management practices for *Orobanche* in tobacco with different chemical treatments on economic feasibility. The soil type was sandy loam having 0.48 per cent organic carbon, 205.46 kg/ha available nitrogen, 24.68 kg/ha available P_2O_5 and 151.36 kg/ha available K_2O. Tobacco variety PT-76 was planted in 90 cm x 90 cm. recommended dose of fertilizers 250 kg N, 70 kg P_2O_5 and 70 kg K_2O/ha were applied.

RESULTS

Neem cake 200 kg/ha at sowing *fb* soil drenching of metalaxyl MZ 02.% at 20 DAP reduced *Orobanche* shoot density with better weed control and higher tobacco yield (2.39 t/ha). Imazethapyr 30 g/ha at 40 DAP caused severe Phytotoxicity on tobacco leaves. The growth of plant was severely stunted and size of leaves was decreased leading to loss in yield of the crop. The highest net return (Rs. 342600/ha) and B:C ratio (3.52) were recorded by Neem cake 200 kg/ha at sowing fb soil drenching of metalaxyl MZ 02.% at 20 DAP which were significantly superior over rest of the treatments.

Table 1. Management of *Orobanche* in Tobacco

Herbicide	Number of orobanche / tobacco plant			Tobacco yield (t/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
	60 DAP	90 DAP	At harvest				
Neem cake 200 kg/ha at sowing fb soil drenching of metalaxyl MZ 02.% at 20 DAP	5.1	8.12	12.05	2.39	478400	342600	3.52
Imazethapyr 30 g/ha at 40 DAP	10.88	13.95	16.75	1.71	341000	190200	2.26
Glyphosate 0.2 g/L at 20 DAP	9.10	11.93	15.18	1.89	377400	227100	2.51
Soil drenching of metalaxyl MZ 0.2% at 20 DAP	6.95	5.80	14.70	1.98	395000	244200	2.62
Weedy check	22.35	25.75	26.85	1.53	305000	155000	2.03
LSD (P=0.05)	0.65	1.83	2.12	0.15	12365	12365	0.19

CONCLUSION

Neem cake 200 kg/ha at sowing *fb* soil drenching of metalaxyl MZ 02% at 20 DAP was found effective in controlling orobanche shoot and producing the highest tobacco yield (2.39 t/ha) and fetching the highest net return (Rs. 342600/ha) and B:C ratio (3.52).

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Theme 1

Innovative approaches for weed management in crops / cropping systems

Management of complex weed flora in wheat

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India is the second largest producer of wheat in the world contributing about 93.5 million tonnes of grains with the productivity of 3.11 t/ha from the area of 30 million hectares. Area under wheat cultivation is 1.02 mha and productivity is 2.88 t/ha in Gujarat. Weed infestation is one of the major barriers in realizing potential yield of wheat. Weeds are reported to causes up to 66% reduction in wheat grain yield if not timely controlled (Kumar *et al*. 2011). So, there is a need to evaluate alternative herbicide or herbicide mixture for the management of complex weed flora in wheat. Thus, the present experiment was conducted with objective to study the bio-efficiency of combination of herbicides against weed complex and their effect on growth and yield of wheat.

METHODOLOGY

A field experiment was conducted at AICRP-Weed Management Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *Rabi* 2014. The soil of the experimental field was sandy loam. The experiment was laid out in RBD with three replications. Wheat was sown with adoption of all the recommended package of practices.

RESULTS

The major monocot weeds were *Phalaris minor, Avena fatua, Asphodelus tenuifolius, Setaria tomentosa* and *Cyperus iria* and dicot weeds were *Chenopodium murale, Chenopodium album, Melilotus indica, Amaranthus viridis, Oldenlandia umbellata,* and *Digera arvensis* observed in the experimental field.

Significantly the lowest weed dry biomass of total weeds were recorded in post emergence application of clodinafop + metsulfuron methyl 64 g/ha and mesosulfuron + iodosulfuron 14.4 g/ha followed by sulfosulfuron 25 g/ha, sulfosulfuron + metsulfuron methyl 32 g/ha PoE and HW carried out at 20 and 40 DAS with more than 98% WCE. Weed control efficiency of different weed management treatments were ranging from 7 to 100 % at 60 DAS. The same results were also reported by Kumar *et al.* (2015).

Table1. Weed dry biomass, grain yield and economics as influenced by different weed management practices in wheat

Treatment	Total weed dry biomass (g/m^2) at 60 DAS	Grain yield (t/ha)	Straw yield (t/ha)	WCE (%) at 60 DAS	B:C ratio
Pendimethalin 500 g/ha PE	18.69^{ab} (348.6)	2.42^{b}	4.20^{b}	7	1.36
2,4-D 750 g/ha PoE	15.53^{c} (240.7)	2.68^{b}	4.87^{b}	36	1.55
Metsulfuron-methyl 4.0 g/ha PoE	17.18^{b} (294.7)	2.36^{b}	4.67^{b}	21	1.38
Clodinafop propargyl 60 g/ha PoE	8.76^{d} (76.2)	3.70^{b}	6.38^{a}	80	2.07
Sulfosulfuron 25 g/ha PoE	1.51^{e} (1.8)	3.76^{a}	6.64^{a}	99	2.12
Sulfosulfuron (75%) + metsulfuron-methyl (5%) 32 g/ha PoE	2.23^{e} (7.1)	4.26^{a}	6.88^{a}	98	2.35
Clodinafop (15%) + metsulfuron-methyl (1%) 64 g/ha PoE	1.00^{e} (0.0)	4.35^{a}	6.88^{a}	100	2.38
Mesosulfuron (3%) + iodosulfuron (0.6%) 14.4 g/ha PoE	1.00^{e} (0.0)	3.93^{a}	6.67^{a}	100	2.17
Hand weeding at 20 and 40 DAS	2.81^{e} (7.0)	3.95^{a}	6.71^{a}	98	1.88
Weedy check	19.34^{a} (373.2)	1.61^{b}	3.91^{b}	-	1.01
CV (%)	9.7	12.9	9.6	-	-

*Values in parentheses are original. Data transformed to square root transformation. Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance.

Significantly more numbers of effective tillers (99.5 no./m) were recorded in the application of sulfosulfuron + metsulfuron-methyl 32 g/ha PoE, but it was remained at par with all post emergence application of herbicides except 2,4-D 750 g/ha, and metsulfuron methyl 4.0 g/ha because these herbicides were found not effective to control complex weed flora.

Significantly higher grain (4.34 t/ha) and straw (6.88 t/ha) yield of wheat were recorded in application of clodinafop + metsulfuron methyl 64 g/ha PoE with maximum B: C ratio (2.38), but remained at par with sulfosulfuron + metsulfuron methyl 32 g/ha PoE, HW carried out at 20 and 40 DAS, mesosulfuron + iodosulfuron 14.4 g/ha PoE and sulfosulfuron 25 g/ha PoE.

CONCLUSION

Application of clodinafop + metsulfuron-methyl 64 g/ha PoE or sulfosulfuron + metsulfuron-methyl 32 g/ha PoE can be used to control complex weed flora of monocot and dicot weeds in wheat, especially *Phalaris minor, Avena fatua, Chenopodium murale and Chenopodium album* without any residual/carry over effect on succeeding greengram, maize and pearlmillet crops.

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Nutrient uptake of wet seeded rice as influenced by new post-emergence herbicides

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Weeds remove a considerable share of plant available nutrients from soil and thus adversely affect crop production. The extent of removal of nutrients depends on type of weeds, their density as well as dry matter production. The present study was undertaken to examine nutrient removal pattern by weeds in low land rice as affected by application of various post emergence herbicides and its effect on crop nutrient uptake and grain yield.

METHODOLOGY

A field experiment was conducted during October 2011 to February 2012 in farmer's field at Alappad in the Kole lands of Thrissur district using Jyothi variety. The soil was clayey with pH 5.5. The experiment comprised of 13 treatments, *viz.* post-emergence spray of metamifop (125 g/ha), metamifop (125 g/ha) *fb* carfentrazone ethyl (20 g/ha), metamifop (125 g/ ha) *fb* Almix (4 g/ha), cyhalofop-butyl (100 g/ha), cyhalofop-butyl (100 g/ha) *fb* Almix (4 g/ha), fenoxaprop-p-ethyl (60 g/ha), fenoxaprop-p-ethyl (60 g/ha) *fb* Almix (4 g/ha), fenoxaprop-p-ethyl (60 g/ha) *fb* ethoxysulfuron (15 g/ha), bispyribac sodium (30 g/ha), penoxsulam (25 g/ha), azimsulfuron (35 g/ha), unweeded control and hand weeded control. The trial was laid out in Randomized Block Design with three replications. All herbicides were sprayed at 20 DAS with follow up spray (*fb*) on the next day using knapsack sprayer. Uptake of major nutrients by the crop was estimated at harvest. The nutrient removal by weeds at 30 and 60 days after sowing and at harvest stage of rice was also estimated.

RESULTS

In general, the removal of nutrients was in the order of K>N>P by crop and weeds. Maximum N, P and K removal by weeds was noticed in unweeded control irrespective of stages of crop growth. Among the various herbicidal treatments, the lowest N and K removal was recorded in bispyribac sodium at 60 DAS as well as at harvest. Total N removal was the lower and also statistically comparable in cyhalofop-butyl *fb* Almix and fenoxaprop p-ethyl *fb* Almix sprayed plots. The lowest P removal was registered in hand weeded control followed by cyhalofop-butyl *fb* Almix at 60 DAS, whereas minimum removal in bispyribac sodium at harvest. Mukherjee and Maity (2011) and Sharma (2007) have also reported the similar pattern in nutrient removal by wet seeded rice.

Among herbicidal treatments, N uptake by the crop was statistically higher in bispyribac sodium. The highest value of crop P uptake was in bispyribac sodium though comparable uptake was registered in cyhalofop-butyl *fb* Almix and fenoxaprop p-ethyl alone. The highest K uptake was registered in azimsulfuron, fenoxaprop p-ethyl *fb* Almix, fenoxaprop p-ethyl *fb* ethoxysulfuron due to higher K content as well as high straw yield. A grain yield of 5.73 t/ha, obtained with bispyribac sodium was statistically on par with cyhalofop-butyl *fb* Almix and fenoxaprop p-ethyl *fb* Almix (5.8 t/ha). Economic analysis of rice cultivation showed that for high returns and B:C ratio (1.8), spraying cyhalofop-butyl *fb* Almix or fenoxaprop p-ethyl *fb* Almix or bispyribac sodium was found to be the best. Hence, it can be inferred that these three can be recommended for maximum net profit as well as higher B:C ratio.

Table 1. Effect of treatments on nutrient uptake by weeds and crop at harvest

Treatment	Nutrient uptake by weed (kg/ha)			Nutrient uptake by rice (kg/ha)		
	N	P	K	N	P	K
Metamifop	2.21^{fg} (4.43)	1.22^{e} (1.0)	2.19^{g} (4.30)	86.27 ^{h}	12.90 ^{cde}	88.86 ^{b}
Metamifop *fb* carfentrazone	2.57^{cd} (6.15)	1.35^{c} (1.33)	2.79^{de} (7.30)	91.15 ^{efg}	14.08 ^{bcd}	78.96 ^{f}
Metamifop *fb* Almix	2.67^{bc} (6.68)	1.35^{c} (1.33)	2.67^{e} (6.67)	87.87 ^{gh}	13.20 ^{cde}	81.56 ^{ef}
Cyhalofop	2.35^{cf} (5.05)	1.27^{d} (1.13)	2.67^{e} (6.64)	93.37 ^{de}	12.83 ^{cde}	81.99 ^{def}
Cyhalofop *fb* Almix	1.98^{h} (3.45)	1.14^{f} (0.81)	2.50^{f} (5.77)	99.01 ^{c}	14.50 ^{bc}	88.11 ^{bc}
Fenoxaprop	2.12^{gh} (4.0)	1.21^{e} (0.93)	2.46^{f} (5.60)	89.66 ^{fgh}	14.10 ^{bcd}	85.42 ^{bcde}
Fenoxaprop *fb* Almix	1.94^{h} (3.27)	1.07^{g} (0.65)	2.28^{g} (4.73)	95.44 ^{d}	13.07 ^{cde}	87.87 ^{bc}
Fenoxaprop *fb* ethoxysulfuron	2.48^{de} (5.66)	1.39^{c} (1.43)	2.91^{cd} (8.0)	98.95 ^{c}	11.98 ^{e}	86.10 ^{bcd}
Bispyribac sodium	1.46^{i} (1.66)	0.94^{h} (0.40)	1.53^{h} (1.86)	102.56 ^{b}	14.99 ^{b}	83.68 ^{cde}
Penoxsulam	2.74^{bc} (7.03)	1.44^{b} (1.60)	2.93^{c} (8.10)	92.92 ^{def}	12.63 ^{de}	82.90 ^{def}
Azimsulfuron	2.84^{b} (7.60)	1.46^{b} (1.63)	3.11^{b} (9.23)	89.05 ^{gh}	12.13 ^{e}	88.27 ^{b}
Unweeded control	6.44^{a} (41.04)	2.70^{a} (6.84)	6.62^{a} (43.33)	61.50 ^{i}	9.83 ^{f}	60.09 ^{g}
Handweeded control	1.05^{j} (0.61)	0.78^{i} (0.11)	1.08^{i} (0.68)	115.91 ^{a}	16.74 ^{a}	97.28 ^{a}

* ($\sqrt{x + 0.5}$)$^{1/2}$ transformed values, Original values in parentheses. In a column, means followed by common letters do not differ significantly at 5 % level by DMRT. fs - Follow up spray

CONCLUSION

Three herbicidal treatments which showed promising in terms of low nutrient removal by weeds and higher grain yield were cyhalofop-butyl or fenoxaprop p-ethyl with a follow up spray of Almix, and bispyribac sodium and can be recommended for effective weed management in wet seeded rice.

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Weed management influenced on onion bulb crop under different fertilizer levels

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Onion (*Allium cepa* L.) belongs to family Alliaceae, is a biennial herbaceous and cross-pollinated winter vegetable. The average yield of onion in India (26.6 t/ha) is very low as compared to other leading countries due to many factors including weed infestation. This study was therefore, conducted to compare the effectiveness of different weed management practices for onion crop under different fertility levels.

METHODOLOGY

Field study was conducted to compare various weed and fertilizer management practices in onion at the research farm of Navsari Agricultural University, Navsari, Gujarat during winter season of 2008-09 and 2009-10. The experiment was laid out in Factorial Randomized Block Design (FRBD) design with thirty treatment combinations consisting of ten treatments of weed management viz. W1:Pendimethalin 1 kg/ha as pre-emergence, W2:Oxyfluorfen 0.24 kg/ha as pre-emergence, W3:Pendimethalin 1 kg/ha pre-emergence + Fluazifop-p-butyl 0.25 kg/ha at 40 DAT, W4:Oxyfluorfen 0.24 kg/ha pre-emergence + Fluazifop-p-butyl 0.25 kg/ha at 40 DAT, W5:Pendimethalin 1 kg/ha pre-emergence + One hand weeding at 40 DAT, W6:Oxyfluorfen 0.24 kg/ha pre-emergence + One hand weeding at 40 DAT, W7:Hand weeding at 20 DAT + Fluazifop-p-butyl 0.25 kg/ha at 40 DAT, W8:Two hand weeding at 20 and 40 DAT, W9:Weed free control (Hand weeding at 20, 40 and 60 DAT), W10:Weedy check and three treatments of fertilizer levels viz., F1: 75 % RDF (75:37.50:37.50, $N:P_2O_5:K_2O$ kg/ha), F2: 100 % RDF (100:50:50, N:P2O5:K2O kg/ha), F3: 125 % RDF (125:62.5:62.5, N:P2O5:K2O kg/ha), each replicated three times.

RESULT

The pre dominant weeds identified in the experimental plots during the course of investigation were *Echinochloa crusgalli* L., *Echinochloa colonum* L., *Eleusine indica* L., *Eragrostis major* L., among monocots, while *Trianthema* spp., *Amaranthus* spp., *Eclipta alba*, L. among dicot weeds. *Cyperus rotundus* L. was the only sedge found throughout the growing season. Significantly least weed population were recorded with application of either pendimethalin at 1.0 kg/ha or oxyfluorfen at 0.24 kg/ha supplement with one hand weeding at 40 days after transplanting. The lowest weed competition index was noted with treatment pendimethalin 1.0 kg/ha + one hand weeding at 40 DAT closely followed by treatment oxyfluorfen 0.24 kg/ha pre-emergence + One hand weeding at 40 DAT. Similarly, maximum weed control efficiency was also recorded with treatment pendimethalin 1.0 kg/ha + one hand weeding at 40 DAT and closely followed by treatments oxyfluorfen 0.24 kg/ha pre-emergence + One hand weeding at 40 DAT and Hand weeding at 20, 40 and 60 DAT.

At 40 days after transplanting, increased rates of fertilizer simultaneously increased the total weeds population. Significantly maximum weeds density were observed with 125 % RDF and minimum with 75 % RDF during both years of experimentation. Similar trend was found in case of dry weight of weeds at harvest. Highest yield (39.33, 36.60 and 37.97 t/ha, respectively) was recorded in treatment Pendimethalin 1 kg/ha supplement with one hand weeding followed by treatments Oxyfluorfen @ 0.24 kg/ha pre-emergence + One hand weeding at 40 DAT and Hand weeding at 20, 40 and 60 DAT during both the years as well as in pooled analysis, respectively.

Results also revealed that crop fertilized with 125 % RDF produce significantly higher bulb yield of 37.3, 34.2 and 35.7, respectively and increased yield by 19.43 and 10.52 % over F2 and F1, respectively. On pooled basis, the treatment combination of pendimethalin 1 kg/ha followed by one hand weeding at 40 DAT and fertilized crop with 125 % RDF recorded higher onion bulb yield over rest of the treatment combinations except very few.

Table 1. Interaction effect of weed management and fertilizer levels on onion bulb yield (t/ha)

Fertilizer levels	Weed management									
	W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_9	W_{10}
2008-09										
F_1	31.5	26.5	35.9	33.3	33.6	36.3	33.1	31.6	33.6	23.6
F_2	27.7	29.7	36.5	36.2	41.2	39.4	36.9	31.3	38.6	23.3
F_3	36.1	36.7	37.0	39.5	43.2	41.0	38.8	36.2	39.9	24.1
LSD (P=0.05)					4.50					
2009-10										
F_1	28.6	25.4	32.8	29.9	31.5	31.2	28.0	26.1	28.9	16.6
F_2	27.9	27.7	32.2	32.5	38.5	36.5	32.1	27.0	36.2	16.2
F_3	34.1	34.0	33.7	35.4	40.1	38.3	35.6	33.9	39.2	17.3
LSD (P=0.05)					4.07					
Pooled										
F_1	30.0	26.0	34.3	31.6	32.5	33.8	30.5	28.8	31.3	20.1
F_2	27.8	28.7	34.3	34.3	39.9	37.9	34.5	29.1	37.4	19.7
F_3	35.1	35.4	35.4	37.4	41.6	39.7	37.2	35.1	39.5	20.7
LSD (P=0.05)					2.85					

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Effect of wheat residue and weed management strategies on weed seedbank and yields of groundnut

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Gujarat is the leading producer contributing 29.63% of the total production and ranks up in most important oilseed and food crop of the world. Keeping in view the harmful effects of weeds, it is therefore essential to keep groundnut fields weed free. The weed seedbank is also an important part of crop-weed ecology. Wheat (*Rabi*)-fallow (summer)-groundnut (*Kharif*) is the predominant crop sequence in the *Saurashtra* region of Gujarat. After harvesting of wheat, usefulness of its residue is considered as an important resource that can bring significant physical, chemical, biological changes into the soil and suppresses weeds (Sharma 2014). Therefore, considering the facts and views highlighted above, the field experiment was undertaken for two years to study effect of residue management and weed management practices in *Kharif* groundnut.

METHODOLOGY

A field experiment was conducted at Weed Control Research Scheme, Department of Agronomy, Junagadh Agricultural University, Junagadh (Gujarat) during *kharif* seasons of 2014 and 2015. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 8.1 and EC 0.43 dS/m). The experiment was laid out in split plot design with three replications. The main plots comprised of residue management treatments, *viz.* (i) burning of wheat residues, (ii) wheat residue incorporation by rotavator *fb* soil solarization with 25 µm polythene sheet for 15 days and (iii) wheat residue incorporation by rotavator *fb* application of *Trichoderma viride* + 20 kg N/ha and sub plots contained weed management treatments, *viz.* (i) stale seedbed *fb* IC & HW at 45 DAS, (ii) suicidal germination (Application of Ethylene 2000 ppm + KNO_3 2000 ppm with pre-sowing irrigation) *fb* tillage *fb* IC and HW at 45 DAS, (iii) pendimethalin 900 g/ha as PRE *fb* IC and HW at 45 DAS, (iv) HW and IC at 15 DAS *fb* pre-mix imazethapyr + imazamox 70 g/ha as POE at 25 DAS, (v) pendimethalin 900 g/ha as PRE *fb* pre-mix imazethapyr + imazamox 70 g/ha as POE at 25 DAS, (vi) weed free and (vii) unweeded check. The Gujarat Groundnut-20 variety was used for the study.

RESULTS

Among the residue management, significantly the highest pod yield (1.47 t/ha) was recorded under the wheat residue incorporation *fb* soil solarisation with increased magnitude of 14.2% over the burning of residues (Table 1). Among the weed management, significantly, the highest pod yield (1.64 t/ha) and haulm yield (3.35 t/ha) was recorded under the weed free, which was statistically at par with the treatments pendimethalin *fb* imazethapyr + imazamox and pendimethalin *fb* IC and HW with increased magnitude of 124.9 and 124.5%.

Table 1. Effect of residue and weed management on yield, weed dry weight, weed seedbank and economics of groundnut

Treatment	Pod yield (t/ha)	Haulm yield (t/ha)	Dry weight of weeds (kg/ha)		Number of weed seeds/core		Gross returns (`/ha)	Cost of cultivation (`/ha)	BCR
			2014	2015	2014	2015			
					215 (Initial)	181 (Initial)			
Residues management									
Burning of wheat residues	1.28	3.11	1142	1419	259	242	71589	28439	2.49
Wheat residue incorporation *fb* soil solarization	1.47	2.86	687	951	161	171	78774	34382	2.27
Wheat residue incorporation *fb T. viride* + N	1.36	3.13	813	1229	234	245	75064	31512	2.36
LSD (P=0.05)	0.07	NS	151	200	45	51	-	-	-
Weed management									
Stale seedbed fb IC & HW	1.08	2.88	979	1272	168	170	61640	30370	2.03
Suicidal germination fb tillage fb IC & HW	1.59	3.14	788	870	99	95	85506	32846	2.61
Pendimethalin fb IC & HW	1.62	3.22	521	553	86	78	87500	31150	2.82
HW & IC fb imazethapyr + imazamox	1.26	3.16	770	1188	191	180	70933	31468	2.26
Pendimethalin fb imazethapyr + imazamox	1.62	3.27	489	628	89	80	87597	32095	2.74
Weed free	1.68	3.35	40	58	68	58	90727	34764	2.62
Unweeded check	0.72	2.21	2577	3825	824	876	42092	27421	1.54
LSD (P+0.05)	0.08	0.29	128	159	50	56	-	-	-

Note: Groundnut yields and economics are pooled over two years.

Significantly the lowest dry weight of weeds and weed seedbank was recorded under the wheat residue incorporation *fb* soil solarization and weed free (Table 1). Among the weed management, the next superior treatments in this respect were pendimethalin *fb* imazethapyr + imazamox, pendimethalin *fb* IC & HW and suicidal germination *fb* tillage *fb* IC and HW. This might be attributed to the effective control of weeds under these treatments through hand weeding or integration of hand weeding with herbicides. In addition to this, dense crop canopy might have suppressed weed growth and ultimately less biomass.

CONCLUSION

It was concluded that effective management of wheat residues, weeds and weed seedbank along with profitable cultivation of groundnut in *Kharif* season can be achieved by incorporation of wheat residues in soil by rotavator followed by either soil solarization for 15 days during hot summer or application *Trichoderma viride* 5 kg/ha + 20 kg N/ha and pre-emergence application of pendimethalin 900 g/ha supplemented with either IC & HW at 45 DAS or pre-mix imazethapyr + imazamox 70 g/ha as post-emergence at 25 DAS according to availability of labourers under south Saurashtra Agro-climatic conditions.

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Effects of weed control measures and intercropping on weed biomass

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Pearl millet is an important staple crop in the semi-arid regions due to its high nutritive value and adaptation to varying stress conditions. Cluster bean [*Cyamopsis tetragonoloba (L.) Taub.*] and Moth bean [*Vigna aconitifolia* (Jacq.) Marchall] are most compatible with pearl millet as intercrops due to dry and warm habitat and shorter life span, respectively among leguminous crops. Herbicide-dominated systems are causes of development of herbicide-resistant biotypes, environmental sustainability and public health risk. Use of herbicides in any crop mixture is a risky endeavor and certainly not eco-friendly approach. Therefore, of late, scientists as well as farmers are seeking a broader perspective to weed management than relying primarily on herbicides (Murphy and Lemerle 2006). Diversification of cropping systems, for instance by increasing the number of crop species grown, has been proposed as a solution to some problems of modern agriculture. Intercropping has gained interest because of potential advantages it offers over yielding, i.e. enhanced utilization of growth resources by the crops. Apart from yield benefits, intercropping (temporal and spatial diversification) strategies altered/reduced weed density and biomass. Reduced weed biomass in intercropping systems has been reported by several workers for sorghum (*Sorghum bicolor*) - red gram (*Cajanus cajan*). Weed management using intercropping, however, has hardly been studied in sub-humid tropics of India.

METHODOLOGY

A field experiment was carried out during *Kharif* 2014 at the Instructional farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan. The area receiving average annual rainfall of 265mm. The experimental soil was loamy sand with slightly alkaline in reaction. The status of soil was poor in organic carbon. The experiment was laid out in split plot design consisting 20 treatments combination, replicated thrice. Five intercropping as main plot treatments comprised sole pearl millet, sole cluster bean, sole moth bean, pearl millet + cluster bean, millet + moth bean. Four weed control treatments in sub plot comprised weedy check, hand weeding twice at 20 and 45 DAS, pendimethalin at 0.75 kg/ha as pre emergence and imazethapyr 40 g/ha as post emergence. Pearl millet, cluster bean and moth bean variety RHB 173, RGC 1066 and RMO 435, respectively used for experiment. The sowing of the crop was done by "kera" method in open furrow on July 23, 2014.

RESULTS

Cluster bean as well as moth bean grown in intercropped with pearl millet reduced significantly total dry matter of weeds over sole crops at 45 DAS and at harvest. All weed control treatments considerably decreased the total weed dry matter over weedy check at 30 DAS, 45 DAS and at harvest. Two hand weeding, pendimethalin at 0.75 kg/ha and imazethapyr at 40 g/ha reduced the weed density by 89.50, 81.65 and 69.52% at 30 DAS, 93.25, 83.82 and 84.34% at 45 DAS and 94.03, 86.38 and 89.11% at harvest, respectively over weedy check. The lower dry matter production of different weeds under intercropping systems may be due to higher crop canopy than sole crop. Extensive canopy of intercrops have smothered them leading to lower weed dry matter. These results are in conformity with the findings of Kiroriwal *et al.* (2012). Maximum weed control efficiency was recorded under two hand weeding and minimum in weedy check treatment. Among herbicidal weed control measures, pre-emergence application of pendimethalin at 0.75 kg/ha have higher (81.65%) weed control efficiency as compared to imazethapyr at 40 g/ha (69.52%) at 30 DAS. However, post-emergence application of imazethapyr at 40 g/ha gave higher weed control efficiency (84.34 and 89.11%) as compared to pendimethalin at 0.75 kg/ha (83.82 and 86.38%) at 45 DAS and at harvest, respectively. Weed smothering efficiency was maximum recorded under pearl millet intercropped with moth bean 33.10, 31.95 and 27.21% followed by pearl millet + cluster bean intercropping system 28.34, 27.08 and 24.5%, respectively, at 30 DAS, 45 DAS and at harvest. These results are in conformity with the findings of Ram *et al.* (2004).

Table 1. Effect of weed control measures and intercropping system on dry matter of weeds

Treatment	Weed dry matter (g/m^2)		
	30 DAS	45 DAS	At harvest
Intercropping			
Pearl millet sole	8.61	97.32	71.72
Cluster bean sole	6.56	84.13	62.85
Moth bean sole	6.41	80.61	62.52
PM+CB (1:2)	6.17	70.96	54.13
PM+MB (1:2)	5.76	66.22	52.20
LSD (P=0.05)	1.05	11.84	8.32
Weed control			
Weedy check	16.82	230.45	186.03
Two hand weeding at 20 and 35 DAS	1.77	15.55	11.10
Pendimethalin 0.75 kg/ha as PE	3.09	37.29	25.34
Imazethapyr 40 g/ha at 25 DAS as PoE	5.13	36.10	20.26
LSD (P=0.05)	0.75	7.62	6.17

CONCLUSION

It was concluded that pearl millet moth bean intercropping was most efficient to reduce weed dry matter. However, under weed control measures two hand weeding was more significantly reduce weed dry matter.

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Effect of tillage and crop diversification on weed dynamics in rice-based cropping systems in middle indo-gangetic plains

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Weeds are one of the major biological constraints in reducing the productivity and input-use efficiency of rice-based cropping systems. Soil tillage plays an important role in weed management by direct killing of weeds or by changing the soil environment and so promoting or inhibiting weed seed germination and emergence (Swanton *et al.* 2000). Most weeds are seasonal and crop specific and therefore, by diversifying the prevalent cropping system may reduce the chance of particular weed infestation and hence may reduce the weed pressure. The variation in tillage practices and crop rotation changes weed dynamics and communities and therefore necessitates adjusting weed management practices (Nichols *et al*., 2015). Therefore, a necessity was felt to study the weed dynamics in rice-based cropping systems as influenced by tillage and crop diversification.

METHODOLOGY

A long-term study was initiated at ICAR Research Complex for Eastern Region, Patna ($25^0$30'N latitude $85^0$15'E longitude, and 52 m above mean sea level) in Bihar, India during 2012-13. Experimental soil was sandy clay loam with pH 6.83 and EC 0.11 dS/m. Treatments involving 3 tillage practices *viz*. conventional tillage (CT), reduced tillage (RT) and RT with 30% crop residues (RTR30) in main plots and 3 cropping system *viz.* rice-wheat, rice-lentil and rice-winter maize as sub-plot were replicated thrice in a split plot design. Rice was taken as puddle transplanted during *Kharif* and treatments were imposed during *rabi* season. Weeds were removed manually in different crops as and when needed. Data on weed density and their composition were recorded after 4^{th} year during fallow period (May 2016) and during winter (December 2016).

RESULTS

Soil tillage and crop diversification had significant influence on weed dynamics (Table 1). Reduced tillage with 30% crop residue significantly reduced the density of *T. portulacastrum*, *P. aviculare* and *P. oleracea* during summer season and *C. album* during *Rabi* season as compared to conventional tillage. However, conventional tillage significantly reduced the density of *S. nigrum* (137/m^2) as compared to RT (356/m^2) and RTR30 (782/m^2) during winter season. The highest density of *P. aviculare* (141/m^2), *C. album* (33/m^2) and *L. pinnatifida* (21/m^2) was recorded with rice-lentil system and *P. oleracea* (171/m^2) and *S. nigrum* (1082/m^2) with rice-maize system. Rice-lentil system caused significant reduction in the population of *S. nigrum* (59/m^2) followed by rice-wheat system (135/m^2). Results revealed that reduced tillage with 30% crop residue increased the population of *T. portulacastrum* in rice-wheat system but drastically reduced its density in rice-lentil system. Similarly, RT decreased the population of *S. nigrum* in rice-wheat system, but increased its density in rice-maize system as compared to CT.

Table 1. Effect of tillage and cropping systems on weed dynamics in rice based cropping system

	Weed density (no./m^2)											
	Trianthema portulacastrum L.			*Polygonum aviculare* L.			*Portulaca oleracea* L.			Total		
Treatment	Rice-Wheat	Rice-Lentil	Rice-Maize	Rice-Wheat	Rice-Lentil	Rice-Maize	Rice-Wheat	Rice-Lentil	Rice-Maize	Rice-Wheat	Rice-Lentil	Rice-Maize
Summer												
CT	37.14(1379)	25.40(645)	9.05(81)	3.58(12)	14.67(215)	1.87(3)	2.12(4)	7.15(51)	12.24(149)	38.07(1449)	32.18(1035)	18.77(352)
RT	37.48(1404)	21.36(456)	5.47(30)	3.98(15)	9.80(96)	9.04(82)	1.08(1)	3.72(13)	13.50(182)	38.88(1511)	27.43(752)	21.47(461)
RT + 30% crop residues	43.58(1899)	10.33(106)	8.61(74)	1.22(1)	10.63(113)	2.55(6)	4.06(16)	2.41(5)	13.48(181)	45.27(2049)	20.33(413)	19.91(396)
Mean	39.41(1561)	19.03(402)	7.71(61)	2.93(10)	11.71(141)	4.49(30)	2.42(7)	4.43(23)	13.08(171)	40.74(1669)	26.65(733)	20.05(403)
	T	CS	T x CS	T	CS	T x CS	T	CS	T x CS	T	CS	T x CS
LSD (P=0.05)	1.16	1.55	2.47	0.35	0.34	0.59	0.51	0.42	0.80	NS	1.70	2.86
Treatment	*Solanum nigrum* L.			*Chenopodium album* L.			*Launaea pinnatifida* Cass.			Total		
Rabi												
CT	13.70(187)	9.30(86)	11.80(139)	2.93(8)	5.87(34)	3.23(10)	2.93(8)	0.70(0)	0.70(0)	14.53(211)	14.73(217)	12.78(162)
RT	10.20(104)	5.07(25)	30.67(939)	0.70(0)	6.37(40)	1.57(2)	0.70(0)	0.70(0)	1.60(2)	13.07(170)	13.53(183)	31.40(987)
RT + 30% crop residues	10.67(113)	8.10(65)	46.57(2167)	0.70(0)	4.97(24)	2.73(7)	2.37(5)	7.97(63)	0.70(0)	10.90(118)	16.93(286)	47.10(2219)
Mean	11.52(135)	7.48(59)	29.68(1082)	1.44(3)	5.73(33)	2.51(6)	2.00(4)	3.12(21)	1.00(1)	12.83(166)	15.07(229)	30.42(1123)
LSD (P=0.05)	T	CS	T x CS		CS	T x CS	T	CS	T x CS	T	CS	T x CS
	1.07	0.84	1.59	0.16	0.17	0.29	0.10	0.08	0.15	1.38	1.04	2.01

CT- Conventional tillage, RT-Reduced tillage; *Data subjected to square root transformation $\sqrt{x + 0.5}$, Values in parentheses are original

CONCLUSION

The present study revealed that rice-wheat cropping system encourages the problem of *Trianthema portulacastrum* and rice-winter maize increases the problem of *Portulaca oleracea* and *Solanum nigrum*. Diversification of rice-wheat with rice-maize along with reduced tillage helps in reducing the problem of *T. portulacastrum*. Similarly diversification of rice-maize with rice-lentil along with reduced tillage minimises the problem of *Solanum nigrum.*

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Effect of crop intensification and establishment techniques on weed dynamics

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The rice-wheat is the principal cropping system in south Asian countries that occupies about 13.5 million hectares in the Indo-Gangetic Plains (IGP), of which 10 million hectares are in India. Weeds are an important constraint in agricultural production systems, acting at same tropic level as the crop; weeds capture a part of the available resources that are essential for plant growth (Smith *et al.* 2010). Crop rotation/ crop diversification Rotating crops with different life cycles can disrupt the development of weed crop associations, through different planting and harvest dates preventing weed establishment and therefore weed seed production (Das *et al.* 2012), mainly by smothering and allopathic effect (Dwivedi *et al.* 2012).

METHODOLOGY

A field experiment was conducted in E_2 Block of Norman E. Borlaug Crop Research centre, G.B. Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, Uttarakhand (India), during 2015-16. The experiment was laid out in a randomized block Design (RBD) with nine treatment combinations viz; T_1 (Rice (TPR) – Wheat – Continue), T_2 (Rice (TPR) - Vegetable pea - Groundnut, T_3 (Rice (DSR) - Vegetable pea - Maize (Grain), T_4 (Rice (DSR) - Potato -Cowpea (Grain), T_5 (Rice (DSR) - Vegetable pea - Maize (cob + fodder), T_6 (Rice (DSR) - Yellow Sarson - Black Gram, T_7 Rice (DSR) (B)+Sesbania (F)- 2:1 (FIRBS 45cm * 30 cm) -Vegetable pea (B) + Toria (F)-2:1 (FIRBS) - Maize (B) (cob + fodder) + Mentha (F) 1:1(FIRBS), T_8 Soybean (B)+Rice (DSR) (F)-2:1 (NBS 60cm * 30 cm) - Wheat + Mentha (3:1) (NBS 60cm * 30 cm) - Continue (NBS 60cm * 30 cm), T_9 Maize (B) (cob + fodder) + Cowpea (B) + Sesbania (F)-2:1:2 (BBF 105cm * 30 cm) - Vegetable pea + Toria-3:1 (BBF) - Groundnut+Mentha-3:1(BBF) in *Kharif*, *Rabi* and Summer season respectively and replicated thrice. The crop was sown as per the package of practices recommended for different crops. The fertilizer was applied through NPK mixture (12:32:16), Urea and potassium chloride (MOP) as per requirement of crops. The crops were irrigated as per need.

RESULTS

Grassy weeds were predominant, followed by sedges and broad-leaved. *Echinochloa colona* among the grassy weeds, *Cyprus rotundus* among sedges weeds and *Celosia argenstia* among the broad-leaved weeds were more dominant. Cropping system treatments significantly influenced the population of different weed species (Table 1).

Table 1. Effect of crop intensification and establishment techniques on weed dynamics in *kharif* season

Treatment	Grassy weeds (no./m²)					Sedge weeds (no./m²)		Broad leaved weeds (no./m²)		
	E. colona	*E. indica*	*L. chinensis*	*D. sanguilaris*	*E. crusgalli*	*C. rotundus*	*C. irria*	*T. monogyana*	*A. sessilis*	*Celosia argentea*
T_1	2.5 (5.2)	1.5 (1.2)	1.5 (1.2)	5.7 (32.0)	1.5 (1.2)	10.2 (104)	1.5 (1.2)	3.0 (8.0)	1.5 (1.2)	2.5 (5.2)
T_2	3.8 (13.2)	1.9 (2.8)	1.9 (2.8)	5.0 (24.0)	1.9 (2.8)	10.2 (104)	1.9 (2.8)	4.1 (16)	1.9 (2.8)	3.4 (10.8)
T_3	7.0 (48.0)	2.2 (4.0)	2.2 (4.0)	5.0 (24.0)	2.2 (4.0)	12.2 (148)	2.2 (4.0)	5.4 (28)	2.2 (4.0)	8.4 (69.2)
T_4	7.9 (61.2)	2.5 (5.2)	2.5 (5.2)	3.6 (12.0)	2.5 (5.2)	10.8 (116)	2.5 (5.2)	5.7 (32)	2.5 (5.2)	8.1 (64.0)
T_5	7.9 (61.2)	2.8 (6.8)	2.8 (6.8)	6.1 (36.0)	2.8 (6.8)	10.6 (112)	2.8 (6.8)	5.4 (28)	2.8 (6.8)	7.4 (53.2)
T_6	7.4 (53.2)	3.0 (8.0)	3.0 (8.0)	4.6 (20.0)	3.0 (8.0)	10.4 (108)	3.0 (8.0)	4.6 (20)	3.0 (8.0)	8.4 (69.2)
T_7	6.6 (42.8)	3.2 (9.2)	3.2 (9.2)	1.0 (0.0)	3.2 (9.2)	16.4 (268)	3.2 (9.2)	3.6 (12)	3.2 (9.2)	7.4 (53.2)
T_8	7.4 (53.2)	3.4 (10.8)	3.4 (10.8)	3.6 (12.0)	3.4 (10.8)	11.2 (124)	3.4 (10.8)	3.6 (12)	3.4 (10.8)	8.1 (64.0)
T_9	7.9 (61.2)	3.6 (12.0)	3.6 (12.0)	3.6 (12.0)	3.6 (12.0)	14.5 (208)	3.6 (12.0)	4.1 (16.0)	3.6 (12.0)	8.7 (74.8)
LSD (P=0.05)	0.2	0.1	0.1	0.1	0.0	0.3	0.0	0.1	0.0	0.1

Abbreviations used: 1-T: Treatment, 2- TPR: Transplanted rice, 3-DSR: Direct seeded rice 4-B.: On raised bed 5-F: Furrow, 6-FIRB: Furrow raised bed system, 7-NBS: Narrow bed system and 8 -BBF: Broad bed system

CONCLUSION

It was found that *Cyprus rotundus* predominant weed species in kharif season

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Effect of tank mix application of post emergence herbicides on weed control and yield of groundnut

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Groundnut is cultivated in an area of 11.76 lakh hectares with a production of 8.81 lakh tonnes and a productivity of 0.749 t/ha in Andhra Pradesh. (2013-14) (ZREAC, 2015). It is mostly cultivated as rainfed crop during *kharif* in the Rayalaseema region of Andhra Pradesh. Apart from uncertain rainfall during *Kharif* season, weeds significantly reduce the yields in groundnut to an extent of 13-80% by competing for soil moisture and nutrients. The present study is aimed to find out the effectiveness of tank mix application of post emergence herbicides viz., Imazethapyr and Quizalofop-p-ethyl on weed growth and yield of groundnut.

METHODOLOGY

The experiment was conducted during *kharif*, 2015 at F. No. 59 of Regional agricultural research station, Tirupati, Acharya N.G. Ranga Agricultural University, Andhra Pradesh in a Randomized Block Design with twelve treatments and three replications with each plot size of 5.0m x 4.5m. The soil of experimental field was sandy loam, low in organic carbon and available nitrogen, medium in available phosphorus and potassium. Groundnut variety Dharani was sown with a spacing of 30 x 10 cm on flat beds and recommended packages of practices were used during experimentation. Post emergence herbicides Imazethapyr 10% S.L and quizalofop-p-ethyl 5% E.C. were applied as tank mix application in 50:50, 60:40 and 40:60 ratios respectively.

RESULTS

The weed flora emerged during the period of experimentation comprised of grassy weeds mainly *Doctylactenium aegyptium, Cynodon doctylon, Chloris barabata, Cyperus rotundus, Boerhavia diffusa, Commelina benghalensis, Indigofera spp., Corchorus spp., Amaranthus viridis etc.*, Among the broad leaved weeds *Boerhaavia diffusa* and *Commelina benghalensis* dominated the experimental field. Significantly least weed dry matter was recorded with weed free treatment (2.6 g/m^2) which was comparable with pre emergence application of pendimethalin followed by hand weeding, pre-emergence application of pendimethalin followed by post emergence application of imazethapyr at 20 DAS, pre-emergence application of pendimethalin followed by tank mix application of imazethapyr and quizalofop-p-ethyl in 50:50 and 60:40 ratios and superior over other treatments. Highest weed control efficiency was recorded with weed free (99.3) followed by pendimethalin 750 g/ha as P.E. + imazethapyr 75 g/ha as PoE as 98.4 and least weed index (1.92) was recorded with the same treatment.

Pendimethalin 750 g/ha as PE + imazethapyr 75 g/ha as PoE has recorded the significantly highest pod yield of 1.53 t/ha after weed free treatment (1.56 t/ha) which was at par with

Table 1. Weed dry matter, weed control efficiency, weed index and Groundnut pod, haulm yield as influenced by different weed management practices.

Treatment	Weed dry matter(g/m^2) at 65 DAS	Weed Control Efficiency (%) at 65 DAS	Weed index (%)	Pod yield (t/ha)	Haulm yield (t/ha)	Net monetary returns (Rs/ha)
Farmers practice (hand weeding at 15 and 30 DAS)	84.6 (20.80)	80.5	14.8	1.33	2.34	25906
Pendimethalin 750 g/ha (PE) + one hand weeding at 25 DAS	103.3 (9.21)	76.2	17.5	1.29	2.31	26130
Pendimethalin 750 g/ha (PE) + imazethpyr 75 g ai/ha at 20- 30 DAS	6.6 (10.17)	98.4	1.92	1.53	2.69	37876
Pendimethalin 750 g/ha (PE) + quizalofop-ethyl 50 g/ha at 20- 30 DAS	11.7(2.63)	97.3	24.3	1.18	2.27	23076
Pendimethalin 750 g/ha as PE + tank mix application of imazethpyr (50%) + quizalofop-ethyl (50%) at 20- 30 DAS	15.3 (10.83)	96.4	4.61	1.49	2.85	36070
Pendimethalin 750 g/ha as PE + tank mix application of imazethpyr (60%) + quizalofop-ethyl (40%) at 20- 30 DAS	22.3 (3.96)	94.8	5.76	1.47	2.68	35576
Pendimethalin 750 g/ha as PE + tank mix application of imazethpyr (40%) + quizalofop-ethyl (60%) at 20-30 DAS	27.3 (4.76)	93.7	8.14	1.43	2.64	33196
Tank mix application of imazethpyr (50%) + quizalofop-ethyl (50%) at 20- 30 DAS	148 (5.26)	65.9	24.2	1.18	2.19	24886
Tank mix application of imazethpyr (60%) + quizalofo-ethyl (40%) at 20- 30 DAS	128 (12.16)	70.5	18.3	1.27	2.35	28623
Tank mix application of imazethpyr (40%) + quizalofop-ethyl (60%) at 20- 30 DAS	158.6 (11.33)	63.4	25.2	1.17	2.11	24190
Control (weedy check)	434.6(1.03)	-	53.5	0.72	1.26	6473
Weed free	2.6 (12.60)	99.3	-	1.56	2.78	34150
LSD (P=0.05)	31.82	-	-	0.21	0.39	8359

Figures in parentheses indicate transformed values by square root transformation ($\sqrt{x + 0.5}$)

the treatments of pendimethalin as PE followed by tank mix application of imazethapyr and quizalofop-p-ethyl in 50:50 and 60:40 and 40:60 ratios. Application of alone imazethapyr and quizalofop in ratios of 50:50, 60:40 and 40:60 as post-emergence without pre-emergence application of pendimethalin has not controlled the weeds effectively at the reduced doses and the lower pod yields were recorded with these weed management practices. Highest net monetary returns per hectare (Rs. 37,876) was recorded with pendimethalin as PE + imazethapyr 75 g/ha as PoE.

CONCLUSION

The results inferred that that pre-emergence application of pendimethalin 30% EC 750 g/ha followed by post-emergence application of imazethapyr 10% SL 75 g/ha at 20 DAS has recorded significantly lower weed dry matter, highest weed control efficiency and least weed index which resulted in highest pod and haulm yield of groundnut which was at par with the pre-emergence application of pendimethalin followed by tank mix application of imazethapyr and quizalofop-p-ethyl in 50-50 and 60-40 ratios.

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Bio-efficacy of herbicide combinations for broad spectrum weed control in wheat

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Wheat is the most widely grown winter cereal with an average annual global production of about 720 million tons (IGC, 2015) and is the backbone of food security in India. The productivity and economic gains of wheat are reducing consistently. Weed is one of the major biotic constraints in wheat production as they compete with crop for nutrients, moisture, light and space (Chhokar *et al*. 2012). Weeds suppress the crop and results in reduction of yield (15-50%) depending upon the weed density and type of weed flora. Selective herbicides effectively control weeds in wheat. However, continuous use of same herbicide or herbicide having similar mode of action results in weed flora shifts and evolution of resistance in weeds. When there is complex weed flora (both grassy and broad-leaf) infestation in wheat crop, the efficacy achieved by one herbicide belonging to single group is limited because of narrow spectrum of weed control. In such situations, mix or sequential application of herbicides with different selectivity can widen the range of weed control, save time, application cost and reduce impact of herbicides on environment, resulting in biological activity higher than their individual applications.

METHODOLOGY

The experiment was carried out at Agronomy Farm, Maharana Pratap University of Agriculture and Technology, Udaipur during *rabi* season of 2015-2016. Soil of the experimental site was clay loam in texture and alkaline in reaction (pH 8.2). The experiment consisted of 13 treatments, laid out in a randomized block design with three replications. Wheat variety 'Raj.-4037' was sown at 22.5 cm row distance using 100 kg/ha seed rate. Fertilizers were applied uniformly through urea, single super phosphate and muriate of potash @ 120-60-40 kg N, P_2O5 and K_2O/ha, respectively. Data on weed growth, yield performance and economics were recorded.

RESULTS

The field was predominately infested with grassy and broad leaf weeds. Among all weeds, *Chenopodium album, Chenopodium murale* and *Phalaris minor* were dominant. The maximum weed density and dry weight were recorded in the weedy check as compared to other treatments (Table 1). Herbicidal treatments significantly influenced the population and dry matter production of weeds. Herbicide mixtures and sequential application were proved significantly superior over signally applied herbicides. Reduction in weed density varies from 57.8 to 96.3% under various treatments over weedy check. Among herbicidal treatments, the lowest density and dry weight of total weeds were observed in sulfosulfuron + metsulfuron (19.80 & 11.94%) followed by mesosulfuron + iodosulfuron (23.64 & 14.0%), clodinafop + metsulfuron (27.84 & 15.71%), pinoxaden + metsulfuron (31.41 and 17.47%) and pendimethalin *fb* sulfosulfuron (32.90 and 28.13%). The data explicitly indicated that weed control through sulfosulfuron + metsulfuron mixtures gave highest weed control efficiency (87.98%), brought about greatest reduction in density (80.19%) and dry matter (88.05%) (Table 1). Collective application of herbicides either as premix, tank mix or sequentially resulted in significantly higher grain yield over singly applied herbicides. Highest grain and straw yield (6.02 & 6.49 t/ha) was obtained under sulfosulfuron+ metsulfuron followed by mesosulfuron + iodosulfuron (5.79 & 6.39 t/ha). These two treatments recorded 67.6 and 61.3% yield improvement over weedy check followed by clodinafop + metsulfuron which brought 54.6% increase and it was at par with mesosulfuron + iodosulfuron. Economic viability of treatments in term of net returns indicated that sulfosulfuron + metsulfuron and mesosulfuron + iodosulfuron were the lead herbicide mixture; accounted for highest net returns worth ₹85566 and 81265 which fetched maximum B C ratio (2.02 & 1.94), respectively.

Table 1. Weed growth, yield and economics of wheat as influenced by different weed control treatments

Treatment	Weed density (no./m^2)	Weed dry matter (g/m^2)	Grain yield (t/ha)	Straw yield (t/ha)	Net return ($x10^3$ `/ha)	B C ratio
Pendimethalin	6.51 (42.0) *	79.73	4.71	6.10	60.64	1.44
Sulfosulfuron	5.01 (24.7)	49.85	4.84	6.39	63.72	1.54
Metribuzin	6.09 (36.7)	77.77	4.50	6.20	57.03	1.36
Clodinafop	5.72 (32.3)	59.23	4.74	6.25	61.54	1.48
Pendimethalin *fb* sulfosulfuron	4.62 (21.0)	45.27	5.28	6.53	72.16	1.69
Pendimethalin+ metribuzin	5.66 (31.7)	52.08	5.32	6.40	72.64	1.70
Sulfosulfuron+metsulfuron	2.78 (7.3)	19.22	6.02	6.49	85.56	2.02
Pinoxaden+ metsulfuron	4.41 (19.0)	28.11	5.40	6.48	74.24	1.75
Mesosulfuron+iodosulfuron	3.32 (10.7)	22.53	5.79	6.39	81.26	1.94
Clodinafop+ metsulfuron	3.91 (15.0)	25.29	5.55	6.44	76.93	1.83
One hand weeding	9.13 (83.0)	96.93	4.07	6.15	49.01	1.09
Two hand weedings	8.61 (73.7)	80.84	4.29	6.36	53.69	1.08
Weedy check	14.0 (196.7)	160.90	3.59	5.80	39.44	0.90
LSD (P=0.5)	0.44	3.65	0.34	0.40	-	-

*Values in parentheses are original. Data transformed to square root transformation

CONCLUSION

Based on the of findings it can be concluded that the pre-mix application of sulfosulfuron + metsulfuron (30 + 2 g/ ha) or mesosulfuron + iodosulfuron (12 + 2.4 g/ha) as post-emergence (35 DAS) were more effective in controlling complex weed flora which in turn into higher grain yield and net return.

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Effect of herbicide on weed flora and yield of blackgram

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Blackgram is a crop, which perform well even under limited soil moisture supply. Thus, there is an ample scope for growing blackgram even in low rainfall condition. However, weeds play vital role in reducing the crop yield and thus resulting in high economic losses to the farmers. Weed species infesting blackgram vary according to the agro-ecosystem of the growing region. Most prominent weed species found in blackgram fields are *Trianthema portulacastrum*, *Cyperus rotundus*, *Euphorbia hirta* and *Phyllanthus niruri* (Raman *et al.* 2005). The productivity of the blackgram is adversely affected due to varying biotic and abiotic stresses. (Ali and Lal 1989). Losses due to uncontrolled weed growth have been observed up to 95% in wet season and 77% in dry season (Ramanamurthy and Rao 1996). Therefore, it is very essential to control the weeds from the beginning of the crop growth period by different weed management practices so that the crop may take efficient utilization of applied resources, hence the present investigation was undertaken.

METHODOLOGY

A field experiment was carried out during *kharif* season of 2009 at the Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The soil of experimental field was clayey in texture with medium nitrogen and phosphorus and high potassium contents. The climate of the state is sub-humid to semi-arid with the average rainfall of 1200 to 1400 mm. The total rainfall received during the course of study was 999.7 mm. The experiment was laid in randomized block design with three replications. The treatment of fourteen weed management practices, *viz*. unweeded check, hand weeding at 20 and 40 DAS, pendimethalin 1.0 kg/ha (PE), quizalofop-p-ethyl 37.5 g/ha PoE (20 DAS), chlorimuron-ethyl 4.0 g/ha PoE (20 DAS), fenoxaprop-p-ethyl 60 g/ha PoE (20 DAS), quizalofop-p-ethyl 37.5 g/ha + chlorimuron-ethyl 4.0 g/ha PoE (20 DAS), fenoxaprop-p-ethyl 60 g/ha + chloromuron-ethyl 4.0 g/ha PoE (20 DAS), imazethapyr 25 g/ha PE, chlorimuron-ethyl 4.0 g/ha PPI, quizalofop-p-ethyl 37.5 g/ha + chlorimuron-ethyl 4.0 g/ha PoE (35 DAS), fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl 4.0 g/ha PoE (35 DAS), pendimethalin 1.0 kg/ha PE *fb* quizalofop-p-ethyl 37.5 g/ha + chlorimuron-ethyl 4.0 g/ha PoE (35 DAS) and pendimethalin 1.0 kg/ha PE *fb* fenoxaprop-p-ethyl 60.0 g/ha + chlorimuron-ethyl 4.0 g/ha PoE (35 DAS). Blackgram variety '*TU 94-2*' was sown on July 6, 2009. Sowing was done with a seed rate of 20 kg/ha at a spacing of 30 x 10 cm. The crop was harvested on September 28, 2009.

RESULTS

In unweeded check plot, *Cynodon dactylon*, *Cyperus rotundus*, *Celosia argentia* and *Phyllanthus niruri* and other were the dominant and found throughout the crop growth period which contributes 17, 15, 9, 13 and 46 per cent of total weed flora at harvest stage. The infestation of weed species increased with the time in unweeded check plot. Use of hand weeding twice (20 and 40 DAS) and at harvest stage checked the weed density considerably as compared to other weed management practices. The minimum density and dry matter production of weeds was recorded under hand weeding twice (20 and 40 DAS) treatment throughout the crop growth period and maximum was recorded under unweeded check plot. The highest weed control efficiency was witnessed under hand weeding twice (20 and 40 DAS).

The yield attributing characters namely pods/plant, seeds/plant, seeds/pod and 100-seed weight were observed maximum under hand weeding twice (20 and 40 DAS). The above said characters were minimum under unweeded check. Under hand weedings twice (20 and 40 DAS) significantly the highest seed yield, stover yield and harvest index were produced and the lowest obtained under unweeded check. Maximum Gross income and net incime (Rs/ha) were observed maximum under hand weeding twice (20 and 40 DAS) though B:C ratio was maximum under imazethapyr 25 g/ha. The aforesaid economic parameters were found the lowest in case of unweeded check.

CONCLUSIONS

It was concluded that the hand weeding twice (20 and 40 DAS) and pre-emergence application of imazethapyr 25 g/ha was the most appropriate weed management practices for maximization of growth yield attributes and seed yield (695 and 610 kg/ha) of blackgram. The minimum density and dry matter production of weeds with maximum weed control efficiency (71.45% and 69%) and the highest economic returns in terms of gross income (Rs 32070 and 28215/ha), net income (Rs 21849 and 20468/ha) and B:C ratio (2.14 and 2.64) were also obtained under the above weed management practice.

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Weed management through new generation herbicides in *Kharif* greengram

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Greengram (*Vigna radiata* L.) is one of the most important and extensively cultivated pulse crops. Due to severe infestation of annual and perennial weeds in *kharif* greengram, the potential yield is generally not realized. Adoption of physical methods in time may not be feasible in *kharif* season. Application of certain selective herbicide as pre- or post-emergence can effectively manage complex weed flora. Hence, the experiment was conducted with objectives to find out appropriate dose of herbicide/herbicide mixtures either pre-emergence or post-emergence for timely control of weeds in *kharif* greengram.

METHODOLOGY

A field experiment was conducted at AICRP-Weed Management farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *kharif* 2014. The soil of the experimental field was sandy loam in texture having low in available nitrogen, medium in available phosphorus and high in available potassium with pH 8.1. The experiment was laid out in randomized complete block design with four replications. Twelve treatments comprised of imazethapyr 70 and 80 g/ha as PE and PoE, imazethapyr + imazamox (RM) 70 and 80 g/ha as PE and PoE, pendimethalin 1000 g/ha PE, imazethapyr + pendimethalin (RM) 1000 g/ha PE, hoeing at 20 and 40 DAS and weedy check. Greengram cv. *Meha* was sown keeping the distance of 45 cm between two rows with adoption of all the recommended package of practices. The weed density and dry biomass of weeds were recorded at 40 DAS.

RESULTS

The predominant weed species were *Eleusine indica* and *Digera arvensis*, in monocot and dicot respectively, observed in the experimental field. The results indicated that pre-emergence application of imazethapyr + pendimethalin 1000 g/ha recorded significantly lower total dry biomass of weeds (8.6 g/m^2) with 95% weed control efficiency at 40 DAS, but it was remained at par with hoeing at 20 and 40 DAS (Table 1).

All the weed management practices produced significantly higher seed and haulm yield of greengram as compared to weedy check (Table 1). Among the weed management practices, post-emergence application of imazethapyr 80 g/ha resulted in significantly higher seed yield (1.47 t/ha) whereas, application of imazethapyr + pendimethalin 1000 g/ha gave significantly higher haulm yield (2.27 t/ha) of greengram, but both were remained at par with all the treatments except imazethapyr + imazamox 80 g/ha PoE for seed yield and imazethapyr + imazamox 80 g/ha PoE and pendimethalin 1000 g/ha PE for haulm yield. Further, it was observed that imazethapyr + imazamox 80 g/ha gave significantly lower seed yield due to phytotoxic effect of applied herbicide on crop at early growth stage. Similar line of results was also reported by Raj *et al.* (2012) in greengram. The growth parameters and seed yield of succeeding mustard crop were not influenced significantly due to different herbicides applied in preceding greengram crop as individual or as mixtures. This indicated that there was no any carry over/residual effect of herbicide noticed on succeeding crop.

Table1. Effect of weed management practices on weed dry biomass, seed and haulm yield and economics as influenced by different weed management practices in greengram

Treatment	Total Weed dry biomass at 40 DAS (g/m^2)	Seed yield (t/ha)	Haulm yield (t/ha)	WCE (%) at 40 DAS	B :C ratio
Imazethapyr 70 g/ha PE	5.81^{cd} (33.2) *	1.26^{ab}	2.10^{ab}	81	2.54
Imazethapyr 80 g/ha PE	5.10^{de} (25.4)	1.37^{a}	2.06^{ab}	85	2.72
Imazethapyr 70 g/ha PoE	5.65^{cd} (31.0)	1.37^{a}	2.02^{ab}	82	2.76
Imazethapyr 80 g/ha PoE	5.10^{de} (24.0)	1.47^{a}	1.91^{ab}	86	2.90
Imazethapyr +Imazamox 70 g/ha PE (RM)	6.38^{c} (40.0)	1.37^{a}	1.96^{ab}	77	2.70
Imazethapyr +Imazamox 80 g/ha PE (RM)	4.46^{ef} (19.0)	1.28^{ab}	1.95^{ab}	89	2.51
Imazethapyr +Imazamox 70 g/ha PoE (RM)	6.31^{c} (39.0)	1.28^{ab}	1.87^{ab}	77	2.53
Imazethapyr +Imazamox 80 g/ha PoE (RM)	6.02^{cd} (35.4)	1.01^{bc}	1.64^{bc}	80	1.99
Pendimethalin 1000 g/ha PE	8.76^{b} (76.3)	1.17^{ab}	1.64^{bc}	56	2.31
Imazethapyr + Pendimethalin 1000g/ha PE (RM)	3.03^{g} (8.6)	1.43^{a}	2.27^{a}	95	2.80
Hoeing at 20 and 40 DAS	3.63^{fg} (12.6)	1.33^{ab}	2.06^{ab}	93	2.80
Weedy check	13.19^{a} (173.4)	0.82^{c}	1.23^{c}	-	1.81
LSD (P=0.05)	Sig.	Sig.	Sig.	-	-
CV %	16.4	0.02	0.02	-	-

* Values in parentheses are original. Data transformed to square root transformation. Treatment means with the letter/letters in common are not significant by Duncan's New Multiple Range Test at 5% level of significance.

The results of the economic analysis of the weed management practices revealed that maximum benefit cost ratio (2.90) was recorded in imazethapyr 80 g/ha PoE followed by imazethapyr + pendimethalin 1000 g/ha PE, hoeing at 20 and 40 DAS, imazethapyr 70 g/ha PoE, imazethapyr 80 g/ha PE and imazethapyr + imazamox 70 g/ha PE. Similarly, Patel *et al.* (2016) also observed higher B:C ratio with IC *fb* HW at 20 and 40 DAS and use of imazethapyr with integration of IC *fb* HW at 30 DAS in greengram.

CONCLUSION

In paucity of labourers, pre- or post-emergence application of imazethapyr 70 to 80 g/ha or pre-emergence application of imazethapyr + imazamox 70 to 80 g/ha or imazethapyr + pendimethalin 1000 g/ha can safely be used to manage weeds in greengram without any residual/carry over effect on succeeding mustard crop.

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Efficacy of pre- and post-emergence herbicides in maize

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Maize (*Zea mays* L.) being one of the most important cereals has attained a commercial crop status and also has scope to achieve the potential yield of crop. Management of weed is considered to be an important factor for achieving higher productivity. Yield loss up to 33% to complete crop failure were reported due to weed competition in maize. Rout *et al.* (1996) revealed that weeds cause enormous damage upto 30 to 50 percent in maize crop. Frequent rainfall during season does not allow manual and mechanical methods of weeding at the appropriate time. Therefore, use of pre- and post-emergence herbicides would make weed control more acceptable to farmers which will not change the existing agronomic practices but will allow for complete control of weeds. The present investigation was therefore, planned with an objective to study the efficacy of pre- and post-emergence herbicides and its effect on weed flora, growth and yield of maize.

METHODOLOGY

The field experiment was conducted during *kharif* 2015-2016 at the research farm of Agronomy Department, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S.) in Randomized Block Design with three replications having eight different treatments i.e. weed free, weedy check, 2,4-D sodium salt 0.80 kg/ha PoE 30 DAS, 2,4-D sodium salt 1.20 kg /ha PoE 30 DAS, atrazine 1 kg/ha PE, atrazine 0.50 kg/ha *fb* 2,4-D sodium salt 0.5 kg PoE 30 DAS, pendimethalin 1.0/ha PE and atrazine 0.50 kg + pendimethalin 0.50 kg/ha PE. The soil of the experimental field was black and clayey in texture and slightly alkaline in reaction, low in nitrogen, medium in phosphorous and fairly rich in potash. The maize variety *Maharaja* was sown at the spacing of 60 x 30 cm on 21st June 2015 with recommended dose of fertilizer 120:60:30 NPK kg/ha.

RESULTS

The major weed flora during *kharif* season in experimental field was composed of *Xanthium strumarium, Celosia argentea, Tridax procumbens, Phyllanthus niruri, Euphorbia geniculata, Euphorbia hirta, Alternanthera triandra, Parthenium hysterophorus, Digera arvensis, Cynodon dactylon, Cyperus rotundus, Amaranthus viridis, Dinebra arabica, Panicum spp., Commelina benghalensis, etc.* Both broad and narrow leaved weeds were observed but dominance of broad leaved weeds was observed in entire field.

The data presented in Table 1 indicated that, the weed control treatments significantly reduced the weed population and weed biomass when compared with unweeded control. The sequential application of atrazine 0.50 kg/ha *fb* 2,4-D sodium salt 0.5 kg PoE 30 DAS followed by atrazine 1 kg/ha PE and atrazine 0.50 kg + pendimethalin 0.50 kg/ha PE showed superiority in minimizing the total weed population and weed dry matter at harvest. Among the herbicides, highest weed control efficiency and less weed index was recorded in atrazine 0.50 kg/ha *fb* 2,4-D sodium salt 0.5 kg PoE 30 DAS.

Table 1. Weed population, weed dry matter, weed control efficiency, yield and economics of maize as affected by different weed control treatments

Treatment	Total weed population (m^2)	Weed dry matter (g/m^2)	Weed control efficiency (%)	Grain weight/ cob (g)	Grain yield (t/ha)	NMR (Rs/ha)	B:C ratio
Weed Free	2.80	2.33	96.51	84.73	4.75	48769	2.87
Weedy check	12.24	11.91	--	48.59	2.02	16144	1.83
2,4-D sodium salt 0.80 kg /ha PoE 30 DAS	8.05	7.65	58.92	58.47	3.40	35014	2.72
2,4-D sodium salt 1.20 kg /ha PoE 30 DAS	7.70	7.39	61.70	60.93	3.45	35753	2.74
Atrazine 1 kg /ha PE	6.36	5.90	75.67	72.81	3.60	37765	2.82
Atrazine 0.50 kg /ha *fb* 2,4-D sodium salt 0.5 kg POE 30 DAS	5.90	5.35	80.09	75.10	4.11	44658	3.11
Pendimethalin 1.0/ha PE	7.56	7.02	65.39	64.69	3.57	35874	2.67
Atrazine 0.50 kg + pendimethalin 0.50 kg/ha PE	6.70	6.34	71.95	68.51	3.61	36982	2.75
LSD (P=0.05)	0.79	0.56	-	8.01	0.52	6958	--

As indicated in the Table1, it was noticed that grain weight per cob and grain yield was found maximum in weed free treatment (4.75 t/ha) while among the pre and post herbicidal treatments application of atrazine 0.50 kg/ha *fb* 2,4-D sodium salt 0.5 kg PoE 30 DAS recorded higher grain yield (4.11 t/ha) which was closely followed by atrazine 0.50 kg + pendimethalin 0.50 kg/ha PE and atrazine 1 kg/ha PE.

The net monetary returns was found maximum under weed free treatment followed by atrazine 0.50 kg/ha *fb* 2,4-D sodium salt 0.5 kg PoE 30 DAS and atrazine 1 kg/ha PE while the maximum B:C ratio was found in atrazine 0.50 kg/ha *fb* 2,4-D sodium salt 0.5 kg PoE 30 DAS (3.11) than weed free treatment (2.87).

CONCLUSION

Sequential application of pre- and post-emergence herbicides *i.e.* atrazine 0.50 kg/ha *fb* 2,4-D sodium salt 0.5 kg PoE 30 DAS provided better weed control and found economical as compared to conventional weed management practices in maize.

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Bioefficacy of herbicide combination on weeds and transplanted rice productivity

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Rice production is an integral part of Indian economy. Rapid population growth in our country demands more attention to be directed towards sustainable rice production. Transplanted rice crop faces diverse type of weed flora consisting of grass, broad leaved weeds and sedges. Different herbicides are used alone or in mixture to eliminate the weeds. But their efficiency differs, because of their narrow spectrum of weed control. Under such situation, combination of herbicides may be a good option to maximize the weed control.

METHODOLOGY

An experiment was conducted during 2012-13 at Agriculture College and Research Institute, Madurai to study the growth and yield of transplanted rice as influenced by application of herbicide combination as tank-mixture and in sequence. A set of 11 treatments were laid out in randomized block design with three replications. Treatments comprised of butachlor 1500 g/ha, pretilachlor 1000 g/ha, pyrazosulfuron 20 g/ha, Bispyribac-Na 25 g/ha, chlorimuron-ethyl + metsulfuron-methyl 4 g/ha, Bispyribac-Na + chlorimuron-methyl + metsulfuron-ethyl 25+4 g/ha, bispyribac-Na + ethoxysulfuron 25+18.75 g/ha, pretilachlor *fb* ethoxysulfuron 750+18.75 g/ha, pretilachlor *fb* chlorimuron-methyl + metsulfuron-ethyl 750+4 g/ha, butachlor *fb* chlorimuron-methyl + metsulfuron-ethyl 1500+4 g/ha, butachlor 1250 g/ha *fb* hand weeding, hand weeding twice 25 and 45 DAT and unweeded control. Rice seedlings of variety ADT-49 were transplanted at a spacing of 20 x 15 cm. Recommended dose of fertilizer (150 kg N, 50 kg P_2O_5 and 50 kg K_2O) per hectare was applied to the crop.

RESULTS

The predominant weeds of the experimental plot were *Echinochloa crusgulli* and *Cynodon dactylon*, under grasses, *Cyperus rotundus*. *Cyperus difformis* and *Fimbristylis milliaceae* among sedges and *Sphenoclea zeylanica*, *Eclipta alba* and *Marsilea quadrifoliata* among broad leaved weeds. All weed control treatments significantly reduced the density of grasses, BLW and sedges. Among the treatments bispyribac-Na + chlorimuron methyl + metsulfuron ethyl recorded highest weed control efficiency (WCE) of 92%. Lowest weed dry matter of 51.53 g/ha was recorded by the tank-mix combination of bispyribac-Na + chlorimuron methyl + metsulfuron ethyl (Table.1). The results are in conformity with the findings of Yogabalalakshmi (2001).

Table.1 Effect of herbicide treatments on weeds, growth and yield of transplanted rice

Treatment	WCE (%)	Total weed DMP (kg/ ha)	Plant height (cm)	LAI	Plant dry matter (kg/ha)	Grain yield (kg/ ha)	Straw yield (kg /ha)
Pre-emergence butachlor alone	66.25	15.29 (233.44)	90.52	1.91	2803	5135	6519
Pre-emergence pretilachlor alone	60.63	16.51 (272.29)	85.70	1.86	2745	5025	6490
Post-emergence bispyribac-Na alone	82.15	11.13 (123.45)	91.40	2.38	3542	5600	7016
Post-emergence chlorimuron-methyl + metsufuron-ethyl	84.62	10.33 (106.37)	95.08	2.42	3649	5602	7127
Pre-emergence bispyribac-Na + chlorimuron-methyl + metsulfuron-ethyl	92.55	7.21 (51.53)	103.89	2.72	4210	6350	7890
Post-emergence bispyribac-Na + ethoxysulfuron	86.50	9.68 (93.35)	95.11	2.07	3428	5483	6831
Post-emergence pretilachlor + ethoxysulfuron	87.19	9.68 (93.35)	92.80	2.19	3478	5535	6990
Pre-emergence pretilachlor *fb* post-emergence chlorimuron-methyl + metsulfuron-ethyl	91.27	7.80 (60.39)	102.72	2.68	3962	6045	7480
Pre-emergence butachlor *fb* post-emergence chlorimuron methyl + metsulfuron-ethyl	84.62	10.33 (106.40)	95.64	2.12	3357	14.51	5417
Pre-emergence butachlor *fb* manual weeding	86.04	9.85 (96.55)	101.70	2.52	3718.8	14.45	5790
Hand weeding twice	88.26	8.66 (74.54)	101.70	2.55	3932	14.8	5898
Control	-	32.21 (1037)	69.22	1.65	2018	14.49	3295
LSD (0.05)	-	0.17	3.34	0.08	119	124	124

Post-emergence application of bispyribac-Na + chlorimuron methyl + metsulfuron ethyl was found to significantly increase plant height (103.89 cm) at 90 DAT and leaf area index (2.72) during active tillering stage. This increase can be attributed to the effective weed control achieved by the mixture of herbicides during the early stage of crop-weed competition. Dry matter production of 4210 kg/ha was also found to increase under the same treatment. This subsequently resulted in highest grain and straw yield of 6350 and 7890 kg/ ha, respectively. There was 50.6% higher grain yield over unweeded check. The increased growth and yield in the above said best treatments clearly indicated the influence of weed free environment on grain production. This is in accordance with the study of Thakur *et al.* (2010)

CONCLUSION

Based on the study, it can be concluded that application of herbicides as mixtures have effective broad spectrum control of complex weed flora in transplanted rice ecosystem. The tank-mix application of bispyribac-Na + chlorimuron-methyl + metsulfuron-ethyl at 25 DAT was found to be an agronomically feasible weed management practice for transplanted rice.

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Weed management in cassava

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Cassava, one of the most important root crops, plays an important role in ensuring food security of resource poor farmers. Although the crop is less susceptible to pests and diseases, weed interferences during the initial months causes reduction in tuber yield upto 40 per cent to 70 per cent (IITA 1990), indicating the necessity for developing a weed management package for cassava. Hence, an experiment was conducted to develop an effective and economic weed management strategy for cassava integrating chemical, physical and agronomic methods which would ensure optimum yield with the lowest cost of production.

METHODOLOGY

The experiment was carried out at the Agronomy farm, College of Horticulture, Kerala Agricultural University Vellanikkara, Thrissur during May to October, 2015. The experimental design adopted was randomized block design (RBD) with eleven treatments and three replications. The treatments included applications of four herbicides, herbicides followed by earthing up, hoeing and earthing up and simultaneous growing and incorporation of green manure cowpea. Vellayani Hraswa, a short duration variety of cassava was planted on mounds with recommended package of practices. Nitrogen, phosphate and potash 100:100:100 kg/ha was applied in three splits. Observations on weed count, weed dry weight, yield parameters and yield were recorded and the data were subjected to analysis of variance (ANOVA). Benefit: cost ratio was worked out based on the prevailing market price.

RESULTS

The experimental field was predominantly infested with monocot and dicot weeds and some sedges. *Borreria hispida* was the most dominant weed throughout the growth period. Broad leaf weeds outnumbered grass weeds at 60 DAP. The least weed counts (54.33 no./m^2) at 60 DAP was recorded in the treatments received hoeing and earthing up at 30 and 60 DAP. However, the weed dry matter production was lower in treatments applied with pre-emergent oxyfluorfen and directed application of glyphosate. At 60 DAP higher weed control efficiencies were shown by pre-emergence oxyfluorfen, oxyfluorfen + hoeing and earthing up at 60 DAP, directed application of glyphosate and glyphosate + hoeing and earthing up at 60 DAP. The lowest weed index (1.65%) was by pendimethalin + hoeing and earthing up at 60 DAP. Higher tuber yield of 31.2, 30.6 and 28.4 t/ha were recorded in the treatments hoeing and earthing up at 30 and 60 DAP, pendimethalin + hoeing and earthing up at 60 DAP, and glyphosate + hoeing and earthing up at 60 DAP respectively. Yield obtained in the treatments with application of pre-emergence herbicides + hoeing and earthing up at 60 DAP were higher compared to those without hoeing and earthing up. This showed the positive influence of secondary tillage on root enlargement and thickening in cassava. As Olorunmaiye *et al.* (2009) reported, application of pre-emergent herbicides followed by one hoe weeding promoted season long weed control and thus better yield advantage. The treatment with pre-emergent application of pendimethalin + hoeing and earthing up at 60 DAP showed the highest B: C ratio of 2.41.

Table 1. Effect of treatments on weed growth (60 DAP), yield and economics of cassava

Treatment	Weed count (no./m^2)	Weed dry matter production (g/m^2)	Weed control efficiency	Weed index	Yield (t/ha)	B:C ratio
Oxyfluorfen 0.2 kg/ha	9.64 (93.33)	4.16 (17.52)	91.11	25.09	23.27	2.27
Pendimethalin 1.5 kg/ha	8.31 (70.67)	7.00 (49.03)	75.22	44.88	17.17	1.73
Imazethapyr 80g/ha	8.58 (74.00)	10.17 (103.81)	47.57	50.02	15.56	1.56
Glyphosate 0.8 kg/ha	8.80 (78.67)	5.36 (29.64)	85.11	29.85	21.79	2.21
Oxyfluorfen + hoeing and earthing up at 60 DAP	10.50 (110.67)	5.45 (29.73)	84.95	21.24	24.55	1.93
Pendimethalin + hoeing and earthing up at 60 DAP	8.99 (83.33)	6.67 (45.07)	77.17	1.65	30.61	2.41
Imazethapyr + hoeing and earthing up at 60 DAP	10.66 (114.00)	9.83 (96.78)	51.18	23.88	23.72	1.87
Glyphosate + hoeing and earthing up at 60 DAP	8.84 (78.67)	4.98 (24.82)	87.46	8.64	28.44	2.24
Concurrent growing of cowpea and *in situ*in corporation and earthing up at 60 DAP	12.14 (148.00)	10.96 (120.53)	39.04	25.75	23.06	1.79
Hoeing and earthing up at 30 and 60 DAP	7.36 (54.33)	6.94 (48.83)	75.29	0.00	31.17	1.89
UWC	12.27(150.67)	14.07 (197.97)	0.00	56.28	13.58	1.42
LSD (P=0.05)	1.89	1.23	9.55	10.69	3.469	
CV(%)	11.22	9.27	8.64	24.02	8.86	

CONCLUSION

Weed control by hoeing and earthing up alone may increase the cost of production because of higher labour requirement. Application of pre-emergence herbicides like pendimethalin along with hoeing and earthing up at 60 DAP can be recommended for effective weed control and reduction in cost of cultivation.

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Herbicides combinations for control of complex weed flora in transplanted rice

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Rice (*Oryza sativa* L.) is an important staple crop in India and its productivity is declining due to many constraints. In Bihar, rice is cultivated in around 3.34 mha with a production of 7.2 million tones and productivity of 2.16 t/ha. Weeds are a major impediment to rice production, causing 15–45% yield losses in transplanted rice. Manual removal of weeds is labour-intensive, tedious, back breaking and does not ensure weed removal at critical stage of crop-weed competition. Thus, herbicides appear to be the suitable alternatives under all situations. Bispyribac- sodium is new herbicide, known to be effective against many annual and perennial grasses, sedges and broad-leaved weeds in rice (Yadav *et al.* 2009)

METHODOLOGY

A field experiment was conducted to evaluate the bio-efficiency of combination of herbicides against complex weed flora, and their effect on growth and yield of transplanted rice at crop research centre, RAU, Pusa in Randomized Block Design replicated thrice. The variety used was Rajendra Sweta. The soil of the experimental plot was sandy loam having pH 8.4, organic carbon 0.42%, Low in available Nitrogen (207 kg/ha), Phosphorus (21.5 kg P_2O_5/ha) and Potassium (114.8 kg K_2O/ha). The recommended dose of fertilizers i.e. 120-60-40 kg N-P_2O_5-K_2O/ha was applied. Half dose of nitrogen and full dose of phosphorus and potassium were applied as basal and remaining dose of nitrogen was applied in two equal splits at active tillering and panicle initiation stages respectively. Herbicides were applied with the help of Knapsack sprayer fitted with flat fan nozzle. Data were recorded on weeds and yield of rice crop.

RESULTS

The dominant weed flora found in the experimental field were *Echinocloa crusgalli, E. colonum, Digitaria sanguilis, Dactyloctenium aegyptium, Cynodon dactylon* under Grasses; *Cyperus rotundus, Cyperus deformis, Cyperus iria* and *Fimbristylis milliaceae* under sedges and *Caesulia auxillaris, Lippia nodiflora, Amaranthus spinosus, Amaranthus viridis, Eclipta alba, Phyllanthus niruri and Monochoria vaginalis* under broad-leaved weeds The results revealed that the lowest weed population and weed dry weight were recorded in hand weeding at 25 and 45 DAT which were significantly superior over rest of the treatments. The highest grain yield of rice (4.97 t/ha) was recorded with the treatment hand weeding at 25 and 45 DAT which was statistically at par with pendimethalin 750 g/ha *fb* bispyribac-sodium 25 g/ha (4.76 t/ha), and bispyribac 25 g/ha + ethoxysulfuron 18.75 g/ha (4.64 t/ha). The highest weed control efficiency (74.22 %) was recorded under the treatment hand weeding at 25 and 45 DAT which was followed by pendimethalin 750 g/ha *fb* bispyribac-sodium 25 g/ha (64.41 %) and bispyribac 25 g/ha + ethoxysulfuron 18.75 g/ha (54.40 %). There were not any phytotoxic effects on rice crop. The highest gross return (Rs 71350/ha) was recorded by hand weeding at 25 and 45 DAT which was statistically at par with pendimethalin 750 g/ha *fb* bispyribac-sodium 25 g/ha (Rs 68212/ha). However, the highest net return (Rs 41492/ha) was recorded by pendimethalin 750 g/ha *fb* bispyribac-sodium 25 g/ha which was statistically at par with bispyribac 25 g/ha + ethoxysulfuron 18.75 g/ha (Rs 40746/ha), pretilachlor 750g/ha *fb* chlorimuron + metsulfuron (almix) 4g/ha (Rs 38165/ha) and pyrazosulfuron 20 g/ha *fb* chlorimuron + metsulfuron (almix) 4 g/ha (Rs 38035/ha). The highest B:C ratio (2.58) was recorded by bispyribac 25 g/ha + ethoxysulfuron 18.75 g/ha which was statistically at par with pendimethalin 750 g/ha *fb* bispyribac-sodium 25 g/ha (2.55), either pretilachlor 750 g/ha or pyrazosulfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (almix) 4 g/ha (25 DAT).

Table 1. Effect of different weed management treatments on weeds, crop yield and economics of transplanted rice

Treatment	Dose (g/ha)	Time (DAT)	Weed density (no./m^2) at 60 DAT	Weed dry weight (g/m^2) at 60 DAT	Grain yield (t/ha)	WCE (%)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C ratio
Bispyribac-Na	25	25	19.03	32.97	3.95	29.12	56569	31594	2.26
Penoxsulam 24% SC	22.5	15	19.33	34.86	3.97	25.09	56972	30102	2.12
Bispyribac + ethoxysulfuron	25+18.75	25 DAT	11.46	21.21	4.64	54.40	66421	40746	2.58
Bispyribac + chlorimuron + metsulfuron (almix)	20+4	Do	13.54	24.99	4.36	46.28	62739	36729	2.41
Pretilachlor *fb* ethoxysulfuron	750/18.75	0-3 *fb* 25 DAT	15.025	26.89	4.32	42.19	61968	37168	2.49
Pretilachlor *fb* chlorimuron + metsulfuron (almix)	750/4	0-3 *fb* 25 DAT	14.49	26.82	4.40	42.34	63300	38165	2.52
Pyrazosulfuron *fb* chlorimuron+metsulfuron (almix)	20/4	0-3*fb* 25	15.615	29.08	4.41	37.49	63030	38035	2.51
Penoxsulam+ cyhalofop 6% OD (RM)	135	15-20	17.97	31.22	4.21	32.88	60316	32946	2.20
Triafamone + ethoxysulfuron 30% WG (RM)	60	15	17.57	32.56	4.12	30.01	59095	33395	2.30
Pendimethalin (38.7% CS) *fb* bispyribac-sodium	750/25	0-3 /25	8.76	16.57	4.76	64.41	68212	41492	2.55
Hand weeding at 25 and 45 DAT			5.7	11.98	4.97	74.22	71350	36150	2.02
Weedy check			29.73	46.53	2.91	-	41136	17936	1.77
LSD (P=0.05)			2.36	2.87	0.33	-	4580	4580	0.16

CONCLUSION

Application of bispyribac sodium 25 g/ha + ethoxysulfuron 18.75 g/ha at 25 DAT or pendimethalin 750 g/ ha (0-3 DAT) *fb* bispyribac-sodium 25 g/ha (25 DAT) or either pretilachlor 750 g/ha or pyrazosulfuron 20 g/ha (0-3 DAT) *fb* chlorimuron + metsulfuron (almix) 4 g/ha (25 DAT) is quite effective in controlling weeds and obtaining higher yield of transplanted rice and fetching higher net return and B:C ratio.

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Integrated weed management with pre- and post-emergence herbicides in turmeric

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Turmeric (*Curcuma longa* L.) is a major spice crop, occupying 6% of the total area under spices and condiments in India. India leads in production of turmeric with 78% of global production, its average productivity is quite low, mainly due to the competition offered by weeds. Uncontrolled weed growth reduces the rhizome yield of turmeric upto 30-75% depending upon the nature of intensity and duration of weed competition in turmeric field (Krishnamurthy and Ayyaswamy 2000). Chemical weed control is a better supplement to conventional methods and forms an integral part of the modern crop production. Straw mulch is another approach adopted by the farmers that conserves soil moisture and modifies soil temperature for benefit of crop, besides controlling weeds (Mahey *et al.* 1986).

METHODOLOGY

The experiment was conducted at Research farm of TCA, Dholi in Randomized Block Design. The variety used was 'Rajendra Sonia'. The experiment comprised of 15 weed management treatments. The recommended dose of fertilizer *i.e.* 150-60-120 kg N-P_2O_5-K_2O /ha was applied. The recommended package and practices of turmeric cultivation was adopted. Herbicides were applied with the help of knapsack sprayer fitted with flat fan nozzle. Data were recorded on weeds and yield of the crop. The soil of the experimental plot was sandy loam having average fertility status of available N (269 kg/ha), available phosphorus (16.95 kg/ha) and available potassium (139.5 kg/ha).

RESULTS

The lowest weed dry weight was recorded under hand weeding thrice (HW at 25, 45 and 75 DAP) which was significantly superior over rest of the treatments except metribuzin 0.7 kg/ha at 3 DAP *fb 2* hand weeding at 45 and 75 DAP respectively. The highest rhizome yield (48.28 t/ha) was recorded under the treatment hand weeding thrice (HW at 25, 45 and 75 DAP) which was statistically at par with metribuzin 0.7 kg/ha or pendimethalin 1.0 kg/ha *fb* 2 hand weeding at 45 and 75 DAP and metribuzin 0.7 kg/ha or pendimethalin 1.0 kg/ha at 3 DAP *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha at 45 DAP and metribuzin 0.7 kg/ha or pendimethalin 1.0 kg/ha at 3 DAP *fb* straw mulch 10 t/ha at 10 DAP *fb* hand weeding at 75 DAP. The highest weed control efficiency (87.78%) was recorded under the treatment hand weeding thrice, which was closely followed by metribuzin 0.7 kg/ha at 3 DAP *fb* 2 hand weedings (HW at 45 and 75 DAP). The highest B:C ratio was recorded by metribuzin 0.7 kg/ha at 3 DAP *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha at 45 DAP (3.17) which was statistically at par with pendimethalin 1.0 kg/ha at 3 DAP *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha at 45 DAP (3.09) only.

Table 1. Effect of different weed management treatments on weeds, crop yield and economics of transplanted rice

Treatment	Weed density (N./m^2) at 60 DAS	Weed biomass (g/m^2) at 60 DAS	Rhizome yield (t/ha)	WCE (%)	Gross Return (Rs./ha)	Net Return (Rs./a)	B:C ratio
Metribuzin 0.7 kg/ha, 0-5 DAP *fb 2* hand weeding 45 and 75 DAP	5.23	9.3	47.6	86.96	333199	219199	2.92
Metribuzin 0.7 kg/ha 0-5 DAP *fb* fenoxaprop + metsulfuron 67 + 4 g/ha 45 DAP	7.91	15.9	47.01	77.71	329105	225433	3.17
Metribuzin 0.7 kg/ha 0-5 DAP *fb* straw mulch 10 t/ha 10 DAP *fb* HW 75 DAP	8.75	19.61	46.56	72.51	325955	202955	2.65
Pendimethalin 1.0 kg/ha 0-5 DAP *fb* 2 HW 45 and 75 DAP	9.01	22.35	46.3	68.67	324100	210600	2.85
Pendimethalin 1.0 kg/ha 0-5 DAP *fb* fenoxaprop + metsulfuron 67 + 4 g/ha 45 DAP	9.83	26.04	45.61	63.49	319269	216097	3.09
Pendimethalin 1.0 kg/ha 0-5 DAP *fb* straw mulch 10 t/ha 10 DAP *fb* HW 75 DAP	10.49	27.55	45.28	61.38	316960	194460	2.58
Atrazine 0.75 kg/ha 0-5 DAP *fb* 2 HW 45 and 75 DAP	12.24	28.72	43.2	59.74	302400	189800	2.68
Atrazine 0.75 kg/ha 0-5 DAP *fb* fenoxaprop + metsulfuron 67 + 4 g/ha 45 DAP	16.0	29.58	42.86	58.53	300055	197783	2.93
Atrazine 0.75 kg/ha 0-5 DAP *fb* straw mulch 10 t/ha 10 DAP *fb* HW 75 DAP	19.09	32.26	40.41	54.77	282905	161305	2.32
Oxyfluorfen 0.30 kg/ha 0-5 DAP *fb* 2 HW 45 and 75 DAP	20.89	35.83	39.52	49.77	276640	161640	2.40
Oxadiargyl 0.25 kg/ha 0-5 DAP *fb* 2 HW 45 and 75 DAP	24.75	43.16	37.14	39.50	259980	146780	2.29
Glyphosate 5.0 ml/lit 25 *fb* 2 HW 45 and 75 DAP	28.29	48.83	36.37	31.55	254590	141840	2.25
Glyphosate 7.5 ml/lit 25 *fb* 2 HW 45 and 75 DAP	30.01	53.88	34.73	24.48	243145	130020	2.14
3 Hand weeding	4.76	7.93	48.28	88.87	337995	219995	2.86
Un-weeded check	42.01	71.35	27.54	-	192780	92780	1.93
LSD (P=0.05)	3.80	3.77	3.53	-	22916	22917	0.20

CONCLUSION

Pre-emergence application of metribuzin 0.7 kg/ha or pendimethalin 1.0 kg/ha at 3 DAP *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha at 45 DAP is effective in controlling weeds and producing good yield of turmeric rhizome with higher B:C ratio.

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Tank-mix application of cyhalofop-butyl with selected herbicides for weed control in wet seeded rice

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Chemical weed control is gaining importance all over the world. Application of pre-emergence and post-emergence herbicides as different sprays increases the total cost of production. Recently, farmers are opting use of single application of herbicide mixtures in rice fields for broad spectrum control of weeds. Cyhalofop-butyl is a cost effective post emergence selective herbicide that controls grassy weeds especially *Echinochloa* spp. and *Leptochloa chinensis* (Saini *et al.* 2001). As it is not effective against sedges or broad leaved weeds, a follow up application of broad spectrum herbicides is usually recommended. However, to reduce the cost of spraying, farmers prefer tank-mix application of these herbicides to achieve broad spectrum weed control in a single application. So, the present study was conducted to find out the best herbicide that can be tank-mixed with cyhalofop-butyl, so that effective control of weeds can be achieved, while reducing the cost of cultivation.

METHODOLOGY

A field experiment was conducted in Alappad *kole* lands from September 2015 to January 2016, using the rice variety Uma (MO-16). There were a total of 16 treatments replicated thrice. Almix (chlorimuron-ethyl (10%) + metsulfuron-methyl (10%), ethoxysulfuron, carfentrazone-ethyl, pyrazosulfuron-ethyl, pretilachlor, pendimethalin were tank-mixed with cyhalofop-butyl and were also applied as follow up sprays, two days after cyhalofop-butyl application. For better comparison, sole application of cyhalofop-butyl, as well as bispyribac sodium, were also included apart from hand weeded and unweeded controls.

Pre-emergence herbicides were sprayed at six days after sowing (DAS), and early post emergence herbicide at 10 DAS. All tank-mix herbicide applications were done at 18 DAS and follow up post emergence herbicide applications at 20 DAS (*i.e.*, two days after the application of cyhalofop-butyl). Hand weeding was carried out at 20 DAS and 40 DAS. Observations on phytotoxicity of herbicides both on rice and weeds, weed growth, crop yield and economics were recorded.

RESULTS

Broad leaf weeds and grasses were predominant and at 30 DAS they constituted 47 and 46% of the population respectively, whereas sedges constituted only 7%. *Echinochloa stagnina* was the dominant grass and *Monochoria vaginalis*, the dominant broad leaf weed in the field.

Among tank mix applications of herbicides, cyhalofop-butyl + pyrazosulfuron-ethyl recorded the least weed dry matter production while among various sequential application of herbicides, the lowest weed dry matter accumulation was noted in cyhalofop-butyl followed by (*fb*) Almix®.

Both tank-mix and sequential applications of carfentrazone-ethyl caused severe phytotoxicity in rice. Langaro *et al.* (2016) reported that the physiology of rice plants get altered by application of herbicides and the triggering responses to oxidative stress was more pronounced when carfentrazone-ethyl was used. However, the crop recovered by seven days after spraying and plant growth parameters were not affected with all the treatments

Table 1. Weed growth and crop yield as influenced by different herbicides and their combinations

Treatment	*Weed dry]weight at 60 DAS (kg/ha)	Weed Index (%)	Weed Control Efficiency at 60 DAS (%)	Grain yield (t/ha)	Straw yield (t/ha)	B:C ratio
Cyhalofop-butyl	19.94^{b} (398.74)	16.58^{bc}	60.59^{g}	3.76^{g}	4.15^{bc}	2.3
Cyhalofop-butyl + Almix®	16.16^{cd} (261.28)	14.87^{bcd}	73.86^{f}	3.83^{efg}	3.84^{ef}	2.2
Cyhalofop-butyl + ethoxysulfuron	13.99^{de} (197.33)	17.82^{b}	85.02^{de}	3.70^{g}	3.63^{f}	2.1
Cyhalofop-butyl + carfentrazone-ethyl	11.29^{ghi} (130.47)	12.80^{cd}	87.61^{cde}	3.93^{ef}	3.87^{cdef}	2.3
Cyhalofop-butyl + pyrazosulfuron-ethyl	9.74^{hi} (96.80)	3.99^{g}	90.58^{bc}	4.32^{b}	4.37^{ab}	2.5
Cyhalofop-butyl + pretilachlor	17.67^{c} (312.29)	16.35^{bc}	69.64^{f}	3.77^{fg}	3.85^{def}	2.1
Cyhalofop-butyl + pendimethalin	13.58^{ef} (185.11)	14.11^{bcd}	83.03^{e}	3.87^{efg}	3.86^{def}	2.2
Cyhalofop-butyl *fb* Almix®	11.00^{ghi} (121.40)	8.20^{ef}	92.44^{ab}	4.13^{cd}	4.10^{bcde}	2.3
Cyhalofop-buyl *fb* ethoxysulfuron	11.37^{gh} (130.00)	8.59^{ef}	87.04^{cde}	4.12^{cd}	4.10^{bcde}	2.3
Cyhalofop-butyl *fb* carfentrazone-ethyl	11.94^{efg} (144.87)	11.15^{de}	85.57^{de}	4.00^{de}	3.93^{cde}	2.2
Pyrazosulfuron-ethyl *fb* cyhalofop-butyl	10.90^{ghi} (118.87)	7.91^{ef}	88.14^{bcd}	4.15^{cd}	4.10^{bcde}	2.3
Pretilachlor *fb* cyhalofop-butyl	11.44^{fgh} (131.40)	8.87^{ef}	87.02^{cde}	4.10^{cd}	4.13^{bcd}	2.2
Pendimethalin *fb* cyhalofop-butyl	12.57^{efg} (161.73)	8.80^{ef}	84.04^{de}	4.11^{cd}	4.12^{bcde}	2.3
Bispyribac sodium	9.14^{i} (84.93)	6.06^{fg}	91.62^{abc}	4.23^{bc}	4.23^{b}	2.4
Hand weeding	6.23^{j} (40.00)	-	96.11^{a}	4.50^{a}	4.57^{a}	1.8
Unweeded control	31.75^{a} (1010.48)	45.23^{a}	-	2.47^{h}	2.65^{g}	1.6

*$\sqrt{x+0.5}$ transformed values, original values in parenthesis. In a column, means followed by common letters do not differ significantly at 5% level in DMRT.

registering comparable plant height at all stages. Highest grain yield was registered in hand weeded treatment. Application of cyhalofop-butyl + pyrazosulfuron-ethyl and bispyribac sodium were the next best treatments with respect to grain yield. The highest net returns (Rs. 78,239/ha) and B:C ratio of 2.5 were recorded in tank mix application of cyhalofop-butyl with pyrazosulfuron-ethyl.

CONCLUSION

It can be concluded from study that tank-mix application of cyhalofop-butyl with pyrazosulfuron-ethyl at 18 DAS can be recommended for effective control of mixed weed flora in wet seeded rice. It is not advisable to go for tank mixing of cyhalofop-butyl with Almix® as it will lead to complete loss of activity of cyhalofop-butyl. Tank mixing of pre-emergence herbicides with cyhalofop-butyl was found to be less effective than their sequential application

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Seed yield and quality of onion as influenced by integrated weed management

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Onion has a leading position in exported agricultural products. India though ranks first in area and second in production, the productivity is low (Thapa *et al* 2004). Weed infestation is the major limiting factor in the production of bolder seeds of onion (Chopra *et al* 2010). Seed onion crop is very sensitive to weed competition because of their slow growth, sparse canopy, wider spacing encourages luxuriant growth of weeds during crop growth. Onion seed crop being long duration crop (October to May), come across many flushes of weeds which cannot be controlled by herbicide alone, hence use of herbicides in sequence (pre- and post-emergence) and weeding as an integrated approach may provide economical acceptable weed control, hence the present study was undertaken to evaluate the effect of integrated weed monument on seed yield and quality of onion seed.

METHODOLOGY

The field experiment was conducted at Indian Agricultural Research Institute, Regional Station Karnal during *Rabi* 2015-16 on sandy loam soils having available N (205 kg/ha), P (20.5 kg/ha) ,K (310 kg/ha) with pH 7.7. The experiment was laid out in randomized block design with four replications. Pendimethalin (1.5 lit/ha), alachlor (1.5 lit/ha) and oxyflourofen (100, 150 and 200 g/ha) were applied one day after planting (DAP), quizalofop-ethyl (25 g/ha) 25 DAP and one hand weeding (HW) as per treatment was applied 35 DAP respectively. Spray volume of 600 lit/ha with knapsack sprayer was used for all the herbicides. Weed density and weed dry weight were recorded from quadrat of 1x1 m^2 from each plot. Germination of resultant seed under different treatments was carried out in paper towels, seedling length and seedling dry weight were recorded as per ISTA (1993).

RESULTS

The weed flora of onion field comprised of *Coronopus didymus* (27.2%), *Medicago denticulata* (44.6%), *Anagalis arvensis* (9.2%), *Phalaris minor* (7.2%) and other weeds (11.2%) which included *Lathyrus aphaca*, *Melilotus indica*, *Poa annua* and *Euphorbia helliscopia*. Maximum reduction in weed density and weed dry weight (87.1 and 91.1 % respectively) was recorded with oxyfluorfen 150g/ha *fb* HW at 35 DAP compared to weed check. Pendimethalin, alachlor and oxyflourfen *fb* quizalofop recorded significantly higher weed density and dry weight compared to oxyfluorfen 150g/ha and pendimethalin 1.5 lit/ha *fb* HW which may be due to the fact that quizalofop was ineffective towards the broadleaf weeds which were the dominating weeds in the experimental plots. Pendimethalin 1.5 lit/ha, Oxyfluorfen 150 g/ha and weed free treatments registered significantly higher number of umbel / plant compared to weedy check. Oxyfluorfen 150g/ha recorded significantly higher seed yield than weed check, alachlor, pendimethalin and oxyfluorfen *fb* quizalofop. There was reduction of 41.6, 22.8, 24.4 and 20.2% in weed check, alachlor pendimethalin and oxyflorofen *fb* quizalofop respectively compared to oxyfluorfen 150g/ha *fb* HW at 35 DAP. Weed stress to mother plants significantly affected the seed quality parameters. Seed germination remained unaffected due to different weed control treatments however, seedling length and seedling vigour index were significantly higher in weed free, oxyfluorfen 150g/ha and pendimethalin *fb* HW owing to higher 1000 seed weight in these treatments than weed check. Shaikh *et al.* 2002 also reported higher seedling vigour index in onion due to higher 1000 seed weight. Seed yield was negatively correlated to weed density and weed dry weight (r = -0.97and -0.94) and negative correlation was due to depletion of various inputs by weeds reducing their availability to onion crop. Reduction in seed yield could be predicted up to 1.439 and 1.239 kg/ha with increase in weed density and weed dry weight by one number and one g/m^2.

Table 1. Effect of Integrated weed management on weed parameters, seed yield and quality in onion

Treatment	Weed density (m^2)	Weed dry weight (g/m^2)	Umbels /plant	1000 seed weight (g)	Seed yield kg/ha	Germination (%)	Seedling length (cm)	Seedling vigour index*
Pendimethalin 1.5 lit/ha + HW	5.9 (36)	4.6 (22)	10.3	3.99	641	77.6	14.0	1090
Alachlor 1.5 lit/ha + HW	7.8 (61)	5.8 (33)	8.8	3.90	555	76.0	14.1	1074
Oxyflourofen 100g/ha + HW	6.7 (45)	5.4 (29)	9.5	3.79	580	77.6	12.9	1003
Oxyflourofen 150g/ha + HW	4.9 (25)	4.3 (18)	10.5	4.01	684	77.0	14.4	1109
Oxyflourofen 200g/ha	6.9 (48)	5.9 (34)	7.7	3.76	582	75.6	13.8	1049
Pendimethalin1.5 lit/ha fb quizalofop 25g/ha	8.8 (79)	7.3 (54)	7.2	3.79	528	78.3	13.1	1027
Alachlor 1.5 lit/ha fb quizalofop25g/ha	9.5 (89)	8.0 (64)	6.4	3.82	517	74.6	12.6	943
Oxyflourofen150g/ha +Quizalofop 25g/ha	9.1 (82)	7.5 (59)	7.1	3.77	546	77.6	13.4	1036
Weed free	1.0 (0.0)	1.0 (0.0)	11.0	4.11	648	79.3	14.5	1150
Weed check	13.5 (195)	14 (207)	5.6	3.64	399	76.3	11.9	908
LSD (P=0.05)	1.3	1.99	3.48	0.3	133	NS	1.18	128.5

*Seedling vigour index: seedling length x germination %

CONCLUSION

Higher seed yield and quality of onion can be realized by controlling the weeds with oxyfluorfen 150 g/ha and pendimethalin 1.5 lit/ha *fb* one HW 35 DAP.

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Increasing availability of weed free seeds through seed village programme

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An adequate plant population of crop in the field is the primary requisite for better, efficient and higher production of the crop. This is depend upon the weed free seed which is the basic and most effective input but there is big gap between demand & supply of quality seeds as in India most of the peasants use their own saved seeds (Almekinders *et al.* 1994) which are full of weeds, so farmer cannot deny the entry and establishment of new weeds in an area not infected with it yet. Weed free seed production and weed management ensure higher seed yield and quality and are complimentary to each other. The success of former is largely dependent on the success of the later. Availability of weed free seeds of improved varieties along with weed management techniques, if made available to farmers, agricultural productivity can be enhanced by 15-20%. By keeping this in mind, ICAR-IARI, RS Karnal started Seed Village Programme in 2009 continued till date with the objective to increase the availability and horizontal spread of quality seeds of improved varieties with the participation of resource poor farmers by capacity building through Seed Village Programme.

METHODOLOGY

Under this programme, quality seeds of latest varieties of wheat and rice were distributed on 50% subsidy. The identified farmers were given trainings on importance of quality seed, selection of land (Free from volunteer/weed plants), isolation distance, seed treatment, agronomic management, identification of objectionable weeds, knowledge of critical period of crop-weed competition, integrated weed management methods and spray volumes / application technique. The Important protocols of seed production based on Indian Minimum Seed Production Standards, 1988 for seed and weeds were followed to produce true to type seeds. Weed free seed production technology was demonstrated to the farmers at ICAR-IARI, RS, Karnal. Group meeting with farmers were also organized in the adopted villages to provide the opportunities for other farmers to witness the benefits of weed management technologies.

RESULTS

Under Seed Village Programme, 1388 farmers /women farmers from 63 villages have taken 86 training in rice and wheat on different aspects of quality seed production

Impact of improved varieties

Study revealed that there was substantial increase in weed free seed production of the latest varieties adopted by farmers in all the three crops (Table 1).

Impact of capacity building

- Farmers were made to understand concept of "Weed Free Seed production", "Objectionable weeds in seed crops" and critical distinction between "grain" and "seed".
- Importance of selection of land to be used for seed production, i.e. free from weeds and volunteer plants to avoid physical admixture.
- Knowledge of rice nursery on old gunny bags results weed free nursery, faster growth, and impediment to germination of volunteer plants to maintain highest level of genetic purity.
- Green manuring with *dhaincha* after harvest of wheat reduce helped in reduced weed emergence particularly *Echinochloa spp*. due to allelopathy effect besides increasing soil fertility.
- Weed management with optimum dose and proper application methods following herbicide rotation resulted in maximum weed control.
- Herbicide rotation increased the weed control efficiency and reduced the problem of herbicides resistance. The best example may be stale seed bed by applying glyphosate before sowing, Pendimethalin as pre emergence (immediately after sowing) and Penoxaden/ Clodinafop as post emergence in different years to avoid herbicide resistance.
- Storage of weed free seed prevent the seed infestation with fungi/moulds because if seeds are stored with weed seeds difference in moisture content results in attack of fungi etc. reducing the viability of seeds.
- Knowledge of proper sprayer and nozzle helped the potential effect/use of applied herbicide.

Table 1. Weed free Sseed production of wheat and rice by farmers under Seed village programme

Year	Crop	Total No. of Farmers	No. of villages	Seed supplied (q)	No. of trainings	Area (ha)	Seed produced (q)
2009 *Kharif*	Rice*	32	1	0.8	6	6.4	272
2009-10 *Rabi*	Wheat**	224	6	22.4	13	44.8	2240
2010 *Kharif*	Rice	76	4	1.9	7	15.2	578
2010-11 *Rabi*	Wheat	76	5	15.2	6	15.2	760
2011 *Kharif*	Rice	80	3	2.0	5	16	720
2011-12 *Rabi*	Wheat	80	3	16.0	4	16	960
2012 *Kharif*	Rice	80	3	2.0	5	16	752
2012-13 *Rabi*	Wheat	80	2	16.0	4	16	880
2013 *Kharif*	Rice	80	2	2.0	4	16.0	696
2013-14*Rabi*	Wheat	116	6	27.2	7	27.2	1442
2014 *Kharif*	Rice	96	6	4.8	6	38.4	2112
2014-15 *Rabi*	Wheat	96	6	38.4	7	38.4	1882
2015 *Kharif*	Rice	96	6	4.8	6	38.4	1632
2015-16 *Rabi*	Wheat	75	4	30	6	30	1650
2016 *Kharif*	Rice	101	6	5.05	3	40.4	1717
Total		1388	63	185.55	89	374.4	18292

Rice*-PB1121/PB1509;Wheat**HD2967/HD3086

CONCLUSION

Availability of quality seeds of high yielding varieties for seed production will replace existing local varieties. Seed production technology package will be available to farmers, as a result, agricultural productivity will be enhanced by 15-20% to ensure food security. Seed revolution will play major role in ushering 2nd Green revolution.

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Bioefficacy of herbicide mixtures for weed management in *Kharif* groundnut

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Groundnut is highly susceptible to weed infestation because of its slow growth in the initial stages up to 40 days after sowing (DAS), short plant height and underground pod bearing habit. Unlike other crops, weeds interfere with pegging, pod development and harvesting of groundnut during different stages of crop growth besides competing for essential resources and thus cause substantial yield losses. Continuous use of a single herbicide may lead to build up of herbicide resistance in weeds and residue problem. Hence, there is need to focus our attention on herbicide mixtures to enhance the weed control efficiency, broadening the spectrum of weed control and saving the herbicide and labour requirement.

METHODOLOGY

A field experiment was conducted at Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during *Kharif* season of 2014 to 2015. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 7.8 and EC 0.36 dS/m) as well as low in available nitrogen (223-236 kg/ha), available phosphorus (19-23 kg/ha) and medium in available potash (272-366 kg/ha). The experiment comprising of 12 treatments *viz*. pendimethalin 900 g/ha as pre-emergence *fb* HW and IC at 40 DAS, oxyfluorfen 240 g/ha *fb* HW and IC at 40 DAS, quizalofop 40 g/ha at 20 DAS *fb* HW and IC at 40 DAS, imazethapyr 75 g/ha at 20 DAS *fb* HW and IC at 40 DAS, tank mix pendimethalin 450 g/ha + oxyfluorfen 120 g/ha as pre-emergence *fb* HW and IC at 40 DAS, pre-mix imazethapyr + pendimethalin 800 g/ha as pre-emergence *fb* HW and IC at 40 DAS, tank mix quizalofop 20 g/ha + imazethapyr 37.5 g/ha at 20 DAS *fb* HW and IC at 40 DAS, pre-mix imazamox + imazethapyr 70 g/ha at 20 DAS *fb* HW and IC at 40 DAS, pendimethalin 900 g/ha as pre-emergence *fb* pre-mix imazamox + imazethapyr 70 g/ha at 20 DAS, HW and IC at 20 and 40 DAS, weed-free check, and weedy check was laid out in randomized block design with three replications. The crop was raised as per the recommended package of practices.

RESULTS

The major weed flora noticed were *Echinochloa colona, Eluropus villosusi, Indigofera glandulosa* and *Brachiaria ramosa* among the monocots; *Ammannia baccifera, Leucas aspera, Digera arvensis, Commelina benghalensis, Eclipta alba, Portulaca oleracea, Commelina nudiflora* and *Phyllanthus niruri* among the dicot weeds and *Cyperus rotundus* as sedge.

Table 1. Effect of weed management on weed, yield attributes and yield of groundnut (pooled over two years)

Treatment	Weed dry weight (t/ha)	Weed index (%)	Weed control efficiency (%)	Plant height (cm)	Branches / plant	Mature pods/ plant	100-kernel weight (g)	Shelling (%)	Pod yield (t/ha)	Haulm yield (t/ha)
Pendimethalin	0.23	13.05	87.23	35.28	6.94	11.35	47.00	62.41	1.36	2.63
Oxyfluorfen	1.08	52.78	39.48	23.08	4.34	9.00	37.04	47.07	0.74	1.67
Quizalofop	0.95	47.79	46.57	23.43	4.53	9.09	37.87	47.30	0.82	1.93
Imazethapyr	0.85	35.06	52.14	27.91	5.13	9.21	38.49	51.17	1.01	2.03
Pendimethalin + oxyfluorfen	0.17	7.93	90.55	41.24	8.15	11.41	47.48	64.12	1.44	2.76
Pendimethalin + imazethapyr	0.13	5.69	92.58	43.95	8.72	12.19	49.44	65.93	1.47	2.85
Quizalofop + imazethapyr	0.62	25.53	65.07	32.05	6.17	10.16	40.45	54.84	1.16	2.30
Imazamox + imazethapyr	0.37	15.55	79.19	34.30	6.55	10.75	46.60	57.45	1.32	2.58
Pendimethalin *fb* Imazamox + imazethapyr	0.75	27.32	58.04	30.74	5.96	10.06	40.34	53.38	1.14	2.15
IC and HW twice	0.47	20.60	73.45	32.37	6.25	10.70	43.82	55.29	1.24	2.38
Weed-free check	0.03	0.00	98.14	45.63	8.79	12.28	50.06	68.07	1.56	2.91
Weedy check	1.78	59.76	0.00	16.07	3.33	8.06	33.63	46.13	0.63	1.28
LSD (P=0.05)	0.09			6.08	1.17	2.21	7.76	10.03	0.15	0.24

Data indicated that the weed-free recorded significantly the lowest dry weight of weeds, followed by tank-mix pendimethalin 450 g/ha + oxyfluorfen 120 g/ha as pre-emergence *fb* HW and IC at 40 DAS, and pre-mix imazethapyr + pendimethalin 800 g/ha as pre-emergence *fb* HW and IC at 40 DAS having WI of 0.00, 5.69 and 7.93% and WCE of 98.14, 92.58 and 90.55%, respectively. Significantly highest plant height, branches/plant, pods/plants, 100-kernel weight and shelling percentage were recorded under the weed-free check, however it remained mostly at par with tank-mix pendimethalin 450 g/ha + oxyfluorfen 120 g/ha as pre-emergence *fb* HW and IC at 40 DAS, and pre-mix imazethapyr + pendimethalin 800 g/ha as pre-emergence *fb* HW & IC at 40 DAS. Data showed that the weed-free check produced significantly the highest mean pod yield of 1563 kg/ha and haulm yield of 2910 kg/ha. The next best treatments in this regard were tank-mix pendimethalin 450 g/ha + oxyfluorfen 120 g/ha as pre-emergence *fb* HW and IC at 40 DAS, and pre-mix imazethapyr + pendimethalin 800 g/ha as pre-emergence *fb* HW and IC at 40 DAS. These treatments increased pod yield by 148, 134 and 129% over the unweeded control.

CONCLUSION

Effective control of weeds in *Kharif* groundnut along with higher yield could be achieved by tank-mix pendimethalin 450 g/ha + oxyfluorfen 120 g/ha as pre-emergence *fb* HW and IC at 40 DAS, or pre-mix imazethapyr + pendimethalin 800 g/ha as pre-emergence *fb* HW & IC at 40 DAS.

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Sown proportions and weed management in runner bean + maize intercropping

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Runner bean (*Phaseolus coccineus)* has a trailing habit; hence it needs support for its growth. The farmer's practice is to grow a sole crop of runner bean and provide staking by installing twigs adjacent to the plants in the field. This practice is time consuming, labour intensive and is expensive. It is also economical to grow runner bean as a sole crop without support on a large scale (Juan Tay, 2007). But, this makes the subsequent intercultural operations like hoeing, weeding, topdressing, etc. very difficult because of netting of the tendrils. Therefore, the intercropping of runner bean with maize, besides acting as biological staking, also serves as a source of additional income and also as source of fodder from the maize stalks. Adequate plant population of component crops with suitable proportions and proper planting geometry is required for maximizing productivity and profitability from the system. Early and effective weed management prior to netting of tendrils boosts crop growth and gives higher yield.

MATERIALS

A field experiment was conducted during *rabi* season of 2016-17 at Agronomy Main Research Farm, Orissa University of Agriculture and Technology, Bhubaneswar- 751 003, Odisha, India. Six different plant population proportions in main plot and five different types of weed management practices in sub plot (Table 1) were allocated in split plot design with two replications. 'Shriram 9220' maize hybrid and 'Raikia local' runner bean were taken as test crops in the experiment. Weed count and dry weight values were recorded at 45 days after sowing. The data was subjected to $\sqrt{(x+1)}$ transformation before analysis.

RESULTS

The pre-dominant grassy weeds were *Eleusine indica* L. and *Echinocloa crus-galli* L., *Cyperus rotundus* L. among sedges and *Melochia corchorifolia* L., *Cleome rutidosperma* DC., *Cleome monophylla* L., *Trianthema portulacastrum* L., *Ipomoea pes-tigridis* L. among broad leaved weeds. Among sown proportions, maize+ runnerbean (100% + 50%) recorded the maximum number of grassy weeds closely followed by maize + runner bean (100% + 100%) when sown in separate rows in both cases. The two same sown proportions recorded significantly less grassy weeds when the component crops were sown in the same row. This finding is in contrast to the findings by Chipomho *et al.* (2015). Similar trend was noted in case of total weed population at 15 days after sowing. Maize + runnerbean (100% + 50%) when sown in the same row recorded the lowest weed dry weight at 15 days after sowing. At 45 days after sowing, among four intercropping combinations, maize + runnerbean (100% + 50%) and maize + runnerbean (100% + 100%) in the same row recorded lesser grassy weed population than when sown in separate rows. All weed management practices recorded significantly less grassy and total weed population. Similar trend was noted in case of dry weight of weed at 15 DAS. At 45 DAS, weedy check plot recorded the maximum value of population of grass, sedge and total weeds and dry weight of total weeds. All other treatments proved significantly superior and recorded significantly lower values of these parameters.

Table 1. Weed population and dry weight of weeds under various sown proportions and weed management

Treatment	Weed population (No./0.25m^2) at 15 DAS	Dry weight of weeds (g/0.25m^2) at 15 DAS	Weed population (No./0.25m^2) at 45 DAS	Dry weight of weeds (g/0.25m^2) at 45 DAS
Sown proportions				
P1- Sole maize (100% Mz + 0 % Rb)	5.5 (30.2)	2.9 (7.5)	3.8 (13.4)	3.9 (4.2)
P2: Sole Rb (0 % Mz + 100% Rb)	5.5 (29.3)	2.2 (4.2)	3.4 (10.5)	3.3 (9.8)
P3-100% Mz + 100% Rb (Mz and Rb in separate rows as a 2:2 combination)	6.3 (38.9)	2.6 (5.8)	5.1 (25.0)	6.2 (37.4)
P4- 100% Mz + 100% Rb (Mz and Rb in the same row)	3.9 (14.6)	2.1 (3.5)	3.5 (11.2)	4.0 (15.0)
P5- 100 % Mz + 50% Rb (Mz maize and Rb in separate rows as a 1:1 combination)	6.3 (39.4)	3.1 (8.3)	5.2 (26.0)	4.6 (20.1)
P6-- 100 % Mz + 50% Rb (Mz and Rb in the same row)	5.1 (25.3)	1.6 (1.7)	3.6 (11.9)	3.2 (9.2)
LSD (P=0.05)	1.1	0.2	1.0	1.2
Weed management				
W1 –Pendimethalin @1.0 kg /ha PE	3.1 (9.0)	1.3 (0.9)	3.3 (9.8)	2.6 (5.7)
W2 –Metribuzine @ 0.03 kg /ha PE	3.7 (12.6)	1.6 (1.6)	4.0 (15.0)	3.4(10.5)
W3 - Pendimethalin 1.0 kg/ha + 1 hoeing and hand weeding at 25 DAS	2.6 (6.2)	1.4 (1.2)	3.0 (8.0)	2.3 (4.2)
W4- Two hand weeding at 25 and 40 DAS	8.8 (76.9)	3.7 (12.9)	2.4 (4.7)	2.2 (3.8)
W5- Weedy check	9.0 (80)	3.8 (13.9)	7.8 (58.2)	10.6 (111.3)
LSD (P=0.05)	0.6	0.4	0.9	0.6

*Original values within parentheses and $\sqrt{(x+1)}$ transformed values outside parentheses; Mz – Maize, Rb – Runner bean, PE – Pre emergence, DAS- Days after sowing

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Evaluation of herbicides and their mixtures for weed management in *Kharif* okra

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Okra [*Abelmoschus esculentus* (L.) Moench] is one of the most popular vegetables in tropical and sub-tropical region. Okra suffers heavy yield losses in rainy season (*kharif*) due to weed infestation owing to congenial environmental conditions for luxurious weed growth coupled with wider row spacing and slow growth at early stages. Yield losses due to weeds varied from 40 to 80%, depending on the type of weed flora, their intensity and stage. Unavailability of labour at the peak time and sometimes unfavourable field conditions do not permit manual weedings. Hence, there is need to evolve weed management strategy by integrating herbicides or their mixtures with manual weeding.

METHODOLOGY

A field experiment was conducted at Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during *kharif* season of 2014 to 2015. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction as well as low in available nitrogen, available phosphorus and medium in available potash. The experiment comprising of 10 treatments, *viz*. pendimethalin 900 g/ha as pre-emergence (PE) *fb* hand weeding (HW) at 40 DAS, oxyfluorfen 240 g/ha as PE *fb* HW at 40 DAS, pre-mix pendimethalin 30.24% + imazethapyr 2.24% 900 g/ha as PE *fb* HW at 40 DAS , tank-mix pendimethalin 450 g/ha + oxyfluorfen 120 g/ha as PE *fb* HW at 40 DAS, quizalofop 40 g/ha as post-emergence (POE) at 20 DAS *fb* HW at 40 DAS, imazethapyr 75 g/ha as POE at 20 DAS *fb* HW at 40 DAS, tank-mix imazethapyr 37.5 g/ha + quizalofop 20 g/ha as POE at 20 DAS *fb* HW at 40 DAS, HW at 15, 30 and 45 DAS, weed-free and weedy check was laid out in randomized block design with three replications. The pre-emergence herbicides were applied to soil on next day of sowing, while post-emergence spray was done at 20 DAS. The spray volume of herbicide application was 500 l/ha. The crop was raised as per the recommended package of practices.

RESULTS

The major weed flora noticed were *Echinochloa colona, Cynodon dactylon, Indigofera glandulosa, Dactyloctenium aegyptium* and *Brachiaria ramosa* among the monocots; *Digera arvensis, Commelina benghalensis, Leucas aspera, Eclipta alba, Portulaca oleracea, Commelina nudiflora* and *Phyllanthus niruri* among the dicot weeds and *Cyperus rotundus* as sedge weed. The data indicated that the weed-free recorded significantly the lowest dry weight of weeds, followed by HW thrice, pendimethalin 900 g/ha as PE *fb* HW at 40 DAS, tank-mix pendimethalin 450 g/ha + oxyfluorfen 120 g/ha as PE *fb* HW at 40 DAS and quizalofop 40 g/ha as POE at 20 DAS *fb* HW at 40 DAS having Weed Index of 0.00, 4.68, 7.87, 12.02 and 17.74%, and WCE of 97.98, 94.86, 93.42, 84.22 and 79.21%, respectively. The results corroborate the findings of Sharma and Patel (2011). Data showed that significantly the highest plant height, fruits/plants, fruit length and fruit weight/plant were recorded under the weed-free check, however it remained mostly at par with HW thrice and pendimethalin 900 g/ha as PE *fb* HW at 40 DAS. Among post-emergence treatments, quizalofop 40 g/ha as PoE at 20 DAS *fb* HW at 40 DAS was found superior. Whereas, significantly the lowest values of these growth and yield attributes were registered under the weedy check. Results showed that weed-free check produced significantly the highest fruit yield of 8504 kg/ha. The next best treatments in this regard were HW thrice and pendimethalin 900 g/ha as PE *fb* HW at 40 DAS. Among post-emergence treatments, quizalofop 40 g/ha as PoE at 20 DAS *fb* HW at 40 DAS was found superior. These results are in conformity with findings of Patel *et al.* (2004).

Table 1. Effect of weed management on growth, yield attributes, fruit yield and weed parameters of okra (pooled over two years)

Treatment	Weed dry weight (kg/ha)	Weed index (%)	Weed control efficiency (%)	Plant height (cm)	Fruits/ plant	Fruit length (cm)	Fruit weight/ plant (g)	Fruit yield (kg/ha)
Pendimethalin	143	7.87	93.42	76.56	15.82	16.63	169.19	7835
Oxyfluorfen	546	24.72	74.89	66.67	13.77	14.05	135.59	6402
Pendimethalin + imazethapyr	882	46.79	59.43	61.87	12.80	13.22	105.69	4525
Pendimethalin + oxyfluorfen	343	12.02	84.22	70.08	14.68	14.29	163.38	7482
Quizalofop	452	17.74	79.21	67.26	14.67	14.21	145.23	6995
Imazethapyr	1067	51.35	50.92	56.81	11.85	12.72	102.14	4137
Imazethapyr + quizalofop	694	33.13	68.08	64.76	13.67	13.39	116.20	5687
HW thrice	116	4.68	94.66	78.80	16.47	17.27	191.83	8106
Weed-free check	44	0.00	97.98	81.17	17.30	17.62	202.43	8504
Weedy check	2174	70.81	0.00	56.52	8.48	9.91	54.68	2482
LSD (P=0.05)	118			13.96	2.18	2.11	23.73	836

CONCLUSION

Effective control of weeds in *kharif* okra along with higher yield could be achieved by HW at 15, 30 & 45 DAS or pendimethalin 900 g/ha as PE *fb* HW at 40 DAS or tank-mix pendimethalin 450 g/ha + oxyfluorfen 120 g/ha as PE *fb* HW at 40 DAS or quizalofop 40 g/ha as POE at 20 DAS *fb* HW at 40 DAS.

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Assessing bioefficacy of herbicides for weed control in Indian bean

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Indian bean [*Dolichos lablab* (Roxb) L.] is one of the most remunerative legume crops grown in late *kharif* or *rabi* season. It is a good cover crop, however wider spacing and frequent irrigation provide congenial condition for weed growth in initial stage, which causes greater yield loss. The conventional method of weed control by manual weeding, though efficient, is expensive and laborious. The herbicides are effective and economical to control weeds. However, herbicides and conventional methods alone are not adequate for effective weed control. Hence, integrated weed management combining both chemical and mechanical methods is ideal.

METHODOLOGY

A field experiment was conducted at Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during late *kharif* season of 2015. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction as well as low in available nitrogen, available phosphorus and medium in available potash. The experiment comprising of 10 treatments *viz*., pendimethalin 30% EC 900 g/ha as PE + HW at 45 DAS, pendimethalin 37.8% CS 900 g/ha as PPI + HW at 45 DAS, oxyfluorfen 240 g/ha as PE + HW at 45 DAS, pre-mix pendimethalin 30.24% + imazethapyr 2.24% 900 g/ha as PE + HW at 45 DAS, quizalofop 40 g/ha as PoE at 15 DAS + HW at 45 DAS, imazethapyr 75 g/ha as PoE at 15 DAS + HW at 45 DAS, pre-mix imazethapyr 35% + imazamox 35% 75 g/ha as PoE at 15 DAS + HW at 45 DAS, HW at 15, 30 and 45 DAS, weed free and unweeded check was laid out in randomized block design with three replications. The pre-emergence herbicides were applied to soil on next day of sowing, while post-emergence spray was done at 15 DAS. The spray volume herbicide application was 500 l/ha. The crop was raised as per the recommended package of practices.

RESULTS

The major weed flora observed were *Echinochloa colona, Eluropus villosus, Indigofera glandulosa* and *Dactyloctenium aegyptium* among the monocots; *Amaranthus viridis, Chenopodium album, Digera arvensis, Portulaca oleracea, Commelina nudiflora* and *Phyllanthus niruri* among the dicot weeds and *Cyperus rotundus* as sedge weed.

The data indicated that the weed-free recorded significantly the lowest dry weight of weeds, followed by HW thrice, pendimethalin 30% EC 900 g/ha as PE *fb* HW at 45 DAS and pendimethalin 38.7% CS 900 g/ha as PPI *fb* HW at 45 DAS having WI of 0.00, 5.24, 16.45 and 19.30%, and WCE of 98.22, 90.31, 83.69 and 76.35%, respectively. The results corroborate the findings of Reddy *et al.* (2002).

Results showed that significantly highest plant height, pods/plant, pod length, seeds/pod and 100-seed weight were recorded under the weed-free check, however, it remained mostly at par with HW thrice, pendimethalin 30% EC 900 g/ha as PE *fb* HW at 45 DAS and pendimethalin 38.7% CS 900 g/ha as PPI *fb* HW at 45 DAS. Whereas, significantly the lowest values of these growth and yield attributes were registered under the weedy check.

Table 1. Effect of weed management on weed parameters, growth, yield attributes and crop yield of Indian bean

Treatment	Weed dry weight (kg/ha)	Weed index (%)	Weed control efficiency (%)	Plant height (cm)	Pods/ plant	Pod length (cm)	Seeds/ pod	100-kernel weight (g)	Pod yield (kg/ha)	Stover yield (kg/ha)
Pendimethalin 30% EC	229	16.45	83.69	46.97	16.05	7.56	3.87	32.63	1117	2293
Pendimethalin 38.7% CS	332	19.30	76.35	46.56	15.48	7.36	3.77	30.58	1079	2223
Oxyfluorfen	1123	49.51	20.01	33.87	13.72	5.55	3.06	25.58	675	1381
Pendimethalin + imazethapyr	516	28.27	63.25	41.36	14.72	6.77	3.75	28.10	959	2147
Quizalofop	983	42.63	29.99	36.14	14.51	6.03	3.19	26.65	767	1657
Imazethapyr	1083	47.79	22.86	36.04	13.78	5.57	3.16	26.20	698	1561
Imazamox + imazethapyr	692	33.06	50.71	41.27	14.62	6.29	3.72	28.01	895	1690
HW twice	136	5.24	90.31	48.48	16.36	7.77	3.91	32.91	1267	2411
Weed-free check	25	0.00	98.22	48.57	16.62	8.02	4.03	34.71	1337	2812
Weedy check	1404	73.00	0.00	29.22	11.96	5.44	2.86	23.07	361	1109
LSD (P=0.05)				9.39	1.48	1.18	0.75	4.21		

The data also showed that weed-free check produced significantly the highest pod yield of 1337 kg/ha and stover yield of 2812 kg/ha. The next superior treatments in this regard were HW thrice, pendimethalin 30% EC 900 g/ha as PE *fb* HW at 45 DAS and pendimethalin 38.7% CS 900 g/ha as PPI *fb* HW at 45 DAS. These treatments increased pod yield by 270, 251, 209 and 199% over the unweeded control. These results are in conformity with findings of Veeranna *et al.* (1997).

CONCLUSION

Effective control of weeds in Indian bean along with higher yield could be achieved by HW at 15, 30 & 45 DAS or pendimethalin (30% EC as PE or 38.7% CS as PPI) 900 g/ha *fb* HW at 45 DAS.

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Management of complex weed flora in sesame with sequential application of herbicides

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Sesame (*Sesamum indicum* L.) is the oldest oilseed crop grown in all the seasons in south and central India. Though, the country ranks first in area and production of sesame in the world, the productivity of sesame is one of the lowest in the world due to its cultivation in marginal and sub marginal soils under rainfed situation with poor agronomic management practices (Bhaduria *et al.* 2012). Sesame crop is associated with heavy weed infestation due to its slow initial growth and less cmpetitive ability compared to other oilseed crops. The loss in seed yield of sesame due to weed competition during the crop growth period was estimated to 65 percent in clay loam soils (Vafaei *et al.* 2013). The selectivity mechanism of pre-emergence herbicides are quite different as the seeds are placed at shallow depth. Keeping this in view, the present experiment was conducted to assess the performance of pre- and post-emergence herbicides on growth and yield of broadcasted sesame and its associated weeds.

METHODOLOGY

A field experiment was conducted at S.V. Agricultural College farm, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India during summer, 2015 on sandy loam soils to evaluate the performance of pre-and post-emergence herbicides in sesame and its associated weeds. The treatmental details are mentioned in Table 1. The sesame cultivar '*YLM-66'* was broadcasted 7 kg/ha in the experimental field with recommended package of practices. The pre-and post-emergence herbicides were applied at 1 and 20 DAS, respectively. The data on weed growth, yield components, yield and economics were recorded.

RESULTS

The pre-dominant weed flora associated with broadcasted sesame consist of *Cyperus rotundus*, *Commelina benghalensis*, *Cleome viscosa*, *Boerhavia diffusa*, *Phyllanthus niruri*, *Dactylocteneium aegyptium* and *Digitaria sanguinalis*. All the pre- and post-emergence herbicides have shown significant influence on the weed growth and yield of sesame (Table 1). Among the herbicidal treatments, the lowest density and dry weight of weeds were recorded with sequential application of oxyfluorfen 75 g/ha as pre-emergence *fb* quizalofop 50 g/ha or propaquizafop 60 g/ha applied at 20 DAS. The same weed management practices were produced significantly higher number of capsules/plant and number of seeds/capsule, which inturn increased the seed and oil yield of sesame. These findings are in agreement with the earlier results of Vafaei *et al.* (2013).

Table 1. Effect of pre-and post-emergence herbicides on weed growth and yield of broadcast sesame

Treatment	Dose (g ha)	Time of application (DAS)	Weed density (no/m^2)	Weed dry weight (g/m^2)	No of capsules/ plant	No. of seeds/ capsule	Seed yield (kg/ha)	Oil yield (kg/ha)	Benefit-cost ratio
Pendimethalin	750	1	14.54 (209.61)	9.77 (94.54)	30.6	43.2	554	268.1	1.67
Oxyfluorfen	75	1	14.18 (199.23)	9.76 (94.38)	31.9	45.4	582	284.6	1.88
Oxadiargyl	75	1	15.20 (229.10)	9.98 (98.74)	28.9	41.0	527	254.5	1.70
Pendimethalin *fb* quizalofop	750 +50	1 + 20	11.44 (129.61)	8.54 (72.15)	35.2	52.5	752	379.0	2.04
Oxyfluorfen *fb* quizalofop	75 + 50	1 + 20	10.34 (105.86)	7.92 (62.00)	37.2	59.0	784	403.8	2.25
Oxadiargyl *fb* quizalofop	75 + 50	1 + 20	12.16 (146.51)	9.00 (80.16)	33.6	48.4	677	334.4	1.95
Pendimethalin *fb* propaquizafop	750 +60	1 + 20	11.48 (130.39)	8.71 (74.93)	34.8	51.2	751	375.5	2.06
Oxyfluorfen *fb* propaquizafop	75 + 60	1 + 20	10.11 (101.01)	8.05 (64.00)	36.8	57.4	779	395.7	2.27
Oxadiargyl *fb* propaquizafop	75 + 60	1 + 20	12.31 (150.12)	9.16 (83.02)	33.1	47.2	666	327.0	1.94
Two hand weedings	-	20 + 40	8.79 (76.31)	4.14 (16.59)	40.1	61.4	833	432.3	1.97
Unweeded check	-	-	17.31 (297.44)	11.93 (141.12)	25.4	38.9	486	233.8	1.65
LSD (P=0.05)			0.91	0.57	0.53	1.65	25.0	4.66	0.03

Data was subjected to ($\sqrt{X+0.5}$) transformation and figures in parentheses are original values; *fb:* followed by

Sequential application of oxyfluorfen 75 g/ha as pre-emergence *fb* quizalofop 50 g/ha at 20 DAS increased the seed and oil yield of sesame by 61.3 and 73.4 %, respectively compared to unweeded check. Pre-emergence application of oxyfluorfen 75 g/ha *fb* propaquizafop 60 g/ha or quizalofop 50 g/ ha applied at 20 DAS were recorded significantly higher benefit-cost ratio compared to rest of the weed management practices due to reduced cost of weeding. Oxadiargyl 75 g/ha as pre-emergence alone or sequential application with quizalofop 50 g/ha or propaquizafop 60 g/ha applied at 20 DAS were failed to supress the weed growth.

CONCLUSION

It was concluded that sequential application of oxyfluorfen 75 g/ha as pre-emergence *fb* post-emergence application of quizalofop 50 g/ha or propaquizafop 60 g/ha applied at 20 DAS proved to be the best weed management practices for broadspectrum weed control, enhanced productivity and profitability of broadcast sesame.

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Evaluation of post emergence herbicides in kabuli chickpea

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Chickpea (*Cicer arietinum* L.) is the principal pulse crop of India grown in an area of 9.93 mha (PC report AICRP on Chickpea 2013-14). Weed management in chickpea is one of the major limiting factor in realizing the potential yield. Selective post emergence herbicides are available for controlling only grassy weeds in chickpea. However, there is no selective post emergence herbicide available for controlling broad leaved weeds in chickpea. Metribuzin 410 g/ha caused injury to chickpea at 7 DAT, though by 28 DAT the crop had out grown most of the injury. Injured plants were stunted and exhibited interveinal chlorosis of the oldest leaf tissue (Dave and Robinson, 2002). Si et. al. (2012) carried out field trials and confirmed that the kabuli chickpea lines (IG 96220 and S98167-CLIMA) possess better tolerance to post emergence application of metribuzin than the standard desi variety Moti. Keeping this in view the present study was carried out to evaluate the tolerance of Kabuli chickpea to post emergence herbicides and their efficacy in controlling weeds.

METHODOLOGY

A field experiment was carried out at the research farm, RARS, Lam during *Rabi* 2015 to evaluate the bio-efficacy of post emergence herbicides in controlling weeds in kabuli chickpea. The experiment was laid out in a randomized block design with ten treatments and three replications. The predominant weeds observed were *Trianthema portulacastrum*, *Phyllanthus niruri*, *Digera arvensis*, *Chrozophora rottleri*, *Cyperus rotundus*, *Cardiospermum halicacabum* etc. The popular kabuli variety KAK-2 was used as test variety. Data on weed density and dry weight were analysed after subjecting it to the square root transformation. The soil of the experiment is clayey in texture with high water holding capacity, with pH 7.8, EC. 0.24 dS/m, medium in available nitrogen and high in available phosphorus and potassium. Post emergence herbicides were applied with knapsack sprayer at 20 days after sowing. The quantum of spray fluid used was 500 l/ha.

RESULTS

The weed control efficiency observed with the atrazine 500 g/ha at 20 DAS, topramezone 25 g/ha at 20 DAS and acifluorfen sodium + clodinofop propargyl 160 + 80 g/ha at 20 DAS as POE were comparable with that of Hand weeding at 20 and 40 DAS. The grain yield observed with topramezone 25 g/ha at 20 DAS (1.67 t/ha) and acifluorfen sodium + clodinofop propargyl 160 + 80 g/ha at 20 DAS (1.66 kg/ha) were comparable with hand weeding at 20 and 40 DAS.

The treatment received topramezone and acifluorfen sodium + clodinofop propargyl at both the levels indicated phytotoxicity in terms of yellowing (topramezone) and tip burning (acifluorfen sodium + clodinofop propargyl), however recovered by 3 weeks after treatment and gave comparable grain yield with the hand weeding at 20 and 40 DAS.

The economics calculated based on the prevailing input costs and output prices in the market indicated that the treatment received acifluorfen sodium + clodinofop propargyl 160 + 80 g/ha at 20 DAS gave highest net returns (Rs 39,600) and benefit cost ratio (1.48) followed by topramezone 25 g/ha at 20 DAS (Rs 37,500 and 1.28) and were higher than the hand weeding at 20 and 40 DAS (Rs 36,540 and 1.12). Though the hand weeding at 20 and 40 DAS observed with higher grain yields, the expensive manual weeding resulted in uneconomical in terms of lower net returns and benefit cost ratio.

Table 1. Weed control efficiency, grain yield and economics of kabuli chickpea as influenced by weed management practices

Treatment	Weed control efficiency (%)		Pod/ plant	Grain yield (t/ha)	Net returns (Rs/ha)	Benefit cost ratio
	30 DAS	60 DAS				
Control	-	-	18.0	1.20	23,380	0.95
Hand weeding at 20 and 40 DAS	76	83	28.6	1.73	36,540	1.12
Atrazine as post 250 g/ha at 20 DAS	47	23	23.6	1.45	33,250	1.33
Atrazine as post 500 g/ha at 20 DAS	53	79	21.6	1.26	24,880	0.98
Metribuzin 350 g/ha at 20 DAS	61	25	21.4	1.14	20,520	0.82
Metribuzin 525 g/ha at 20 DAS	47	49	26.2	0.68	1,920	0.08
Topramezone 15 g/ha at 20 DAS	45	64	24.6	1.47	31,500	1.15
Topramezone 25 g/ha at 20 DAS	64	35	24.4	1.67	37,500	1.28
Aciflourfen sodium + clodinofop propargyl 120 + 60 g/ha at 20 DAS	69	60	25.0	1.57	36,540	1.39
Aciflourfen sodium + clodinofop propargyl 160 + 80 g/ha at 20 DAS	64	76	25.1	1.66	39,600	1.48
LSD (P=0.05)	-	-	**4.9**	**0.45**	-	-

CONCLUSION

The treatments involving application of acifluorfen sodium + clodinofop propargyl 160 + 80 g/ha or topramezone 25 g/ha at 20 DAS controlled weeds thereby increased yield and profitability of kabuli chickpea.

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Yield and economics of maize as influenced by weed management through sequential application of herbicides

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Weed problem in *kharif* maize is considered to be an important factor for achieving higher productivity as it is more severe during continuous rains in early stages of maize growth. Weed management by traditional and cultural practices alone is problematic due to too much wetness and high cost involvement. Sequential use of pre- and post-emergence herbicides at temporal variation may help in avoiding the problem of weeds throughout the maize growth stages. The current study was taken up with the objectives to find out weed control efficiency, yield and economics of maize crop as influenced by application of pre- and post-emergence herbicides in sequence.

METHODOLOGY

A field experiment was conducted during *kharif* 2014 at Main Agricultural Research Station (MARS), College of Agriculture, Dharwad which is situated at 15^0 29' N latitude, $74^0$59' E longitudes and at an altitude of 689 m above mean sea level and it comes under Northern Transition Zone (Zone-8) of Karnataka. The soil of the experimental site was black clayey soil with pH 7.1, available N, P_2O_5 and K_2O as 229, 34, and 484 kg/ha, respectively. Treatments comprised of six herbicides namely glyphosate (2.5 kg/ha), paraquat (1 kg/ha), glufosinate ammonium (0.375 kg/ha), saflufenacil (75 g/ha), halosulfuron (90 g/ha) and imazathapyr (75 g/ha) were tried as post-emergence (Directed spray) in addition to pre-emergence application of atrazine (1 kg/ha) along with atrazine + 2 interculture + 1 hand weeding, weed free and weedy check. Total nine treatments were tested using Randomized Block Design with three replications. The test variety was '900 M Gold' and the crop received a rainfall of 633.5 mm during crop growing period.

RESULTS

At 60 DAS, weed free check was recorded higher WCE than rest of the weed control methods. With application of post emergence herbicides, atrazine 1 kg/ha *fb* glyphosate 2.5 kg/ha, atrazine 1 kg/ha *fb* glufosinate ammonium 0.375 kg/ha, atrazine 1 kg/ha *fb* saflufenacil 75 g/ha and atrazine 1 kg/ha *fb* paraquat 1 kg/ha recorded WCE of 92.1, 91.7, 90.0 and 89.1 percent, respectively which were found on par with each other. It might be due to better control of weeds following exposure to post-emergent treatment which might have resulted in lower weed population as well as dry weight of weeds. Similar kind of results were observed by Shantveerayya *et al.* 2012.

Table 1. Grain yield, Stover yield and B:C ratio as influenced by weed control methods in maize

Treatment	Grain yield (t/ha)	Weed control efficiency (%) 60 DAS	B:C ratio
Atrazine 1 kg/ha *fb* glyphosate 2.5 kg/ha (directed spray)	5.91	92.12	2.22
Atrazine 1 kg/ha *fb* paraquat 1 kg/ha (directed spray)	7.06	89.14	2.68
Atrazine 1 kg/ha *fb* glufosinate ammonium 0.375 kg/ha (directed spray)	6.58	91.73	2.52
Atrazine 1 kg/ha *fb* saflufenacil 75 g/ha (directed spray)	8.14	90.40	3.14
Atrazine 1 kg/ha *fb* halosulfuron 90 g/ha (directed spray)	6.78	81.09	2.28
Atrazine 1 kg/ha *fb* imazathapyr 75 g/ha (directed spray)	6.27	75.56	2.41
Atrazine 1 kg/ha + 2 IC + 1 HW (RPP standard check)	6.82	86.62	2.40
Weed free check	8.46	97.26	2.77
Weedy check	4.51	-	1.92
LSD (P=0.05)	0.20	4.63	0.08

Significantly higher grain yield (8.46 t/ha) was observed in weed free check which was 87.68% higher than weedy check (4.51 t/ha) followed by atrazine 1 kg/ha *fb* saflufenacil 75 g/ha that resulted in an yield of 8.14 t/ha which was 80.56% higher than the weedy check. The next to it atrazine 1 kg/ha *fb* paraquat 1 kg/ha recorded with grain yield of 7.06 t/ha (56.55% more than weedy check). The lowest grain yield (4.5.1 t/ha) was noticed in weedy check as a consequence of the highest removal of nutrients and moisture by weeds and severe crop weed competition resulting in poor source-sink relationship with poor yield components. Similar type of results were also reported by Singh *et al.* (2014) and Patil (2014). Significantly higher B:C ratio (3.14) was observed with atrazine 1 kg/ha *fb* saflufenacil 75 g/ha followed by weed free check (2.77). Atrazine 1 kg/ha *fb* paraquat 1 kg/ha which recorded B:C ratio of 2.68 was the next best treatment. The lowest B:C ratio was recorded with weedy check which might be due to less gross returns as a result of lower yield of maize. Similar type of result were also reported by Singh *et al.* (2014) and Patil (2014).

CONCLUSION

Atrazine 1 kg/ha *fb* saflufenacil 75 g/ha as directed spray at 45 days after sowing is found to be the best weed control method for rainfed maize because it is recorded higher grain yield, net returns, B:C ratio as well as WCE as compared to other herbicides treatments.

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Bio-efficacy of acifluorfen+clodinafop propargyl against *Vicia sativa L.* and other weeds in relay crop of greengram

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Vicia sativa L. is a very problematic weed in relay crop of greengram (Vigna radiate (L.) Wilczek) in north coastal districts of Andhra Pradesh. This weed being leguminous it is difficult to control even with selective post-emergence herbicide like imazethapyr and hand weeding is also difficult due to its twining habit, besides presence of dense stubbles of rice, forcing the farmers sometimes to leave the fields even without harvesting. Though, ample information on use of pre- and post-emergence herbicides like pendimethalin, fenoxaprop-ethyl, imazethapyr etc. is available for control of all other weeds (Ramana Murthy and Rao 1996, Chhodavadia *et al.* 2013 and Singh *et al.* 2015) but information pertaining to control of *Vicia sativa* in greengram is scanty. Hence, the present investigation was undertaken.

METHODOLOGY

A field experiment was conducted during *Rabi* 2014-15 at the Agricultural College Farm, Naira, Andhra Pradesh. The soil was sandy clay loam in texture with a neutral pH of 7.1 and EC of 0.10 dS/m, medium in organic carbon (0.54%), low in available nitrogen, high in available phosphorus and in available potassium. The sprouted seeds of greengram cultivar, LGG 402 were broadcasted two days before harvest of rice crop in the experimental field and all the recommended package of practices except weed control followed to raise the crop. The experiment consisting of seven treatments (Table 1) was conducted in a randomized block design with three replications. The post-emergence herbicides were sprayed by using a knapsack sprayer fitted with flat fan nozzle using a spray volume of 500 l/ha. The data on weed dry weight per unit area were recorded at harvest and transformed to "x+½ transformation to normalize their distribution. The prevailing input and output costs were taken into consideration for calculating the economics of different treatments.

RESULTS

Vicia sativa was the dominant weed among all the species in the experimental plots, which consisted about 70% of the total weed population. Other important weed flora observed in this investigation were *Echinochloa colona* (grass), *Cyperus haspan* (sedge), *Ammania baccifera*, *Cardiospermum helicacabum*, *Grangea maderaspatana* and *Phyllanthus maderaspatensis* (broad-leaf weeds).

Among the treatments, post-emergence application of aciflourfen + clodinafop propargyl 0.4 kg/ha significantly reduced the weed dry weight of *Vicia* with 62% WCE and other weeds (59%). No crop injury was observed with the different doses of herbicide mixture used under the study. The highest seed yield (907kg/ha) was obtained in hand weeding at 15 and 30 DAS and the lowest (500kg/ha) under unweeded check. The yield loss due to uncontrolled growth of weeds as compared to hand weeding was 45%. Among the different treatments, significantly maximum seed yield (812 kg/ha) was obtained with post emergence application of aciflourfen + clodinafop propargyl 0.4 kg/ha which was at par with its all lower doses except at 0.20 kg/ha. Herbicidal treatments resulted in considerably lower cost of cultivation compared with hand weeding at 15 and 30 DAS. The B:C ratio was found maximum (1.82) with post emergence application of aciflourfen + clodinafop propargyl 0.3 kg/ha followed by its next higher dose of 0.35 kg/ha (1.77). Though, hand weed recorded the highest seed yield but has lower BCR (1.24) because of higher cost involved in manual weeding.

Table 1. Effect of different treatments on weed growth, yield and economics in relay crop of greengram

Treatment	Dose (kg/ha)	Time of application (DAS)	At harvest				Weed control efficiency (%)	Seed yield (kg/ha)	Cost of cultivation ($x10^3$ Rs/ha)	BCR (Rs/Rupee)
			Weed dry weight of *Vicia* (g/m^2)	Weed control efficiency (%)	Dry weight of other weeds (g/m^2)					
Unwedded check	-	-	10.7 (115.8)	-	8.3 (68.9)		-	500	15.00	1.00
Hand weeding	-	15 and 30	3.9 (15.0)	64	3.2 (10.0)		62	907	24.30	1.24
Acifluorfen + clodinafop propargyl	0.20	20	5.9 (35.0)	45	4.2 (18.0)		49	700	16.55	1.54
Acifluorfen +clodinafop propargyl	0.25	20	5.5 (30.0)	49	4.0 (16.0)		52	750	16.91	1.66
Acifluorfen+ clodinafop propargyl	0.30	20	5.0 (25.0)	53	3.8 (14.0)		54	807	17.19	1.82
Acifluorfen+ clodinafop propargyl	0.35	20	4.7 (22.0)	56	3.5 (12.0)		59	810	17.53	1.77
Acifluorfen+ clodinafop propargyl	0.40	20	4.1 (16.7)	62	3.5 (12.0)		59	812	17852	1.73
LSD(P=0.05)	-	-	**1.7**	-	**1.4**		-	**99.8**	-	-

Note: DAS: Days after sowing. Data transformed to $\sqrt{x+0.5}$ transformation; Figures in parentheses are original value.

CONCLUSION

It was concluded that post-emergence application of aciflourfen + clodinafop propargyl 0.3 kg/ha was most effective in controlling *Vicia sativa* and other weeds and increasing seed yield with profitability in relay crop of greengram.

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Nutrient depletion by weeds and quality of mustard as influenced by different levels of fertilizers and weed management practices

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India is the third largest rapeseed-mustard producer in the world after Canada and China. This crop accounts for nearly one-third of the oil produced in India, making it the country's important edible oilseed crop. Rajasthan is one of the major mustard producing states in the country, contributing 46.2% of total production of India. Although, yield of mustard in Rajasthan is more than its national average yield, but it is still lagging behind by 840 kg/ha as compared to the world's productivity. Rapeseed-Mustard crop offers immense scope for further yield enhancement. The impact of improved technological components on the productivity in irrigated conditions in mustard during 2002-03 to 06-07 showed that by proper nutrient and weed management, the productivity of mustard crop can be increased upto 50%. (Kumar *et al*. 2004).

METHODOLOGY

The field experiment was conducted at research farm, RARI, Jaipur for two consecutive years during *Rabi* 2014-15 and 2015-16 on loamy sand soil. The twenty-four treatment combinations consisting of 3 fertility levels {100% RDF; 100% RDF + K + Zn and 125% (RDF + K + Zn)} and 8 herbicides (weedy check, weed free, pendimethalin 30 EC, pendimethalin 38.7 CS, pyrazosulfuron-ethyl 10 WP, oxydiargyl 6 EC, propaquizafop 10% EC and fluazifop-p-butyl 13.4% EC) were tested in factorial randomized block design with three replications.

RESULTS

Analysis revealed that besides weed free, pre-emergence application of pendimethalin 38.7 CS recorded the lowest nitrogen and phosphorus depletion by weeds, whereas nitrogen depletion was remained at par with pendimethalin 30 EC only and phosphorus depletion was remained at par with oxydiargyl 6 EC and pendimethalin 30 EC both. Pendimethalin 38.7 CS significantly reduced the potassium depletion by weeds. Further it was recorded that application of 125% (RDF + K + Zn) recorded highest nitrogen depletion by weeds, remained at par with 100 % RDF + K + Zn whereas 125% (RDF + K + Zn) significantly increased the phosphorus depletion by weeds. Fertility levels could not bring significant variation in potassium depletion by weeds during both the years of experimentation and in pooled analysis (Table 1).

Table 1. Effect of treatments on nutrient depletion by weeds and oil

Treatment	N depletion by weeds (kg/ha)	P depletion by weeds (kg/ha)	K depletion by weeds (kg/ha)	Oil content (%)	Oil yield (kg/ha)
Fertility levels					
100% RDF*	19.89	3.61	17.21	38.93	555.64
100% RDF + K + Zn	20.85	3.94	17.76	39.76	616.19
125% (RDF + K + Zn)	21.26	4.27	17.98	40.00	692.31
LSD (P=0.05)	1.10	0.25	N.S.	0.32	33.34
Herbicides					
Weedy check	41.66	7.57	35.86	39.43	553.87
Weed free	0.00	0.00	0.00	39.59	789.40
Pendimethalin 30 EC pre-emergence 750 g/ha	15.19	3.12	23.47	39.77	742.72
Pendimethalin 38.7 CS pre-emergence 750 g/ha	13.97	2.77	11.39	39.75	770.51
Pyrazosulfuron-ethyl 10 WP pre-emergence 150 g/ha.	37.12	7.56	32.12	39.19	156.30
Oxydiargyl 6 EC pre-emergence 90 g/ha.	16.05	2.86	13.90	39.62	588.59
Propaquizafop 10% EC 100 g/ha at 20-25 DAS	21.43	3.91	17.56	39.63	666.21
Fluazifop-p-butyl 13.4 % EC 134 g/ha at 20-25 DAS	19.93	3.73	16.39	39.53	703.43
LSD (P=0.05)	1.79	0.40	1.92	N.S.	54.44
Interaction (FX H)	N.S.	N.S.	N.S.	N.S.	N.S.

* Recommended Dose of Fertilizer: 60 kg N + 30 kg P_2O_5 + 40 kg S per hectare. 30 kg K_2O + 20 Kg $ZnSO_4$ per hectare was also applied in second treatment of fertility level

Although herbicide treatments could not bring significant variation in oil content of mustard but maximum oil yield was recorded in weed free which was at par with pendimethalin 38.7 CS and pendimethalin 30 EC. It was further recorded that application of 125% (RDF + K + Zn) recorded the highest oil content and oil yield, remained at par with 100 % RDF + K + Zn during both the years of experimentation and in pooled analysis.

CONCLUSION

Minimum nutrient depletion by weeds was observed in pre-emergence application of pendimethalin 38.7 CS in comparison to other herbicidal treatments and 125 % (RDF + K + Zn) recorded the maximum oil content and oil yield. Hence, application of pendimethalin 38.7 CS 750 g/ha (PE) in combination with 125 % (RDF + K + Zn) gives the best result.

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Assessment of various herbicides in berseem under sub-mountainous conditions of Punjab

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Berseem (*Trifolium alexandrinum* L.) is one of the prominent winter season forage crop. It is a fast growing annual legume which provides high quality green forage, rich in protein (15-25%), minerals (11-19%) and carotene (Sharma and Murdia 1974). Being a winter season crop several weeds infest berseem crop. Common weeds found in berseem are *Cichorium intybus*, *Chenopodium album*, *Amaranthus viridis*, *Rumex dentatus*, *Melilotus indica*, *Medicago denticulata*, *Lathyrus aphaca*, *Spergula arvensis* among broadleaf weeds and *Poa annua, Polypogon monspeliensis* among the grassy weeds. Weed infestation reduces normally 25-35% green fodder and seed yield. Weeds decrease the acceptability of the fodder and also pose problems in harvesting of the crop (Walia 2003). Being a dense crop (broadcast seeding) manual weeding is not practicable in removing weeds. Herbicides offer a scope to control weeds, but not all herbicides are selective to berseem and effective against infesting weed species. Therefore, it is of utmost importance to control the berseem weeds for enhancement of fodder productivity and seed yield. Keeping in the view the facts, the current study was explored to assess various pre-plant, pre- and post-emergence herbicides in berseem to evaluate their efficacy on weeds and crop selectivity.

METHODOLOGY

The field experiment was conducted at farmer's field of district Gurdaspur during the rabi season of 2014-15 and 2015-16 in sub-mountainous region of Punjab (Latitude- 31Ë%562 43.4" N, Longitude- 75Ë%132 39.5" E and Altitude -265.17 m from mean sea level). The experimental site was clay loam in texture, medium in organic carbon (0.72%), high in available phosphorus (35 kg/ha) and low in potassium (80 kg/ha) at 0-15 cm soil depth. The soil was neutral in reaction (pH - 7.1) with normal electrical conductivity (0.61 dS/m). The experiment was laid out in randomized block design having three replications and comprised eight treatments, *viz.* fluchloralin 0.45 kg/ha, pendimethalin 0.75 kg/ha, imazethapyr 0.075 kg/ha, oxyfluorfen 0.1 kg/ha, fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha, pendimethalin 0.75 kg/ha *fb* imazethapyr 0.075 kg/ha, oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha and a weedy check.

RESULTS

The results revealed that all the weed control treatments caused significant reduction in weed density and dry weight of weeds as compared to weedy check. The lowest weed density (13.5 weeds/ m^2) and dry weight of weeds (10.2 g/m^2) were observed under fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha closely followed by application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha, which were significantly lower than all other herbicidal treatments. The results are in conformity with the findings of Kumar and Shivadhar (2008). However, the application of pendimethalin 0.75 kg/ha *fb* imazethapyr 0.075 kg/ha and imazethapyr 0.075 kg/ha alone, being at par with each other, registered significantly lower weed density and dry weight of weeds than fluchloralin 0.45 kg/ha, oxyfluorfen 0.1 kg/ha and pendimethalin 0.75 kg/ha. Moreover, application of fluchloralin 0.45 kg/ha which was statistically at par with oxyfluorfen 0.1 kg/ha caused significantly higher reduction in weed density and dry weight of weeds than pendimethalin 0.75 kg/ha. Pre-plant application of fluchloralin followed by post-emergence application of imazethapyr 0.075 kg/ha recorded maximum weed control efficiency (82.8%) which was closely followed by application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha (77.5%).

Among the herbicidal treatments, fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha, being at par with oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha recorded significantly more number of tillers as compared to all other herbicidal treatments. This indicates that effective weed control might have created favourable environment for the development of tillers which led to increase in green fodder and seed yield. The maximum pooled green fodder (98.64 t/ha) and pooled seed yield (0.70 t/ha) were recorded with fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha which was closely followed by application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha. These results were in agreement with the findings of Pathan *et al.* (2013). However, pendimethalin 0.75 kg/ha *fb* imazethapyr 0.075 kg/ha and imazethapyr 0.075 kg/ha caused significant enhancement in green fodder and seed yield as compared to remaining herbicidal treatments. Significantly superior green fodder and seed yield were noticed under fluchloralin 0.45 kg/ha and oxyfluorfen 0.1 kg/ha as compared to the application of pendimethalin 0.75 kg/ha.

CONCLUSION

The present study indicated that application of fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha closely followed by oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha appeared to be more useful for effective weed control in berseem which resulted in maximum green fodder and seed yield.

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Chemical control of weeds in dry-seeded rice

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Weeds are the main biological constraint in dry seeded rice (DSR), comprise of grasses, broadleaf and sedges and cause severe yield losses. Herbicides, being economical option, provide timely management of diverse weeds in DSR systems (Chauhan and Yadav 2013). Yaduraju and Mishra (2008) opined that although effective herbicides are available but problems of wild rice and sedges may increase in future, especially in DSR. Sedges are ranked second in density after grasses for infesting rice crop. Moreover, sedges and broad leaf weeds become highly competitive with the crop when grasses are kept under control. The study was done to find out chemical control of sedges and broadleaf weeds and its impact on DSR productivity.

METHODOLOGY

A field experiment was conducted at Department of Agronomy, Punjab Agricultural University, Ludhiana and at Regional Research Station, Kapurthala during *kharif* 2015. Sowing of rice cultivar PR 115 was done in randomized complete block design with four replications comprising 12 treatments including metsulfuron 8, 12, 16 g/ha, 2, 4-D amine salt 435, 580, 725 g/ha, pre-mix of metsulfuron + chlorimuron 2, 4, 6 g/ha, azimsulfuron 20 g/ha, weedy and weed free. All herbicides were applied at 15 days after sowing using 375 litres of water/ha with knap sack sprayer. The comparisons were made with Tukey HSD (honest significant difference) test using functional analysis.

RESULTS

Metsulfuron recorded effective control of broadleaf weeds only and was found ineffective against sedges. Application of azimsulfuron 20 g/ha recorded the lowest biomass of sedges which was similar to metsulfuron + chlorimuron 4 g and 6 g and 2, 4-D amine salt 725 g/ha at both the locations (Table 1). The maximum weed biomass of sedges was recorded in unweeded control which was similar to metsulfuron 8 g and 12 g/ha. Application of azimsulfuron 20 g, metsulfuron + chlorimuron 4 g and 6 g, 2, 4-D amine salt 580 g and 725 g and metsulfuron 16 g/ha resulted in significantly lower biomass of broad leaf weeds and more number of tillers compared with other herbicidal treatments. In DSR, 51.7-65.1 % yield reduction was caused by broadleaf weeds and sedges. Azimsulfuron 20 g, 2, 4-D amine 725 g, metsulfuron + chlorimuron 4 g and 6 g/ha resulted in maximum yield and controlled weeds with > 90% WCE. Metsulfuron + chlorimuron 6 g/ha was slightly phytotoxic to crop.

Table 1. Effect of weed control treatments on weed biomass, number of tillers and yield of DSR.

Treatment (g/ha)	Weed biomass* (g/m^2) at 60 DAA				Tiller density/m^2 at 60 DAS		Grain yield (t/ha)	
	Sedges		Broad leaf weeds					
	LDH	KPR	LDH	KPR	LDH	KPR	LDH	KPR
Metsufuron 8	19.4 (379)	13.0 (169)	6.7 (45)	11.0 (120)	231	243	3.4	3.7
Metsulfuron 12	17.9 (321)	12.2 (147)	5.7 (32)	6.2 (38)	279	275	3.9	3.9
Metsulfuron 16	17.0 (292)	11.2 (125)	3.5 (12)	2.3 (4)	331	288	4.9	4.1
2, 4-D amine salt 435	16.6 (277)	8.0 (64)	8.6 (73)	9.5 (92)	289	336	4.3	5.0
2, 4-D amine salt 580	9.6 (94)	5.0 (26)	3.6 (12)	7.5 (58)	363	357	5.2	5.6
2, 4-D amine salt 725	6.5 (42)	2.6 (7)	2.2 (4)	4.0 (16)	406	381	6.2	6.0
Metsulfuron + chlorimuron 2	15.5 (240)	4.0 (16)	7.7 (60)	7.3 (55)	329	366	4.6	5.7
Metsulfuron + chlorimuron 4	7.6 (59)	2.8 (7)	3.0 (9)	4.1 (17)	389	384	6.1	5.9
Metsulfuron + chlorimuron 6	5.3 (30)	2.6 (6)	2.2 (4)	2.3 (5)	372	379	5.7	5.6
Azimsulfuron 20	4.4 (19)	2.4 (5)	2.4 (5)	1.8 (2)	399	389	6.2	6.0
Weedy	20.3 (412)	13.9 (195)	10.4 (108)	19.2 (366)	150	180	2.2	2.9
Weedfree	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	408	394	6.3	6.0
HSD[a] (p=0.05)	4.0	2.3	2.0	2.4	101	96	1.4	1.5
HSD[b] (p=0.05)	3.1	1.7	1.5	1.8	76	72	1.0	1.1

*Data is subjected to square root transformation $(\sqrt{x+1})$. Figures in parenthesis are original means. DAA- days after application; HSD[a]: Amongst Herbicide, and HSD[b]: Herbicide v/s Control; LDH- Ludhiana, and KPR- Kapurthala

CONCLUSION

Post-emergence application of metsulfuron + chlorimuron (pre-mix) 4 and 6 g, 2,4-D amine 725 g and azimsulfuron 20 g/ha at 15 DAS controlled sedges and broadleaf weeds effectively in dry seeded rice and increased rice grain yield.

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Evaluation of new herbicides to control weed flora and to enhance the profitability of maize in Southern Rajasthan

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Maize, a miracle crop, is grown over a wide range of climate conditions in semi-arid and sub-tropics on India continent. It is one of the major stable food crops of Southern Rajasthan, which has mostly cultivated in rainfed area during the rainy season. Maize suffers from a heavy weed infestation which leads to yield losses ranging between 28 to 100% (Patel *at al* 2006). Manual weeding and mechanical operations are still widely adopted, but several times, as these operations are not possible due to incessant rains during the critical period of crop-weed competition makes the situation worse to worse. Few herbicides like Atrazine as pre-emergence and 2, 4-D amine as post- emergence is available for controlling weed in maize, but 2,4–D amine control only broad leaf weeds. Grasses and sedges remain a problem for farmers, especially when the too high or too low soil moisture in standing crop. Keeping above point in view, a study was undertaken to evaluate the weed control efficiency of new herbicide in standing crop.

METHODOLOGY

A field experiment was conducted during *Kharif* season of 2015 at Agricultural Research Station (MPUAT), Banswara to test the weed control efficiency of new herbicides for enhancing maize productivity. Ten treatments consisting of Control (weedy check), weed free, atrazine 1.5 kg/ha pre-emegence (PE), atrazine (750 g/ha) + pendemathalin (750 ml/ ha) PE, atrazine (750 g/ha) + 2, 4-D amine (500 g/ha) at 25 DAS as post-emergence (PoE), halosulfuron (90 g/ha) PoE at 25 DAS, atrazine 1.5 kg/ha PE *fb* halosulfuron 90 g/ha PoE at 25 DAS, tembotrione (120 g/ha) PoE at 25 DAS, pendemathalin (1000 ml/ha) PE *fb* atrazine (750 g/ha) + 2,4-D amine (1000 ml/ ha) PoE at 25 DAS and atrazine 1.5 kg/ha PE *fb* tembotrione (120 g/ha) PoE at 25 DAS were laid out in randomized block design with three replications. The seed of maize hybrid 'Bio-9681' was dibbled manually at spacing of 60 x 25 m using 20 kg seed/ha in first week of July and fertilized with 120 + 60 + 40 kg N + P_2O_5 + K_2O/ha as per recommended practices.

RESULTS

The predominant species of grassy weeds were *Echinochloa colonum*, *Dactyloctenium aegyptium*, *Eleusine indica*, *Digitaria sanguinalis*, *Cynodon dactylon* while broad-leaved weeds were *Trianthema portulacastrum*, *Commelina benghalensis*, *Amaranthus spp.*, *Digera arvensis*, *Phyllanthus niruri* and sedge *Cyperus rotundus*. Among, the herbicidal treatments, the lowest weed density (8.92/m²) and weed dry weight were observed under application of atrazine 1.5 kg/ha PE *fb* tembotrione 120 g/ha PoE, followed by tembotrione 120 g/ha PoE. The similar findings were recorded by Sweta *et al* (2015). Among the herbicidal treatments, atrazine 1.5 kg/ha PE *fb* tembotrione 120 g/ha PoE recorded maximum weed control efficiency (90.6%) followed by tembotrione 120 g/ha PoE at 25 DAS and significantly superior over rest of the treatments. The highest grain yield (6.69 t/ha) was recorded with weed free and lowest (2.38 t/ha) was recorded under weedy check. Among the herbicidal treatments, atrazine 1.5 kg/ha PE *fb* tembotrione 120 g/ha PoE at 25 DAS obtained maximum grain yield (6.42 t/ha), which was significantly superior to rest combination of chemicals. Tembotrione 120 g/ha at DAS and atrazine 1.5 kg/ ha followed by tembotrione 120 g/ha PoE produced 22.96 and 4.17% less yield as compared to weedy free. The maximum stover yield (8.03 t/ha) was recorded in weed free followed by atrazine 1.5 kg/ha PE *fb* tembotrione 120 g/ha (7.70 t/ha) and significantly superior over rest of the treatments. The maximum B: C ratio (2.32) was recorded in atrazine 1 kg/ha PE *fb* tembotrione 120 g/ha PoE at 25 DAS which significantly superior over rest herbicidal treatment and lowest B:C ratio (0.61) recorded in Halosulfuron 90 g/ha PoE at 25 DAS.

Table 1. Response of different weed management practices on weed growth, yield and economics of maize

Treatment	Weed density (no./m²) at 50 DAS	Weed dry weight (g/m²) at 50 DAS	Weed control efficiency (%) at 50 DAS	Grain yield (t/ha)	Stover yield (t/ha)	Cost of cultivation (x10³/ha)	B:C ratio
Weedy check	10.01 (100.11)	9.15 (83.00)	0.0	2.38	4.76	20.69	0.61
Weedy free	1.00 (0.00)	1.00 (0.00)	100.0	6.69	8.03	30.69	2.05
Atrazine 1. 5 kg/ha PE	6.12 (36.71)	5.60 (30.59)	63.1	3..79	5.69	22.49	1.36
Atrazine 750 g/ha + pendimenthalin 750 ml as PE	5.63 (31.35)	5.15 (26.12)	66.5	3.72	5.58	22.77	1.29
Atrazine 750 g + 2,4-D 1000 ml as PoE at 25 DAS	5.40 (28.38)	4.95 (23.65)	69.5	4.27	6.40	22.86	1.61
Halosulfuron 90 g/ha PoE at 25 DAS	6.79 (45.56)	6.22 (37.97)	53.3	2.80	3.64	24.37	0.61
Atrazine 1.5 kg/ha PE *fb* halosulfuron 90 g/ha PoE at 25 DAS	5.33 (27.78)	4.88 (23.15)	72.4	3.66	5.48	26.17	0.95
Tembotrion 120g/ha PoE at 25 DAS	4.31 (17.65)	3.95 (14.71)	81.5	5.76	6.70	25.29	1.85
Pendimethalin 1000 ml/ha PE *fb* atrazine 750 g/ha + 2,4-D amine 1000 ml/ha PoE at 25 DAS	4.41 (18.49)	4.05 (15.41)	81.1	4.60	6.44	23.52	1.74
Atrazine 1.5 kg PE *fb* tembotrion 120 g/ha PoE at 25 DAS	3.03 (8.92)	2.98 (8.32)	90.6	6.42	7.70	27.09	2.32
LSD (P=0.05)	1.23	1.15	11.9	0.93	0.13		0.54

CONCLUSION

It was concluded that atrazine 1.5 kg/ha applied as pre-emergence *fb* tembotrione 120 g/ha applied as post-emergence at 25 DAS was found most effective for controlling weeds, improving yield and economics to the cultivation of maize in rainy season.

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Economic benefit analysis of assert™ herbicide in paddy

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Weeds in rice are one of the most important biological hindrances to maximizing crop yield. Weed emergence in relation to crop emergence is an important factor in crop-weed competition. Crop losses due to weed competition varies with the duration (days) and intensity (plants/m^2) of weed infestation in the crop. The crop is likely to experience yield reduction, unless it is kept weed free during an early part of its growing period (Azmi *et al*. 2007). In general, controlling weeds to provide a period of minimal weed competition is one of the important weed management strategies in order to minimize the labour requirement for weeding operations, enhance the efficiency of herbicide use, maximize crop yields and thus maximize economic returns to rice farmers.

Therefore, present studies were initiated to evaluate the yield advantage and economic benefit of Assert™ herbicide application in comparison to the current weed control options used by rice farmers.

METHODOLOGY

Field studies were conducted in transplanted rice during the 2015 crop season in the state of West Bengal and Uttarpradesh in India. Assert™ 2.5% OD (at 25 g/ha) was compared with farmer practice of bispyribac-sodium 10% SC (at 25 g/ha). Application time for assert varied from 15-20 Days After Transplanting (DAT) across locations while bispyribac was applied between 20-25 DAT as per farmer practice in that area. Need based hand weeding (one time) was also performed in the Assert and bispyribac treatments at 25-30 days after application At two field sites, a pre–emergence herbicide was applied before treatment of assert and bispyribac, while at the other two sites, no pre-emergence herbicide was applied. These were large plot (200 m^2) non-replicated trials. All other cultural practices and plant protection measures were kept the same for all treatments. Total weed control cost (Herbicide cost + labour cost for hand weeding) was calculated for each treatment and crop yield was recorded, using the complete large plot. Yield of trial plots was converted into yield per acre and multiplied by prevailing market price of rice to arrive at the farmer value of rice harvest.

RESULTS

Dominant weed flora in experimental fields consisted of grasses *(Echinochloa colona, Echinochloa crus-galli),* sedges *(Cyperus difformis)* and broad-leaf weeds (*Monochoria vaginalis, Ludwigia sp*). Weed control treatments were applied as per dose rate and application time described in methodology. Based on the cost of the herbicide treatment, number of labourers required to hand weed each plot and final yield, Assert followed by (*fb*) 1 Hand Weeding (HW) recorded a saving of 0-2 labours/acre over current farmer practice of bispyribac fb 1 HW and 23.5 to 25.5 labours per acre over non-herbicide but hand- weeded only plots. The use of an herbicide treatment followed by hand weeding to clean out the weeds occurring later, after initial herbicide treatment, showed a yield increase of 60 to 65 kg per acre over farmer practice by reducing the crop weed competition.

Table 1. Economic value of Assert™ compared to current weed control practices

Location/ Crop culture	Treatment	No of Field Sites	Cost of herbicide treatment (Rs/acre)	Cost of Hand weeding (Rs/acre)	Total weed control input (Rs/acre)	Grain yield (kg/acre)	Value of Rice Harvest (Rs/acre)	Net value per acre** (Rs)	Economic value addition over Untreated (Rs)
West Bengal-TPR	Assert 25 g/ha at 15-20 DAS fb one HW	2	850	1375 (5.5X250)*	2225	2897	34764	32539	9394
	Bispyribac 25 g/ha at 20-25 DAS fb one HW	2	700	1875 (7.5X250)	2575	2837	34044	31469	8324
	Untreated- no herbicide application – hand weeded only	2	0	6375 (25.5X250)	6375	2460	29520	23145	0
Uttar Pradesh-TPR	Pretilachlor *fb* Assert 25 g/ha *fb* 1 HW	2	1050	150 (1X150)	1200	3255	39060	37860	22989
	Pretilachlor *fb* Bispyribac 25 g/ha at 20-25 DAS *fb* HW	2	900	150(1X150)	1050	2928	35136	34086	19215
	Untreated- no herbicide application – hand weeded only	2	0	3525 (23.5X150)	3525	1533	18396	14871	0

*Figure in parenthesis are Number of Labour X cost per Labour. One labour is equal to 8 hrs; ** Net value per acre calculated by multiplying the yield per acre with prevailing price of Rice in that area

Finally, a net value increase (economic benefit addition) of Rs 1070 to 3774 per acre over Bispyribac program and Rs 9394 to 22,989 per acre over the non-herbicide hand weeded treatment was recorded.

CONCLUSION

Economically better productivity with reduced labour costs and higher yields was obtained with application of Assert ™ at 25 g/ha *fb* 1 hand weeding over the current farmer practice of either bispyribac *fb* 1 hand weeding or hand weeding only in transplanted rice. Assert ™ application at 15-20 days after transplanting resulted in significant labour savings and higher economic profit compared to hand weeding only, reducing the dependence on labour under present conditions of labour scarcity.

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Bioefficacy of propanil on weed flora in direct seeded rice

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Rice (*Oryza sativa* L.) is the principal crop of India cultivated in an area of 43.95 mha annually with a production of 106.7 mt, with an average productivity of 2.4 t/ha (Ministry of Agriculture 2014). Weeds are the main biological constraints to the production of direct seeded rice which may cause 60-80% reduction in grain yield. Chemical weed control has expanded manifold in DSR (Chauhan and Opena 2013) and is likely to increase further with the increased adoption of direct seeding. For the last many year many pre-emergence herbicides have been recommended for controlling grassy weeds. However, under aerobic soil conditions post-emergence herbicides may perform better. Among the post-emergence herbicides ethoxysulfuron, cyhalofop-butyl, pretilachlor, chlorimuron, metsulfuron, bispyribac sodium, penoxsulam effectively controlled weeds in aerobic rice. Hence, there is need to identify the most suitable broad-spectrum herbicides for controlling monocot as well as dicot weeds. Therefore, the present investigation was undertaken to study the bio-efficacy of Propanil 35 % EC against mixed weed flora and yield of direct -seeded rice.

METHODOLOGY

A field experiment was conducted during *kharif* season of 2015 and 2016 at G.B Pant University of Agriculture and Technology, Pantnagar to test the bio –efficacy of Propanil 35 % EC against mixed weed flora in direct-seeded rice. The soil of experimental site was silty loam in texture having high organic carbon (0.89%), medium available P (21.7 kg/ha) and available K (144.8 kg/ha), low available N (228.9 kg/ha) and pH (7.4). The experiment was laid out in randomized block design and replicated thrice. Experiment consisted of eight treatments comprised of four doses of Propanil 1000, 2000, 3000 and 4000 g/ha, oxyfluorfen 240 g/ha, cyhalofop-butyl 80 g/ha, twice hand weeding at 15 and 30 DAS and weedy check. The rice variety 'Narendra 359' was sown at row spacing of 20 cm on June 24, 2015 and June 26, 2016. All the herbicidal applications were done with the knapsack sprayer fitted with flat fan nozzle by using water volume of 375 l/ha. The crop was raised by following recommended packages of practices of direct-seeded rice in Uttarakhand.

RESULTS

The major weeds appeared in experimental field were *Echinochloa colona* and *Echinochloa crus-galli* among grasses, *Celosia argentea*, *Trianthema monogyna*, *Amaranthus viridis*, *Cleome viscosa*, *Eclipta alba* and *Commelina benghalensis* among broad leaved weeds and *Cyperus iria*, *Cyperus difformis*, *Brachiaria ramosa*, and *Fimbristylis miliacea* as sedges during 2015 and 2016 respectively. Application of propanil 3000 and 4000 g/ha provided complete reduction of grassy weeds which was statistically at par with its lower dose 2000 g/ha and twice hand weeding as compared to rest of the herbicidal treatments. Propanil 4000 g/ha showed significant superiority in reducing the density of broad leaved weeds than rest of the herbicidal treatments except 3000 and 2000 g/ha which were at par with each other. Among the herbicidal treatments, propanil 4000, 3000 g/ha and oxyfluorfen 240 g/ha were at par and exhibited greater reduction in density of sedges than rest of the herbicidal treatments. Total density of weeds was also effectively reduced by propanil 3000, 4000 and 2000 g/ha and twice hand weeding than rest of the treatments. The lower weed dry weight was also recorded with these three doses of propanil which were at par with twice hand weeding and significantly lower than other treatments. The maximum weed control efficiency was recorded with propanil 4000, 3000 and 2000 g/ha respectively as well as twice hand weeding. The maximum grain yield was also obtained with propanil 4000 , 3000 and 2000 g/ha which were at par with each other and significantly higher than rest of the herbicidal treatments. The results were in conformity with the findings of Jamshid Abbassi *et al.* (2012).

Table 1. Effect of treatments on weed density, weed biomass, weed control efficiency at 45 DAS and grain yield of direct seeded rice (pooled of 2015 and 2016)

Treatment	Weed density (no./m^2)			Total weed density (no./m^2)	Weed Dry weight (g/m^2)	WCE (%)	Grain yield (t/ha)
	Grasses	Broad-leaved weeds	Sedges				
Propanil 35 % EC 1000g/ha	2.4 (5.5)	4.8 (22.7)	3.0 (8.8)	6.1 (37.0)	4.7 (22.0)	76.8	4.2
Propanil 35 % EC 2000 g/ha	1.3 (1.5)	2.2 (4.7)	2.8 (7.3)	3.8 (13.5)	3.1 (8.2)	91.4	5.4
Propanil 35 % EC 3000 g/ha	0.7 (0.0)	1.8 (3.5)	1.1 (1.2)	2.3 (4.7)	2.4 (3.9)	95.9	5.6
Propanil 35 % EC 4000 g/ha	0.7 (0.0)	1.5 (2.0)	1.1 (0.9)	1.6 (2.9)	1.5 (2.5)	97.4	5.8
Oxyfluorfen 23.5 % EC 240g/ha	2.1 (4.0)	2.5 (5.7)	1.8 (3.7)	3.7 (13.4)	3.5 (11.9)	87.5	4.8
Cyhalofop-butyl 10 EC 80g/ha	2.5 (5.7)	6.4 (40.2)	4.8 (23.2)	8.3 (69.1)	7.2 (51.5)	45.8	4.6
Hand weeding 15 and 30 DAS	1.2 (1.3)	1.8 (3.3)	2.4 (5.3)	3.2 (9.9)	2.1 (4.0)	95.8	5.7
Weedy check	5.7 (32.2)	6.6 (42.9)	5.0 (24.5)	10.0 (99.6)	9.7 (95.0)	-	3.5
LSD (P=0.05)	0.6	0.8	1.1	2.2	1.7	-	0.4

*Values in parentheses are original value. Data are subjected to square root transformation $\sqrt{x+0.5}$

CONCLUSION

It can be concluded that post-emergence application of propanil 2000 g/ha was found more economical and effective in controlling weeds and recorded higher direct seeded rice grain yield.

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Assessing the efficacy of cyhalofop butyl against weeds in direct (dry) seeded rice under irrigated ecosystem

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Direct (dry) seeded rice under irrigated ecosystem is a cost effective technology as it saves irrigation water by 12-35% and labor up to 60%. Despite multiple benefits of direct (dry) seeded rice, weed control is one of the major challenges for its success in South Asia (Kumar and Ladha, 2011). In direct seeded aerobic rice, yield loss is as high as 50-91% (Rao *et al.* 2007). Therefore, pre- and post-emergence herbicides can be used in aerobic direct seeded rice fields and they are effective, if properly used in appropriate quantity and time (Singh *et al.* 2006). Keeping this in view, the present study was undertaken to determine the efficacy of cyhalofop-butyl applied as post emergence (3-5 leaf stage of weeds) against the grassy weeds in direct-seeded rice.

METHODOLOGY

The field experiment was conducted in N.E. Borloug Crop Research Centre, at GBPUA&T Pantnagar during the *kharif* season of 2014 and 2015 and was laid out in randomized block design with three replications. Rice variety 'Sarjoo 52' was seeded on June 13th and 11th during 2014 and 2015, respectively with recommended package of practice of rice cultivation. Observations were taken on total weed dry weight, WCE and HEI at 45 DAA and grain yield. Crop was harvested on Oct. 27th and 25th during 2014 and 2015, respectively.

RESULT

The plots of direct seeded rice crop was infested at 45 DAA with different prominent grassy and non-grassy weeds during both the years. Among grassy weeds *Echinochloa colona*, *E. crus-galli* and *Leptochloa chinensis* were dominant while among non-grassy weeds *Alternanthera sessilis*, *Caesulia axillaris*, *Cyperus iria* and *C. rotundus* were major weeds that in total accounted for 75.1 and 83.6% relative density during 2014 and 2015, respectively. Among different weed management practices, minimum total weed dry biomass, maximum WCE and HEI was achieved with post-emergence application of cyhalofop butyl at 90 g/ha which was at par with twice hand weeding during both the years while in 2015 higher dose of cyhalofop butyl (90 g/ha) also found comparable with its lower dose as well as standard check applied at 75 and 80 g/ha. Grain yield was attained maximum with twice hand weeding followed by cyhalofop butyl aaplied at 90 g/ha which was comparable with all herbicidal treatments except lower dose of cyhalofop-butyl (65 g/ha) during both the years (Table 1).

Table 1. Effect of weed management practices on total weed dry biomass, WCE and HEI at 45 DAA and yield of direct seeded rice

Treatment	Dose (g/ha)	Total weed dry weight (g/m^2)		WCE (%)		HEI (%)		Grain Yield (t/ha)		Straw yield (t/ha)	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Cyhalofop-butyl 10% EC	65	11.7 (135.1)	9.1 (82.9)	37.9	63.5	5.8	5.3	2.97	3.50	4.31	6.30
Cyhalofop-butyl 10% EC	75	9.4 (87.0)	8.1 (65.5)	60.0	71.1	13.3	8.5	4.07	4.10	7.36	7.38
Cyhalofop-butyl 10% EC	80	8.8 (76.7)	7.9 (60.9)	64.7	73.2	15.3	9.3	4.16	4.16	7.46	7.48
Cyhalofop-butyl 10% EC	90	8.1 (64.9)	7.7 (59.0)	70.2	74.0	18.4	10.1	4.21	4.29	7.29	7.73
Cyhalofop-butyl 10% EC (std. check)	75	9.4 (86.6)	8.0 (63.4)	60.2	72.1	12.9	8.5	4.00	4.02	7.19	7.24
Cyhalofop-butyl 10% EC (std. check)	80	8.8 (76.5)	7.8 (60.4)	64.8	73.4	15.2	9.1	4.12	4.07	5.99	7.44
Hand weeding 20&40 DAS	-	8.3 (67.5)	6.3 (38.4)	68.9	83.1	-	-	4.25	4.34	6.67	7.81
Weedy check	-	14.8 (217.6)	15.1 (226.9)	-	-	-	-	0.65	1.19	1.17	2.13
LSD (0.05)		0.40	0.77	-	-	-	-	0.38	0.29	0.48	0.50

Value in parentheses was original and transformed to square root " X+1 for analysis, DAS- days after sowing, DAA- days after herbicide application, WCE- weed control efficiency, HEI- herbicide efficiency index.

CONCLUSION

It was concluded that post-emergence application of cyhalofop butyl at 75 and 80 g/ha was as effective as its higher dose (90 g/ha) for controlling weeds and improving grain yield of direct-seeded rice.

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Effect of post emergence application of haloxyfop 10.8% EC for weed control in mentha herb

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Mentha is an important essential oil bearing crop belongs to family Lamiaceae. Its oil is extensively used in perfumery and flavor industries. India is a leading producer of this crop in world having 1,60,000 ha area with an annual production of 16000 tonnes essential oil (Kumar *et al*. 2011). In India, it is commercially grown in sub-tropical plains as a summer season crop after the harvest of winter crops. Weeds deteriorate the quality of crop produce as separating out weed plants from crop produce during oil extraction is not possible. Both *rabi* and *kharif* season weeds emerge and compete with the crop and the yield losses due to weeds could be up to 74% (Walia *et al*. 2006). Manual weeding is arduous, costly and time consuming and is not possible on a large scale. Under such situations, use of herbicides for weed control holds a great promise. Post-emergence herbicides will be a mean for controlling the weeds in view of effectiveness in mentha. Hence, an investigation was carried out to study the application of post-emergence herbicides in maize during *kharif* 2015 and 2016.

METHODOLOGY

Field experiment was conducted during *kharif* season of 2015 and 2016 at N.E. Borlaug Research Center, GBPUA&T, Pantnagar. The experiment was laid out in Randomized Block Design with three replications. The mentha variety 'Sim Kranti' was planted on 17th March during 2015 and 16th March during 2016. Test herbicide haloxyfop 10.8% EC at various dosages, *viz*. 81, 108 and 135 g/ha, quizalafop 5% EC used as standard check at 50 g/ha and all these were applied as post-emergence on 11th and 6th April, 2015 and 2016, respectively. A quadrate of 0.25 m^2 was placed at four randomly selected places in all the plots of the experimental field and the number of weed flora were count at 60 DAA. Data on dry matter production, weed control efficiency, yield and weed index were recorded and analyzed statistically following standard methods.

RESULTS

Statistically analyzed data of both the years showed that among all the weed control treatments, total reduction of weed biomass with 100% weed control efficiency was achieved under weed free situation. Whereas, among the herbicidal treatments, minimum dry matter accumulation and maximum weed control efficiency was obtained with application of haloxyfop at higher dose (135 g/ha) which was also found significantly superior to rest of the doses as well as quizalofop applied as standard check (50 g/ha). Among the different herbicides, maximum herb yield was achieved with higher dose of haloxyfop (30.2 and 27.2 t/ha) with minimum weed index (1.6 and 0%) during both the years, respectively and was at par with its respective lower dose applied at 108 g/ha.

Table 1. Effect of treatment on weeds dry matter accumulation, weed control efficiency at 60 DAA, weed index and herb yield of mentha

Treatment	Dose g/ha	Weed dry weight (g/m^2)		Weed control efficiency (%)		Herb yield (t/ha)		Weed index (%)	
		2015	2016	2015	2016	2015	2016	2015	2016
Haloxyfop10.8% EC	81	19.4 (376.7)	8.7 (75.2)	59.1	86.6	21.4	20.0	30.3	26.5
Haloxyfop10.8% EC	108	15.1 (226.5)	6.1 (36.9)	75.4	93.4	30.1	25.5	2.0	6.25
Haloxyfop10.8% EC	135	13.1 (170.8)	5.2 (26.6)	81.5	95.3	30.2	27.2	1.6	0.0
Quizalafop 5% EC	50	16.4 (267.3)	8.2 (66.5)	71.0	88.2	19.2	20.0	37.5	26.5
Hand weeding (2)	20 & 40 DAP	16.6 (278.5)	9.2 (82.9)	69.8	85.3	23.5	21.5	23.5	21.0
Weed free	-	1.0 (0.0)	1.0 (0.0)	100	100.0	30.7	27.2	-	-
Weedy	-	30.4 (921.1)	23.7 (562.8)	-	-	2.8	3.2	-	-
LSD(P=0.05)		1.6	0.84	-	-	3.3	2.4	-	-

DAA: Days after herbicide application DAP- days after planting, Value in parentheses were original and transformed to square root " X+1 for analysis

CONCLUSION

The present study concluded that the application of haloxyfop 10.8% EC at 108 to 135 g/ha applied as post-emergence effectively controlled the weed dry biomass for achieving highest herb yield of mentha.

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Nutrient and weed management for improving productivity and nutrient uptake of basmati rice

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Rice (*Oryza sativa* L.) accounts for about 43% of total food grain production and 55% of cereals production in the country, contributing 20- 25% of the agricultural GDP. In India, rice is being grown on an area of 42.75 million hectares which is maximum among all rice growing countries having annual production about 105.24 mt and productivity of 2.46 t/ha (Anonymous, 2013-14). A major hindrance in successful cultivation of transplanted rice is heavy infestation of weed causing drastic reduction in yield. Uncontrolled weed growth caused 33-45% reduction in grain yield (Singh *et al.* 2007, Manhas *et al.* 2012). Besides chemical fertilizer, organic manure is also important source of nutrient addition to soil but contain low amount of nutrient and therefore, whole crop requirement cannot be fulfilled by their application. Chemical fertilizers are available in fixed grades, hence all nutrient are not supplied in balanced quantities. Therefore, for maintaining soil fertility, there is a need to integrate these two sources of nutrients. (Laximinarayan *et al.* 2001).

METHODOLOGY

A field experiment was conducted during *Kharif* season of 2014 at Crop Research Center, Chirori of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.). The soil of experimental field was sandy loam in texture, low in organic carbon (0.40%), and available nitrogen (225.40 kg/ha), medium in available phosphorus (14.76 kg/ha) and available potassium (170.82 kg/ha) with pH 7.5. The experiment was laid out in a factorial randomized design with three replications. A set of 18 treatment combinations consisting of three nutrient levels *viz.* 100% RDF, 75%RDF+5 t/ha FYM, 50% RDF+10 t/ha FYM and six levels of weed management practices viz. brown manuring, bispyribac sodium (10% SC) 25 g/ha 20 DAP, Almix 4 g/ha 25 DAP, pyrazosulfuron (10% WP) 25 g/ha 3 DAP, weed free and weedy check. Rice variety 'Pusa Basmati-1509' was transplanted on 21 July, 2014 with recommended fertilizer dose of nitrogen (120 kg/ha), phosphorus (60 kg/ha), potash (40 kg/ha) and 15 t farm yard manure (FYM) as per treatment was applied. Half of nitrogen and total phosphorus, potassium and FYM were applied as basal doses. Remaining quantity of nitrogen was top dressed in two splits. For brown manuring, *Sesbania* seed 40 kg/ha was used.

RESULTS

The major weed flora observed in the experimental field included *Echinochloa crusgalli* (32.05%), *Cyperus rotundus* (29.90%), *Eclipta alba* (17.79%), and others (21.21%) viz, *Echinochloa colona*, *Eleusine indica*, *Cyondon dactylon*, *Commelina benghalenssi*, *Phyllanthus niruri*, etc. The effect of nutrient management practices on dry weight of *Echinochloa crusgalli*, *Cyperus rotundus*, *Eclipta alba* and others weeds were found significant. The lower dry weight of all weeds was found with 100% RDF (120:60:40) which was significantly lower than 75% RDF + 5 t FYM and 50% RDF + 10 t FYM at 60 days of crop growth.

Among the weed control treatments, significantly lower dry weight of the entire weeds flora was found in bispyribac-Sodium 25 g/ha as compared to brown manuring practice, Almix 4 g/ha and pyrazosulfuron 25 g/ha. Bispyribac-sodium is the most popular herbicide for weed management in rice. It is widely recommended for weed control without any adverse effect on crop growth.

Table 1. Effect of nutrient and weed management practices on dry weight of weeds at 60 DAT, yield of rice crop and nutrient uptake of rice crop

Treatment	Total weed dry weight at 60 DAT	WCE (%)	Grain yield (t/ha)	Straw yield (t/ha)	N		P		K	
					Grain	Straw	Grain	Straw	Grain	Straw
Nutrient management										
100% RDF (120:60:40)	4.00 (19.06)	-	3.68	5.08	46.94	30.28	12.96	8.21	11.79	69.53
75%RDF+5 t FYM	4.25 (21.46)	-	3.49	4.87	43.74	28.08	11.81	7.38	10.82	65.67
50%RDF+10 t FYM	4.46 (23.62)	-	3.39	4.72	42.11	26.27	11.14	6.69	10.16	62.77
LSD (P=0.05)	0.08	-	1.93	2.67	2.36	2.00	0.85	0.67	0.63	3.85
Weed management										
Brown manuring	5.17 (25.78)	57.84	3.37	4.55	41.58	26.90	10.79	6.84	10.12	61.01
Bispyribac-Sodium 25 g/ha	3.20 (9.38)	84.66	4.12	5.51	52.50	33.62	14.45	8.83	13.19	76.61
All-mix 4 g/ha	4.42 (18.63)	69.53	3.52	4.74	44.22	27.05	11.65	6.64	10.57	64.08
Pyrazosulfuron 25 g/ha	3.77 (13.35)	78.16	3.60	4.86	45.51	28.24	12.25	7.32	11.17	66.20
Weed Free	1.00 (0.00)	0.00	4.29	5.77	54.76	35.83	15.90	9.83	14.20	79.08
Weedy	7.87 (61.15)	-	2.24	3.91	27.01	17.61	6.77	5.10	6.29	48.96
LSD (P=0.05)	0.12	-	2.73	3.78	1.61	2.83	1.21	0.95	0.89	5.45

The nutrient uptake was the highest under 100 % RDF, while the lowest value was observed under 50% RDF + 10 t FYM. The uptake of N, P and K was maximum under bispyribac-sodium, which was significantly more than rest of the treatments. The decrease in uptake of N, P and K under unweeded control was to extent of 41- 49%.

CONCLUSION

It was concluded that rice with 100 % RDF and weed control with bispyribac-sodium might be best option for higher productivity.

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Efficacy of new generation herbicides on weed flora in sugarcane ratoon

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Sugarcane (*Saccharum officinarum* L.) is a versatile crop that provides sugar, bio-fuel, fiber and manure besides many byproducts. In India, sugarcane is grown under diverse agro climatic situations covering an area of 5.30 million ha producing 366 million tonnes of sugarcane with the productivity of 69.02 t/ha accounting over one-fifth of the total area under cane in the world (Anonymous, 2015). Cultural method of weed management is most effective to control weeds but timely availability of labourers is a problem besides increase in wages. Therefore, herbicidal control of weeds has been considered to be economical in sugarcane. Continuous use of herbicides with similar mode of action may lead to shifting of weed flora and also development of herbicidal resistance. So there is a need to study the use of new herbicides having different mode of action in sugarcane; hence the present investigation was undertaken.

METHODOLOGY

A field experiment was carried out during rainy season of 2016 at ICAR- Directorate of Weed Research, Jabalpur (M.P.) to test the efficacy of new generation herbicides in sugarcane ratoon. Twelve treatments consisting of halosulfuron methyl, topramezone, tembotrione along with conventional herbicides (atrazine and metribuzin) and hand weeding were arranged in a Randomized Block Design with three replications. Sugarcane variety 'Co 3505' was ratooned in the experimental field with recommended package of practices. Post-emergence herbicides like 2,4-D, halosulfuron, topramezone and tembotrione etc. were applied to respective plots 25 days after the application of pre-emergence herbicides with knapsack sprayer. Data on weed flora, weed density and weed dry matter were recorded.

RESULTS

Broad-leaved weeds were predominant (65%), followed by grassy weeds (29%) and sedges (6%). Post-emergence herbicides like halosulfuron, topramezone, tembotrione and 2,4-D did not show any phytotoxic effects on sugarcane. Herbicidal treatments significantly influenced the density and dry matter production of weeds. Unweeded control recorded higher total weed density which was on par with atrazine applied alone. Among different post-emergent herbicides in sugarcane lowest total weed density was observed in topramezone + atrazine applied plots which was on par with halosulfuron + metribuzin, halosulfuron + atrazine, metribuzin *fb* 2, 4-D, halosulfuron + 2,4-D, atrazine *fb* 2,4-D and tembotrione + atrazine. The minimum weed dry weight was also recorded in these treatments, which was significantly lower than all other treatments. Among the herbicidal treatments, topramezone + atrazine recorded maximum weed control efficiency (66.3%). This clearly indicated that weeds were controlled effectively under topramezone + atrazine.

Table 1. Weed density, weed dry weight and weed control efficiency as influenced by different weed control treatments

Treatment	Weed density (no./m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)
Atrazine 1.5 kg/ha pre-emergent (PE)	7.81 (61)	9.33 (87.1)	22.4
Atrazine 1.5 kg/ha PE *fb* 2,4-D 1.0 kg/ha at 2-4 leaf stage of weed	5.55 (32.3)	6.64 (47.1)	44.8
Metribuzin 1.0 kg/ha pre-emergent (PE)	6.77 (46.7)	7.96 (64.9)	32.7
Metribuzin 1.0 kg/ha PE *fb* 2,4-D 1.0 kg/ha at 2-4 leaf stage of weed	4.95 (26.3)	5.91 (38.0)	50.8
Halosulfuron-methyl 67.5 g/ha at 2-4 leaf stage of weed	7.31 (54.0)	9.01 (82.1)	27.3
Halosulfuron-methyl 67.5 g/ha + atrazine 625 g/ha at 2-4 leaf stage of weed	4.98 (25.7)	5.74 (33.7)	50.5
Halosulfuron-methyl 67.5 g/ha + metribuzin 525 g/ha at 2-4 leaf stage of weed	4.32 (18.3)	5.49 (30.3)	57.1
Halosulfuron-methyl 67.5 g/ha + 2,4-D 500 g/ha at 2-4 leaf stage of weed	5.13 (26.7)	7.07 (51.0)	49.0
Topramezone 25.2 g/ha + atrazine 625 g/ha at 2-4 leaf stage of weed	3.39 (12.7)	4.44 (22.2)	66.3
Tembotrione 120 g/ha + atrazine 625 g/ha at 2-4 leaf stage of weed	5.32 (30.0)	6.28 (41.0)	47.1
Mechanical hoeing at 90 and 120 days of ratooning	2.04 (3.7)	3.36 (10.8)	79.7
Unweeded Control	10.06 (101)	11.10 (123)	-
LSD (P=0.05)	2.45	2.78	-

CONCLUSION

It was concluded that post-emergence application of topramezone + atrazine, halosulfuron + metribuzin, halosulfuron + atrazine, tembotrione + atrazine may be suitable options for controlling the diverse weed flora in sugarcane.

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Assessment of performance of different herbicide for controlling weeds in onion in farmers' field

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Onion (*Allium cepa* L.) is one of the most important vegetable crops in Hooghly district. Low productivity of onion in irrigated farming situation of this district was observed due to severe infestation of weeds. Weed competition in onion is a global problem because in its initial growth period it has very poor root system to compete with weeds. Uncontrolled weed growth can reduce the bulb yield to the tune of 40-80% depending upon the intensity of weeds during its critical crop-weed competition period (Mishra *et al.* 1986). Keeping these in view, the present experiment was carried out to study the effect of different herbicides in onion in farmer's field of Hooghly district of West Bengal.

METHODOLOGY

Hooghly Krishi Vigyan Kendra has conducted a field experiment in On Farm Testing mode in farmer's field during 2014-15 and 2015-16 with 7 farmers at Balagarh block of Hooghly district of West Bengal, India. The micro farming situation of those experimental areas was Irrigated medium land having clay to clay loam soil with major cropping system of jute-aman- paddy-onion. In total four treatments were taken along with farmer's own practice of two hand weeding at 14 and 42 DAT (FP). The other three treatments were application of oxyflurofen 23.5 EC 1 ml/l of water at 7 DAT + one hand weeding at 42 DAT (TO-I), application of oxyflurofen 23.5 EC 0.75 ml along with quizalofop-p-ethyl 10 EC 1.25 ml/l of water at 15 DAT + one hand weeding at 42 DAT (TO-II), and application of pretilachlor 30.7 EC 1ml/l at 1 DBT *fb* oxyflurofen 23.5 EC 0.75 ml along with quizalofop-p-ethyl 10 EC 1.25 ml/l of water at 15 DAT (TO-III). Seedlings of onion *cv.* 'Sukhsagar' were transplanted with its normal package of practices and the recommended fertilizer dose of 150:80:100:40 kg NPKS/ha.

RESULTS

The predominant weed species present in experimental field were *Digitaria sanguinalis*, *Cynodon dactylon*, *Echinochloa colonum*, *Eleusine indica*, *Cyperus rotundus*, *Euphorbia hirta*, *Ageratum conyzoides*, *Amaranthus viridis*, and *Physalis minima*. The data indicated that different weed management practices exerted significant effect on dry weight of weeds during the experimental period and significantly reduced the dry weight of weeds over the farmers practice. In both 21 and 31 DAT, lowest weed dry weight (2.23 and 2.53 respectively) was recorded with pretilachlor 30.7 EC 1 ml/l 1 DBT and followed by oxyflurofen 23.5 EC 0.75 ml along with quizalofop-p-ethyl 10 EC 1.25 ml/l of water at 15 DAT because use of combination of herbicides are controlling the weeds with a broad spectrum in later part of crop growth stage. This result was accordance with the findings of Bhutia *et al.* (2005) whereas pre-planting application of pretilachlor again controlling the grassy just after transplanting of seedling. The best weed control efficiency (WCE) was observed with TO-III (45.82 %) at 35 DAT followed by TO-II (33.19 %).

Table Effect of different treatments on weed, yield component, yield and economics in onion

Technology option	No. of trials	Weed dry matter (g 0.5/m^2)		Yield component		Yield (t/ha)	Cost of cultivation (Rs./ha)	Gross return (Rs./ha)	Net Return (Rs/ha)	BC Ratio
		21 DAT	35 DAT	Bulb weight (g)	Bulb diameter (cm)					
FP	7	3.01	4.67	95.4	5.33	2.44	156375	221700	65325	1.41
TO-I		3.22	4.17	99.9	5.39	2.50	144125	226500	82375	1.57
TO-II		2.64	3.12	106.7	5.56	2.59	145625	235200	89757	1.61
TO-III		2.23	2.53	113.5	5.82	2.66	138000	241200	103200	1.75
LSD(P=0.05)		0.52	0.69	5.97	NS	0.08	-	-	-	-

Experimental data showed that all the different weed management practices significantly influenced the growth and yield of the crop. Higher values for bulb weight (g) and bulb diameter (cm) were obtained from those plot where combination of herbicides were used for controlling the weeds and also for maintaining long weed free situation resulting in better growth of the crop. The maximum yield was received from the TO-III (2.66 t/ha) which is significantly higher than all other treatments and the lowest yield was obtained from the farmers' practice (2.44 t/ha) where no herbicide was applied.

The maximum net returns of Rs. 103200/ha was received in TO-III where herbicides were applied twice as PP and as PoE and the minimum was Rs. 65325/ha where weeds were controlled manually using labours. Similarly, the maximum B: C ratio of 1.75 was accrued with the TO-III.

CONCLUSION

It can be concluded that application of pretilachlor 30.7 EC 1 ml/l 1 DBT *fb* oxyflurofen 23.5 EC 0.75 ml along with quizalofop-p-ethyl 10% EC 1.25 ml/l of water at 15 DAT was found most effective and economic for controlling weeds and can be recommended for better productivity of onion at Hooghly.

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Response of rice to different herbicides under dry direct seeded rice system in Nagaland

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Direct seeded rice, a common practice before green revolution in India, is becoming popular once again because of its potential to save water and labour (Gupta *et al.* 2006). Currently, direct seeded rice in Asia occupies about 29 Million hectares which approximately 21% of the total rice area in the region. In Nagaland, rice is the for most cereal crop of the people with about 70% of the population directly or indirectly engaged in agriculture. It is grown under varying agro climatic condition rain fed upland/jhum land, rain fed, lowland/ waterlogged area, wet paddy lands terraces with irrigation facility etc. The weed presence is higher in dry direct-seeded culture than in wet direct-seeded and transplanted rice cultures mainly because of differences in land preparation. The use of only one method of weed control in a direct-seeded rice crop may not be successful for raising a good crop. Various methods such as cultural practices and manual, mechanical, and chemical methods should be carried out together. Therefore keeping these facts into consideration, the present investigation was taken up to find out the suitable weed management practices for production of rice in Nagaland.

METHODOLOGY

Field experimental was conducted at School of Agricultural Science and Rural Development (SASRD), Nagaland University, Medziphema Campus during rainy season of the 2013. The soil of the experimental field was sandy loam, well drained with strong acidic pH (4.8), high organic carbon (1.70%), medium in available nitrogen (280.21 kg/ha), low in available phosphorus (15.5 kg/ha) and medium in available potassium (256.97 kg/ha). The design was randomized block design (RBD) with three replications to evaluate effectiveness of different weed management practices. The crop variety *'Likhemo'* was used for study. In case of observation on weeds, normality of distribution was not seen and hence, the values were subjected to square root transformation ($\sqrt{X+0.5}$) prior to statistical analysis to normalize their distribution.

RESULTS

The dominant weed species *Brachiaria reptans* (L.), *Cynodon dactylon* (L.), *Digitaria sanguinalis* (L.), *Echinochloa crusgalli* (L.), *Eleusine indica* and *Poa annua* (L.) in grassy weeds, *Ageratum conyzoides* (L.), *Amaranthus viridis* (L.) *Bidens pilosa* (L.), *Borreria hispidia, Cassia tora* (L.), *Chromoleana odorata, Commelina benghalensis* (L.), *Ipomoea hispidia* Roem. and Sch., *Leucas aspera, Mimosa spinosa, Portulaca oleracea* L., *Sida acuta* L. and *Sida cordifolia* (L.) in broad leaved weeds and *Cyperus rotundus* (L.) and *Cyperus iria* (L.) in sedges were present in experimental field.

The weed density and dry weight of weeds were significantly reduced by all treatments over weedy check. The lowest weed density and dry weight was recorded under bispyribac sodium salt 250 ml/ha PoE at 15 DAS + 1 Hand weeding at 30 DAS followed by stale seed bed technique followed by bispyribac sodium salt 250 ml/ha POE at 15 DAS.

Table 1. Effect of different herbicides on weed density, dry weight, crop growth, yield and economics of rice

Treatment	Weed density	Dry weight (g/m^2)	Plant height (cm)	No. of grains/ panicle	Test weight (g)	Grain yield (t/ha)	B:C
W_1 Weed free	0.71 (0.00)	0.71 (0.00)	130.22	166.67	22.10	3.32	0.56
W_2 Weedy check	10.1 (100.5)	13.83 (190.9)	114.17	65.62	20.54	1.24	0.22
W_3 Farmer's practices (common salt 180 kg/ha)	9.31 (89.77)	12.28 (169.74)	119.75	96.56	20.85	1.51	0.29
W_4 Bispyribac-sodium salt 25 g/ha POE at 15 DAS	6.61 (45.88)	7.01 (48.78)	123.49	131.78	21.07	2.19	0.83
W_5 Bispyribac-sodium salt 25 g/ha POE at 15 DAS + 1 hand weeding at 30 DAS	4.68 (22.00)	4.53 (28.54)	129.95	157.90	21.93	3.11	1.18
W_6 Stale seed bed technique followed by Bispyribac sodium salt 25 g/ha POE at 15 DAS	5.59 (31.55)	6.52 (44.76)	125.94	153.34	21.79	3.08	1.43
W_7 Brown manuring followed by 2,4-D 1/ha at 30 DAS	8.68 (77.11)	11.89 (146.37)	124.10	115.87	21.56	2.41	1.21
W_8 Plastic mulching up to 50 DAS	5.59 (36.00)	10.57 (125.04)	125.39	146.68	21.58	2.73	0.90
LSD(P=0.05)	2.65	4.13	7.23	19.46	1.18	0.24	

*The data is subjected to square root transformation. Values in parenthesis are original values.

All the growth and yield parameters were significantly influenced by all weed control treatments. Weed free treatment had got significant superiority over weedy check. Under chemical weed control, bispyribac sodium salt 25 g/ha PoE at 15 DAS + 1 Hand weeding at 30 DAS recorded maximum plant height and number of tillers, which was significantly superior over weedy check and farmers practice. Higher grain yield was also recorded with this treatment and it was found at par with all treatments except weedy check and farmer practice. In economics, stale seed bed technique followed by bispyribac sodium salt 25 g/ha PoE at 15 DAS was recorded highest B:C ratio than other treatments.

CONCLUSION

It was concluded that stale seed bed technique followed by bispyribac sodium salt 25 g/ha PoE at 15 DAS was most effective for controlling weeds, improving grain yield and profitability of direct seeded rice in Nagaland.

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Efficacy of imazethapyr on weed management in lentil under lateritic soil of West Bengal

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Lentil is a poor competitor of weed due to its short stature and early slow growth and it suffers from weed competition resulting in considerable yield loss. In general, pre-emergence herbicides are recommended for weed management in lentil, but their efficacy is sometimes reduced due to variation in climatic and edaphic factors. Pre-emergence herbicides also have the limitation of narrow elasticity in time of application. Recently the post-emergence herbicide imazethapyr has shown promising results in management of broad spectrum weeds in pulses including lentil (Chandrakar *et al.* 2016). Since the information on the efficacy of the herbicide especially in lentil is lacking under lateritic soil of West Bengal, the present investigation was carried to find out the efficacy of post-emergence application of imazethapyr at different doses on weed management and productivity of lentil.

METHODOLOGY

A field experiment was carried out during the *Rabi* season of 2014 and 2015 in the farmer's field of village Binuria, Sriniketan, Birbhum, West Bengal with lentil variety '*Asha*' (*B-77*). Eight treatments comprising of imazethapyr at 12.5, 25, 37.5, 50 g/ha and quizalofop-ethyl at 50 g/ha at 25 DAS, pendimethalin at 750 g/ha as pre-emergence, hand weeding twice at 20 and 40 DAS and untreated control were replicated thrice in a randomized block design. The crop was fertilized with 30 kg N, 50 kg each of P_2O_5 and K_2O per hectare. All other recommended agronomic practices and plant protection measures were adopted to raise the crop. The data on density and dry weight of weeds were recorded at 60 DAS. Weed control efficiency (%) was computed using the dry weight of weeds.

RESULTS

Total seven weeds species were present in the experiment field out of which *Digitaria sanguinalis* and *Cynodon dactylon* among the grasses and *Croton bonplandianum* and *Gnaphalium indicum* among the broadleaved weeds were predominant during both the years. The lowest count and dry weight of weeds were registered under hand weeding twice at 20 and 40 DAS. Imazethapyr at 50 g/ha applied at 25 DAS registered the highest weed control efficiency but it showed phytotoxicity in lentil crop. Singh *et al.* (2014) also reported phytotoxic effects of imazethapyr in lentil at higher doses. Among the herbicidal treatments, application of imazethapyr at 50 g/ha registered the lowest density and dry weight of weeds which were statistically at par with imazethapyr at 37.5 g/ha (Table 1). Post emergence application of imazethapyr at 37.5 g/ha at 30 DAS registered the higher weed control efficiency at 60 DAS. About 30.9-34.8% yield reduction was observed due to weed competition in lentil. The highest seed yield (1.09 and 1.11 t/ha) was recorded with hand weeding twice at 20 and 40 DAS which was statistically at par with imazethapyr at 37.5 g/ha at 30 DAS (1.06 and 1.05 t/ha). Effective and timely management of broad spectrum weeds by these treatments facilitated better crop growth with sufficient space, light, nutrient and moisture which resulted in higher seed yield in lentil.

Table 1. Effect of treatments on density and dry weight of weeds, weed control efficiency and seed yield of lentil

Treatment	Total weed density (no. /m^2) at 60 DAS		Total weed dry weight (g /m^2) at 60 DAS		Weed control efficiency (%)		Seed yield (kg/ha)	
	2014	2015	2014	2015	2014	2015	2014	2015
Imazethapyr at 12.5 g/ha	42.11	45.30	42.33	45.12	44.3	45.4	825	811
Imazethapyr at 25 g/ha	21.48	22.12	19.37	18.15	74.5	78.0	973	955
Imazethapyr at 37.5 g/ha	14.33	15.50	11.28	10.21	85.2	87.6	1064	1053
Imazethapyr at 50 g/ha	11.03	12.32	7.98	8.25	89.5	90.0	912	899
Quizalofop-ethyl at 40 g/ha	40.16	43.98	31.07	32.95	59.1	60.1	848	865
Pendimethalin at 750 g/ha	39.80	37.36	37.82	35.36	50.2	57.2	842	854
Hand weeding twice	6.39	6.44	2.84	1.72	96.3	97.9	1090	1114
Unweeded control	63.52	66.43	75.95	82.66	0	0	752	727
LSD (P=0.5)	5.15	4.08	3.62	4.85	-	-	86.9	85.2

CONCLUSION

Post-emergence application of imazethapyr at 37.5 g/ha at 25 DAS appeared to be a promising and effective weed management practice for managing broad spectrum weeds and obtaining higher seed yield of lentil.

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Effect of new herbicide molecules on weed growth and yield of groundnut

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Groundnut (*Arachis hypogaea* L.) is most important oilseed crop of India grown during *kharif* season. The slow initial growth of groundnut and favourable weather conditions during *kharif* season allow the weeds to grow faster. Season long weed competition reduces the yield as high as 24 to 70% (Wani *et al.* 2010) in groundnut. The first four to eight weeks of crop growth period are critical for weed control in groundnut (Jat *et al.* 2011). During rainy season, effective and economical weed control is not possible through manual and mechanical weeding due to unfavourable soil condition and also the unavailability of costly laborers. Herbicides have been accepted as cost-effective tool to manage weeds menace in groundnut. Considering the above facts, an attempt was made to study the comparative efficacy of pre- and post- emergence herbicide in groundnut.

METHODOLOGY

A field experiment was conducted during *kharif* 2016, on clay loam soil of Main Agricultural Research Station, UAS, Raichur coming under the North eastern dry zone of Karnataka, to study the bioefficacy of combination of pre- and post- emergence herbicides against complex weed flora and their effect on growth and yield of groundnut. Ten treatments consisting of combination of pre- and post- emergence herbicides and hand weeding thrice at 15, 30 and 45 DAS were replicated thrice in a randomized complete block design using groundnut *cv* 'K-9' which was sown at a common spacing of 30 x 10 cm and 25 kg N, 50 kg P_2O_5 and 25 kg K_2O/ha was applied at the time of sowing.

RESULTS

The Major weed flora observed in the experimental plots were *Alternenthera sessilis, Ocimun cannum, Dinebra retroflexa, Parthenium hysterophorus, Cynodon dactylon, Phyllanthus niruri, Amaranthus viridis, Echinochloa colona* and *Sida acuta.*

At 60 DAS, significantly lower weed density, weed dry weight and higher weed control efficiency was recorded in the plots where hand weeding (HW) carried out at 15, 30 and 45 DAS as compared to other treatments. Among the herbicidal treatments, sequential application of pendimethalin at 750 g/ha as pre-emergence *fb* imazethapyr at 75 g/ha at 2-5 leaf stage, pendimethalin at 1000 g/ha as pre-emergence *fb* imazethapyr at 75 g/ha at 2-5 leaf stage, imazethapyr + imazamox (RM) at 75 g/ha at 10-15 DAS, imazethapyr + pendimethalin (RM) at 1000 g/ha as pre emergence recorded lower weed density and dry weight of weeds. The highest weed control efficiency was recorded in pendimethalin at 750 g/ha as pre-emergence *fb* imazethapyr at 75 g/ha at 2-5 leaf stage (81.37%), pendimethalin at 1000 g/ha as pre- emergence *fb* imazethapyr at 75 g/ha at 2-5 leaf stage (78.16%), imazethapyr + imazamox (RM) at 75 g/ha at 10-15 DAS (75.62%), imazethapyr + pendimethalin (RM) at 1000 g/ha as pre-emergence (72.15%) (Table 1).

Table 1. Effect of herbicide mixtures on density and dry weight of weed, weed control efficiency at 60 DAS, pod yield, haulm yield and harvest index in groundnut

Treatment	Weed density (no./m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)	Pod yield (kg/ha)	Haulm yield (kg/ha)	Harvest index
Pendimethalin at 30 EC 1000 g/ha as pre-emergence	8.41 (69.77)	4.12 (16.01)	53.76	1450	1652	0.47
Pendimethalin at 38.7 CS 750 g/ha as pre-emergence	8.02 (63.28)	3.94 (14.62)	57.77	1501	1756	0.46
Imazethapyr 10% EC 75 g/ha as pre-emergence	8.76 (75.77)	4.28 (17.34)	49.91	1375	1584	0.46
Imazethapyr + pendimethalin (RM) 32% EC 1000 g/ha as pre-emergence	6.61 (42.70)	3.26 (9.64)	72.15	1741	2002	0.47
Imazethapyr 10% EC 75 g/ha at 2-5 leaf stage	7.22 (51.10)	3.56 (11.71)	66.18	1613	1833	0.47
Imazethapyr + imazamox (RM) 70% WG 75 g/ha at 10-15 DAS	6.19 (37.30)	3.07 (8.44)	75.62	1906	2211	0.46
Pendimethalin at 30 EC 1000 g/ha as pre-emergence *fb* Imazethapyr 10% EC 75 g/ha at 2-5 leaf stage	5.82 (32.90)	2.93 (7.56)	78.16	2014	2199	0.48
Pendimethalin at 38 CS 750 g/ha as pre-emergence *fb* Imazethapyr 10% EC 75 g/ha at 2-5 leaf stage	5.37 (27.90)	2.73 (6.45)	81.37	2154	2468	0.47
Hand weeding thrice at 15, 30 and 45 DAS	4.30 (17.50)	2.22 (3.95)	88.59	2344	2643	0.47
Weedy check	12.67 (159.4)	5.97 (34.62)	53.76	582	711	0.45
LSD (P=0.05)	**0.14**	**0.24**	**-**	**161**	**71.00**	**NS**

Values in parenthesis are original. Data transformed to square root transformation; NS: Non significant

Significantly higher pod (2.34 t/ha) and haulm yield (2.64 t/ha) was recorded with hand weeding (HW) carried out thrice at 15, 30 and 45 DAS. Among the herbicidal treatments, the plots treated with pendimethalin at 750 g/ha as pre-emergence *fb* imazethapyr at 75 g/ha at 2-5 leaf stage recorded higher pod and haulm yield (2.15 and 2.47 t/ha, respectively), pendimethalin at 1000 g/ha as pre-emergence followed by imazethapyr at 75 g/ha at 2-5 leaf stage (2.01 and 2.20 t/ha, respectively) and imazethapyr + imazamox (RM) at 75 g/ha at 10-15 DAS (1.90 and 2.21 t/ha, respectively). Unweeded control gave the lowest pod (0.58 t/ha) and haulm yield (0.71 t/ha) due to severe competition from all types of weeds.

CONCLUSION

Under labour scarce condition, farmer can go for sequential application of pendimethalin at 750 g/ha as pre-emergence *fb* imazethapyr at 75 g/ha at 2-5 leaf stage for better control of weeds as well as for higher pod yield.

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Effect of herbicide combinations on weed flora and yield of direct seeded rice

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Rice (*Oryza sativa L.*) is a major cereal crop and staple food for more than half of the world's population. About 90% of the world's rice is produced and consumed in Asia (FAO 2014). Direct seeding of rice has more benefits as compared to traditional transplanting. However, weeds are one of the limiting factors in direct- seeded rice, which reduce the yield up to 50-100%. Adoption of DSR technology usually leads to shift in weed flora composition towards difficult-to-control weeds (Singh *et al.* 2013). In this situation, use of herbicides and combination of herbicides are becoming more popular in DSR because they are more effective, easy to apply, provide selective control, saves labour and costs less. However, meager information is available on the use of combination of herbicide for control of weeds, hence the present investigation was undertaken.

METHODOLOGY

A field experiment was conducted at College of Agriculture, Dapoli (MS) during *kharif* 2015. Ten treatments consisting of different herbicides and combination of herbicides and hand weeding were arranged in a randomized block design with three replications. Rice variety 'Ratnagiri-1' was direct seeded in the experimental field with recommended package of practices. Fertilizers were applied uniformly through urea, single super phosphate and muriate of potash 100 kg N, 50 kg P_2O_5 and 50 kg K_2O/ha, respectively.

RESULTS

Grassy weeds and sedges were predominant (73%), followed by broad-leaved (27%). *Cyperus rotundus* and *Isachne globosa* among the sedges and grassy weeds while *Mimosa pudica* among the broad-leaved weeds were more dominant. Herbicidal treatments significantly influenced the population and dry matter production of weeds. Among the herbicidal treatments, the lowest weed density (7.33/0.25m^2) and dry weight were observed under pendimethalin 1000 g/ha (PE) *fb* one hand weeding at 25-30 DAS, followed by pendimethalin 1000 g/ha (PE) *fb* bispyribac-Na 25 g/ha (20 DAS) *fb* manual weeding (45 DAS) (9.0/0.25m^2) (Table 1). These results are in conformity with the findings of Prabhakaran *et al*. (2016). Maximum weed index (25.77%) was recorded in unweeded check. Among the herbicidal treatments, pendimethalin 1000 g/ha (PE) followed by one hand weeding recorded minimum weed index (4.3%). This clearly indicated that weeds were controlled effectively under pendimethalin 1000 g/ha (PE) followed by one hand weeding (25-30 DAS). The highest grain yield (3.96 t/ha) was recorded with hand weeding (20, 40 and 60 DAS) and the lowest (2.49 t/ha) was under unweeded check. The yield loss due to uncontrolled growth of weeds as compared to hand weeding was 74.2%. Among the herbicidal treatments, pendimethalin 1000 g/ha (PE) *fb* one hand weeding (25-30 DAS) recorded maximum grain yield (3.21 t/ha), which was at par with pendimethalin 1000 g /ha (PE) *fb* bispyribac-Na 25 g/ha (20 DAS) *fb* manual weeding (45 DAS) but significantly higher as compared to rest of the herbicides and their combinations.

Table 1. Weed growth, yield and economics of rice as influenced by different weed control treatments

Treatment	Weed density (no./0.25m^2)		Weed dry matter (g/0.25m^2)		Weed Index	Grain yield (t/ha)	Straw yield (t/ha)	Cost of cultivation (Rs/ha)	B:C ratio
	Grsses & sedges	BLWs	Grasses & sedges	BLWs					
Bispyribac-Na 25 g/ha	4.26 (18.0)	2.66 (6.67)	1.77 (2.67)	1.66 (2.27)	17.09	2.78	3.35	43408	0.91
Pendimethalin 1000 g/ha *fb* bispyribac-Na 25 g/ha	4.79 (22.7)	2.45 (5.67)	1.83 (2.87)	1.77 (2.65)	16.94	2.79	3.39	52546	1.01
Oxadiargyl 100 g/ha *fb* bispyribac-Na 25 g/ha	4.61 (21.0)	2.54 (6.00)	1.81 (2.82)	1.61 (2.11)	13.72	2.89	3.54	52740	1.03
Pyrazosulfuron 20 g/ha *fb* bispyribac -Na 25g/ha	5.31 (28.3)	2.59 (6.33)	1.91 (3.16)	1.78 (2.68)	23.05	2.58	3.06	44694	1.02
Pendimethalin 1000 g/ha *fb* bispyribac-Na 25 g/ha *fb* manual weeding	3.07 (9.0)	2.47 (5.67)	1.25 (1.08)	1.58 (2.08)	4.41	3.21	3.86	52505	1.19
Pendimethalin 1000 g/ha *fb* manual weeding (Pendistar)	2.79 (7.3)	2.09 (4.00)	1.64 (2.18)	1.55 (1.99)	4.29	3.21	3.88	50032	1.28
Bispyribac –Na 25 g/ha + (chlorimuron + metsulfuron) 4 g/ha	4.34 (18.7)	2.59 (6.33)	2.67 (6.67)	1.81 (2.77)	18.49	2.73	3.32	44329	1.04
Three mechanical weedings (cono / rotary weeder)	3.23 (10.3)	2.15 (4.33)	1.76 (2.60)	1.54 (1.99)	25.23	2.51	3.14	55225	0.92
Weed free check (HW at 20,40, and 60 DAS)	2.18 (4.3)	1.76 (2.67)	1.67 (2.31)	1.30 (1.24)	-	3.35	4.02	56873	1.19
Weedy check	6.37 (40.3)	3.18 (9.67)	2.45 (5.59)	2.51 (5.85)	25.77	2.49	2.92	35935	0.73
LSD (P=0.05)	(0.90)	0.64	(0.42)	(0.52)		0.16	0.17		

Figures in parentheses are original values. Data was subjected to square root transformation $\sqrt{x+0.5}$ before the analysis.

The maximum straw yield (4.02 t/ha) was recorded in hand weeding (20, 40 and 60 DAS) and the lowest (2.92 t/ha) in unweeded check. Herbicidal treatments resulted in considerably lower cost of cultivation compared with hand weeding. The B:C ratio was found maximum with pendimethalin 1000 g /ha (PE) *fb* one hand weeding (25-30 DAS), followed by pendimethalin 1000 g/ha (PE) *fb* bispyribac-Na 25 g/ha (20 DAS) *fb* manual weeding (45 DAS). These results are in conformity with the findings of Prabhakaran *et al.* (2016).

CONCLUSION

It was concluded that post-emergence application of pendimethalin 1000 g/ha (PE) *fb* one hand weeding (25-30 DAS) was most effective for controlling weeds, improving grain yield and profitablility of direct-seeded rice.

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Effect of different post-emergence herbicides on weed and yield of wheat

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Wheat is one of the most important cereal crops of the world and the second important staple food crop of India after rice. Inadequate weed control in wheat is one of the important reasons of poor productivity of this crop. Acute problem of booth grassy and broad leaf weeds is becoming very common in this crop, which often results in huge yield loss and makes the weed control more complex (Singh *et al.* 2002). Weeds in this crop are controlled by many methods including different herbicides but most of the methods are not perfect due to one or other reasons. Since the continuous use of herbicides with similar mode of actions may results in resistance development as well as build up residue in soil, hence it was felt necessary to evaluate various herbicides, their combinations and ready mix herbicides against the mixed weed complex in this crop.

METHODOLOGY

A field experiment on weed control through of use of the post-emergence herbicides in wheat was conducted at Research Farm of Agronomy, N.D. University of Agriculture and Technology, Kumarganj, Faizabad (U.P.) during *Rabi* 2012-13. Experiment consisted of 12 weed control treatments namely isoproturon 1000 g/ha, isoproturon + 2,4-D 1000 + 500 g/ha, clodinafop + metsulfuron-methyl 60 + 4 g/ha, clodinafop + metsulfuron-methyl 400 g/ha, clodinafop + 2,4-D 60 + 500 g/ ha, sulfosulfuron 25 g/ha, sulfosulfuron + metsulfuron-methyl 25 + 4 g/ha, sulfosulfuron + metsulfuron-methyl 40 g/ha, metribuzin 175 g/ha, mesosulfuron + iodosulfuron 400 g/ha, weed free and weedy check. Experiment was conducted in RBD with three replication using wheat variety 'NW- 1014'. All the herbicides were applied as post emergence at 35 DAS. The soil of the experiment was silt loam in texture, slightly alkaline in reaction, low in organic matter and available N and P and medium in potassium.

RESULTS

Clodinafop + metsulfuron-methyl 400 g/ha was more effective in reducing density of weeds as compared to other herbicides (Table 1). This might be due to the fact that clodinafop 60 g/ha controls the *P. minor* and metsulfuron-methyl at 4 g/ha controls the *P. minor* as well as all the broad leaf weeds. On the other hand, alone application of either of the herbicide was not found effective to control all the weeds in the entire crop season. Similar results were found by Malekian *et al.* (2014).

Clodinafop + metsulfuron-methyl 400 g/ha was recorded higher dry matter accumulation which is at par with mesosulfuron + iodosulfuron 400 g/ha, sulfosulfuron + metsulfuron-methyl RM 40g/ha, clodinafop + metsulfuron-methyl 60 + 4 g/ha, sulfosulfuron + metsulfuron-methyl 25 + 4 g/ha, and clodinafop + 2,4-D 60 + 500 g/ha, significantly superior over rest of the treatments. However, lowest and highest dry matter accumulation was recorded with weedy and weed free treatments, Crop dry matter is a net result of photosynthesis which remain in balance after respiration process. At the same time, growth attributes *e.g.* plant height, LAI and number of shoots (m^{-2}) have the direct effect in contributing the dry matter accumulation.

Table 1. Effect of post-emergence herbicides on various parameters in wheat

Treatment	Weed density	Dry matter accumulation (g/m^2)	Grain yield (kg/ha)	Straw yield (kg/ha)	HI
Isoproturon 1000 g/ha	5.0 (25.00)	670.56	35.23	51.45	40.64
Isoproturon + 2,4-D 1000 + 500 g/ha	4.8 (23.00)	730.80	36.69	52.50	41.13
Clodinafop + metsulfuron-methyl 60 + 4 g/ha	3.5 (12.00)	780.15	39.34	54.30	42.01
VESTA (clodinafop15% + metsulfuron-methyl 1%) RM 400 g/ha	2.3 (5.00)	860.50	41.80	55.00	43.18
Clodinafop + 2,4-D 60 + 500 g/ha	4.6 (21.00)	745.65	37.58	53.50	41.26
Sulfosulfuron 25 g/ha	5.0 (24.75)	690.45	36.25	52.30	40.93
Sulfosulfuron + metsulfuron-methyl 25 + 4 g/ha	3.8 (14.00)	765.60	38.90	54.10	41.82
Total (sulfosulfuron 75% + metsulfuron-methyl 5%) RM 40 g/ha	2.9 (7.75)	795.25	39.47	54.50	42.00
Metribuzin 175 g/ha	4.8 (23.05)	710.20	36.57	52.40	41.10
Atlantis (mesosulfuron 3% + iodosulfuron 0.6%) RM 400 g/ha.	2.6 (6.50)	800.25	40.00	55.00	42.10
Weed free	0.7 (0.00)	885.15	42.76	56.90	42.90
Weedy check	12.9 (134.65)	590.30	29.54	42.01	41.29
LSD (P=0.05)	0.46	70.285	4.173	7.007	-

A combination of clodinafop + metsulfuron-methyl 400 g/ha (41.80) followed by mesosulfuron + iodosulfuron 400 g/ ha, sulfosulfuron + metsulfuron-methyl RM 40 g/ha, clodinafop + metsulfuron-methyl 60 + 4 g/ha and sulfosulfuron + metsulfuron-methyl 25 + 4 g/ha being at par, recorded significantly higher grain yield over rest of the treatments.. It may also be due to the effective control of *C. album* and other BLWs along with *P. minor*. clodinafop + metsulfuron-methyl 400 g/ha (5.50 t/ha) followed by mesosulfuron + iodosulfuron 400 g/ha being at par recorded significantly higher level of straw yield over rest of the treatments. These results are also in conformity with the Anonymous (2009). The highest value of HI was recorded with clodinafop + metsulfuron-methyl 400 g/ha (43.18%) followed by mesosulfuron + iodosulfuron 400 g/ha (42.10%), and sulfosulfuron + metsulfuron-methyl RM 40 g/ha (42.00%) respectively. Same result also found by Singh *et al.* (2012).

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Effect of green manuring and weed control measures on weed flora and yield of rice

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Rice (*Oryza sativa* L.) being a major food crop of Konkan Region of Maharashtra is cultivated on 4.136 lakh ha with production of 10.42 lakh tones and productivity of 2.56 tones/ ha (Thaware *et al.* 2011). Weed cause yield losses from 15 to 79% in rice crop. Besides, weeds remove about 21-42 kg N, 10-13.5 kg P and 17-27 kg K/ha in transplanted rice. To maintain the soil fertility, addition of organic matter has become necessary which can be done either by applying farmyard manure or by growing green manure crops. The addition of organic matter has a relationship with the efficacy of soil-applied herbicides. The continuous use of herbicide resulted in causing resistance in grassy and broad leaved weeds against the chemicals and shortage of labours, lack of suitable weed control implements and problem of specific weeds have compelled the farmers to think for alternative strategies and herbicides have been the obvious choice for the farmers. Therefore, present experiment was undertaken to examine the combined effect of herbicides and green manuring on weed dynamics, herbicide efficacy and growth and productivity of rice.

METHODOLOGY

A field experiment was conducted at College of Agriculture, Dapoli (MS) during *kharif* 2014 The experiment was laid out in spilt plot design with three replication and eight treatment combinations. The main plot treatment was green manuring (*Sesbania rostrata*) and without green manuring whereas sub plot treatment consist of different weed control treatments, *viz.* pretilachlor-S 50 EC 0.75 kg/ha 3-7 DAT, oxadiargyl 80 WP 0.100 kg/ha 0-5 DAT, weed free check (2 HW at 20 and 40 DAT), weedy check. Green manuring of *Sesbania rostrata* was incorporated in soil after one month during puddling. After the puddling 25 to 30 days old seedling of rice *cv.* 'R-24' was transplanted with spacing 20 × 15 cm. Fertilizer dose of 100:50:50 NPK kg/ha was applied to rice crop and it was raised by following all recommended package of practices.

RESULTS

The data revealed that the weed density as well as weed growth of monocot and BLWs in kharif rice were not significantly influenced due to green manuring. Among the herbicidal treatments, application of oxadiargyl 80 WP 0.100 kg/ha 0-5 DAT recorded the lowest weed growth with maximum WCE. Interaction effect between green manuring and weed control measures on density of monocots as well as BLWs was found to be non-significant. These results are in conformity with Simerjeet Kaur and Surjit Singh (2015).

Table 1. Effects of green manuring and weed control on weed and yield of rice

Treatment	Weed density no/0.25m^2				Weed dry matter g/0.25m^2				Yield (t/ha)		WI %
	G & S	BLWs	Total	WCE	G & S	BLWs	Total	WCI	Grain	Straw	
Main plot treatment : Green manuring											
M_1: Green manuring	2.76 (7.33)	2.45 (5.58)	12.91		1.18 (1.29)	1.11 (0.75)	2.56		3.13	3.74	
M_2: without green manuring	2.70 (7.08)	2.22 (4.92)	12.00		1.30 (1.22)	1.06 (0.64)	3.10		3.00	3.60	
LSD (P=0.05)	(N.S)	(N.S.)	-		(N.S)	(N.S.)	-		N.S	N.S	
Sub plot: Weed control measures											
Pretilachlor-S 50 EC 0.75 kg/ha 3-7 DAT	2.97 (8.33)	2.34 (5.00)	13.33	24.56	1.27 (1.14)	1.10 (0.72)	1.86	10.58	3.14	3.61	14.84
Oxadiargyl 80 WP 0.100 kg/ha 0-5 DAT	2.43 (5.50)	2.36 (5.17)	10.67	39.62	1.32 (1.26)	1.13 (0.79)	2.05	1.44	2.87	3.39	21.01
Weed free check	2.19 (4.33)	1.91 (3.83)	8.16	53.82	1.24 (1.05)	1.02 (0.55)	1.60	23.08	3.49	4.43	-
Weedy check	3.34 (10.67)	2.73 (7.00)	17.67		1.36 (1.35)	1.19 (0.83)	2.18	-	2.27	2.83	35.62
LSD (P=0.05)	(0.35)	(0.38)			(0.05)	(0.08)	-	-	0.18	0.22	
Interaction effects											
LSD (P=0.05)	(N.S)	(N.S.)			(N.S)	(N.S.)	-	-	N.S	N.S.	

Figures in parentheses are original values. Data was subjected to square root transformation $\sqrt{x+0.5}$ before the analysis.

The grain and straw yield of rice were not influenced significantly due to green manuring while the significantly highest grain and straw yield was recorded with weed free check and lowest in weedy check. Among the herbicidal treatments, the application of pretilachlor-S 50 EC 0.75 kg/ha 3-7 DAT recorded maximum grain and straw yield. These results corroborates the findings of Tomar *et al.* (2009).

CONCLUSION

It can be concluded that, application of pretilachlor-S 50 EC 0.75 kg/ha 3-7 DAT in *kharif* rice reduced the weed growth and gave more grain and straw yield of rice as compared to other herbicidal treatments.

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Effect of sequential application of pre- and post-emergence herbicides on weeds and productivity of soybean

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Soybean (*Glycine max* L. Merril) grown in *kharif* season is heavily infested with weeds due to favorable moisture and temperature. Yield reduction due to uncontrolled weeds in soybean has been recorded to the tune of 30-80% (Yaduraju, 2002). Soybean yield can be enhanced by almost 50% by adopting timely weed management practices. Some weed species can be controlled with the application of pre-emergence herbicides. Tuti and Das (2011) suggested that sequential application of herbicides may provide most effective weed control than single application. Therefore, an experiment was conducted to assess the effects of sequential application of pre- and post-emergence herbicides against weeds in soybean.

METHODOLOGY

An experiment was conducted at ICAR-Directorate of Weed Research, Jabalpur during *kharif* season of 2015. Ten treatments comprising of pendimethalin (750 g/ha PE), pendimethalin (750 g/ha PE) *fb* imazethapyr (100 g/ha at 20 DAS), pendimethalin (750 g/ha PE) *fb* 1 HW (at 20 DAS), metribuzin (500 g/ha), metribuzin (500 g/ha) *fb* imazethapyr (100 g/ha at 20 DAS), metribuzin (500 g/ha PE) *fb* 1 HW (at 20 DAS), imazethapyr (100 g/ha at 20 DAS), imazethapyr (100 g/ha at 20 DAS) *fb* 1 HW (at 40 DAS), 2 HW (at 20 and 40 DAS) and unweeded control were laid out in randomized block design with three replications. The quadrat of 0.25 m^2 (0.5 m x 0.5 m) was randomly placed at four places in each plot and the species-wise weed density and weed dry biomass were recorded.

RESULTS

The experimental field of soybean was infested with monocot weeds like *Echinochloa colona* (29.28%), *Dinebra retroflexa* (35.85%), *Cyperus iria* (1.65%) and dicot weeds like *Euphorbia geniculata* (24.67%), *Phyllanthus niruri* (8.53%) and *Commelina benghalensis* (2.63%) *etc*. Pre-emergence application of pendimethalin (750 g/ha) / metribuzin (500 g/ha) was not effective in controlling second flush of weeds. Weed control efficiency was increased by either sequential application of pendimethalin (750 g/ha) / metribuzin (500 g/ha) *fb* imazethapyr 100 g/ha at 20 DAS or pre-emergence herbicide *fb* 1 hand weeding.

Pre-emergence application of pendimethalin (750 g/ha) and metribuzin (500 g/ha) slightly reduced the dry biomass of weeds as compared to unweeded check. Post-emergence application of imazethapyr (100 g/ha) at 20 DAS or 1 hand weeding at 20 DAS after pendimethalin (750 g/ha) or metribuzin (500 g/ha) increased the weed control index. Among all the treatments, post-emergence application of imazethapyr (100 g/ha) at 20 DAS followed by 1 hand weeding at 40 DAS reduced the dry biomass of all kinds of weeds to the maximum extent (98.8%). Two hand weedings done at 20 and 40 DAS was the most effective treatment in reducing the biomass of weeds.

Table 1. Effect of sequential application of herbicides on weed density, weed dry biomass, weed control efficiency, weed control index and seed yield of soybean

Treatment	Total weed density (no./ m^2)	Total weed dry biomass (g/m^2)	Weed control efficiency (%)	Weed control index (%)	Seed yield (t/ha)
Pendimethalin 750 g/ha PE	6.52 (42.00)	9.73 (94.12)	58.18	68.21	0.38
Pendimethalin 750 g/ha PE *fb* imazethapyr 100 g/ha at 20 DAS	4.49 (19.67)	3.61 (12.50)	79.29	95.49	0.86
Pendimethalin 750 g/ha PE *fb*1 HW at 20 DAS	6.23 (38.33)	4.53 (20.02)	61.92	93.10	0.72
Metribuzin 500 g/ha	6.77 (45.33)	11.73 (137.09)	55.54	54.38	0.41
Metribuzin 500 g/ha *fb* imazethapyr 100 g/ha at 20 DAS	4.81 (22.67)	2.95 (8.22)	77.63	97.26	0.78
Metribuzin 500 g/ha PE *fb* 1 HW at 20 DAS	5.99 (35.33)	9.69 (93.43)	65.66	68.42	0.80
Imazethapyr 100 g/ha at 20 DAS	5.85 (33.67)	6.30 (39.21)	67.28	87.15	0.78
Imazethapyr 100 g/ha at 20 DAS *fb*1 HW at 40 DAS	4.56 (20.33)	2.00 (3.51)	80.01	98.86	0.88
2 HW at 20 and 40 DAS	4.71 (21.67)	3.06 (8.88)	78.97	96.80	1.07
Unweeded control	10.09 (101.33)	17.35 (300.69)	0.00	0.00	0.17
LSD (P=0.05)	1.73	2.83	17.19	15.39	0.18

Values given in parenthesis are original values. Data was subjected to $\sqrt{x+0.5}$ transformation before the analysis.

Among the herbicidal treatments, sequential application of pendimethalin (750 g/ha *fb* imazethapyr (100 g/ha) attained higher values of seed yield (Table 1)

CONCLUSION

It can be concluded that sequential application of pendimethalin (750 g/ha) /metribuzin (500 g/ha) *fb* imazethapyr (100 g/ha) was the most effective strategy in controlling grassy, sedges and broad-leaved weeds and higher seed yield soybean.

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Bioefficacy of post-emergence herbicides in soybean

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Soybean occupies 42% of India's total oilseeds and 25% of edible oil production. The production incentive is related to growing global demand for oil and protein for food and feed, as well as the feasibility of crops for biodiesel production, which is extremely important for the global economy. Meanwhile, weeds are considered as the major problem in all soybean producing countries. Weeds creating competition for nutrients, space, water *etc*. reduce the crop yield and deteriorate the quality of produce hence, reduce the market value of the turnout (Arif *et al*. 2006). Even with advanced technologies, producers observed high losses due to interference by weeds. According to estimates, weeds, alone, cause an average reduction of 37% on soybean yield, while other fungal diseases and agricultural pests account for 22% of losses. Herbicide combinations are more effective weapons in tackling weed menace and thereby nutrient depletion by them than a single herbicide approach (Pisal and Sagarka 2013). Therefore, present study works out nutrient removal by weeds and crops and effect on system productivity as influenced by herbicide combinations in soybean.

METHODOLOGY

A field experiment was conducted during *kharif* 2015-16 and 2016-17 at Instructional Farm, Rajasthan College of Agriculture, Udaipur (24º35' N latitude, 74°42' E longitude and 582.17 meter above mean sea level). The soil of experimental site was clay loam in texture, medium in organic carbon (0.75%) medium in available nitrogen (277.0 kg/ha), medium in available phosphorus (20.10 kg/ha) and high in available potassium (286.0 kg/ha). Eleven weed control treatments, *viz.* weedy check , two hand weeding, pendimethalin 1.5 kg/ha (pre), quizalofop-ethyl 75 g/ha at 15 DAS, imazethapyr 100 g/ha at 15 DAS, chlorimuron-ethyl 10 g/ha at 21 DAS, propaquizafop 10 g/ha at 15 DAS, imazethapyr 75 g/ha + quizalofop ethyl 60 g/ha at 21 DAS (tank-mix), quizalofop-ethyl 60 g/ha + chlorimuron-ethyl 7 g/ha (tank-mix) at 21 DAS, propaquizafop75 g/ha + imazethapyr 75 g/ha (tank-mix) at 21 DAS and propaquizafop 75 g/ha+ chlorimuron-ethyl 7 g/ha (tank-mix) at 21 DAS as main plot factors and NP (N 20 + P_2O5 40 kg/ha), NPK (N 20 + P_2O5 40 + K_2O 30 kg/ha), NPKS (N 20 + P_2O5 40 + K_2O 30 + S 40 kg/ha) as sub-plot factors were tested in split plot design with three replications. The seeds of soybean variety '*JS 335'* were sown in rows 45 cm apart on June 10, 2015 and June 7, 2016 using 80 kg seed/ha.

RESULTS

The experimental field was infested with *Commelina benghalensis* (42.56 and 52.26% during 2015 and 2016, respectively), *Digera arvensis* (12.45 and 9.45 %), *Trianthema portulacastrum* (18.39 and 17.55%) *Echinochloa colona* (17.04 and 15.02%), *Cyperus* sp. (9.56 and 5.42%). Among all weeds, *Commelina benghalensis* was the most dominant and most dry matter accumulated weed in soybean. Among all herbicides combinations, propaquizafop 75 g/ha and imazethapyr 75 g/ha at 21 DAS significantly reduced weed density and dry matter accumulation than other herbicides combinations. Maximum weed index (66.4%) was recorded in unweeded check. The highest grain yield (2.09 t/ha and 2.16 t/ha) was recorded with imazethapyr 75 g/ha + propaquizafop 75 g/ha at 21 DAS and the lowest (0.89 t/ ha and 0.86 t/ha) was under unweeded check. The yield loss due to uncontrolled growth of weeds as compared to imazethapyr 75 g/ha + propaquizafop 75 g/ha was 57.45 % and 59.76% in 2015 and 2016 respectively.

Table 1. Effect of different herbicide combinations and nutrient management on yield of soybean

Treatment detail	Seed yield (t/ha)		Straw yield (t/ha)		Biological yield (t/ha)		Harvest index (%)	
Weed management	2015	2016	2015	2016	2015	2016	2015	2016
Weedy check	0.89	0.86	1.10	1.16	2.00	2.02	44.44	42.65
Two HW	1.99	2.05	2.46	2.31	4.45	4.36	44.65	46.98
Pendimethalin	1.11	1.26	1.37	1.48	2.48	2.73	44.51	45.94
Quizalofop-ethyl	1.73	1.70	2.14	2.25	3.87	3.95	44.60	43.06
Imazethapyr	1.82	1.88	2.24	2.37	4.06	4.25	44.68	44.21
Chlorimuron-ethyl	1.50	1.24	1.85	2.04	3.35	3.29	44.59	37.84
Propaquizafop	1.77	1.53	2.18	2.04	3.95	3.56	44.59	42.84
Imazethapyr + quizalofop	2.02	2.24	2.50	2.37	4.52	4.61	44.73	48.65
Quizalofop + chlorimuron	1.78	2.05	2.20	2.45	3.98	4.51	44.60	45.60
Imazethapyr + propaquizafop	2.10	2.14	2.59	2.51	4.69	4.64	44.79	46.01
Propaquizafop + chlorimuron	1.88	2.07	2.25	2.30	4.13	4.36	44.60	47.39
LSD (P=0.05)	0.22	0.21	0.27	0.27	0.49	0.48	NS	NS
Fertility levels								
NP	1.56	1.65	1.93	2.06	3.49	3.71	44.59	44.59
NPK	1.71	1.77	211	2.14	3.82	3.91	44.57	45.19
NPKS	1.80	1.79	220	2.35	4.00	4.14	44.70	43.14
LSD (P=0.05)	0.10	0.08	1.19	0.12	0.22	0.20	NS	41.17

CONCLUSION

It was concluded that post-emergence application of imazethapyr 75 g/ha + propaquizafop 75 g/ha at 21 DAS was most effective for controlling weeds, improving grain yield and profitability of soybean.

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Sacciolepis interrupta- an emerging weed menace in the wetlands of Kerala

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Sacciolepis interrupta is a tropical grass weed which mimics rice crop and of late has been appearing as a major weed in many rice growing areas. *Sacciolepis interrupta* is widespread in tropical and warmer temperate regions and is distributed in Asia and Africa. In India, it is reported in rice growing areas of eastern India and Kerala. The occurrence of weed was endemic in early *Kharif* and not reported in *Rabi* season, as it enjoyed the ecological situations associated with semi-dry rice, where rice is sown either by broadcasting/ drilling immediately after the receipt of pre-monsoon rains. In Kerala, the occurrence of *Sacciolepis interrupta* was earlier confined to semi-dry rice, however, now it has been reported in wet-seeded as well as transplanted rice (Renu 1999). Latha and Jaikumaran (2015) reported that in a quantitative weed survey in the rice fields of Kole lands, Sacciolepis accounted for a relative density of 2.46 per cent. The problem of *Sacciolepis interrupta* assumes significance as more and more farmers resort to direct seeding mainly because of uncertainty of timely receipt of rains and also to avoid the hassles of transplanting.

METHODOLOGY

A survey was conducted in two major rice tracts of Kerala *i.e.* Kole areas and Palakkad to study the two important aspects i.e. distribution of *Sacciolepis interrupta* in different ecological conditions of Kerala; and the extent of incidence and menace of *Sacciolepis interrupta* in these tracts. Rating of *Sacciolepis* infestations in cropped fields was given as low: (2-5 *Sacciolepis* plants/m^2), medium (6-10 *Sacciolepis* plants/m^2), and high (Ã *Sacciolepis* plants/m^2). A structured questionnaire was used as an instrument to collect data on *Sacciolepis* occurrence, its distinguishing features and management practices taken up to control it. Groups of farmers were randomly chosen for collecting data at panchayath level and questionnaire was circulated among 10 farmer groups from Kole and Palakkad. 18 statements were formulated to understand the pattern of weed occurrence and impact of the weed on yield. The major statements used to study the knowledge of farmers on period of occurrence and weed biology were:

1. Common weeds in the area
2. Period from which *Sacciolepis* become a problem
3. Season in which the weed is a problem
4. Ease of identification at seedling stage
5. Morphological characters aiding in identification
6. Herbicides usually applied
7. Herbicides effective against *Sacciolepis*
8. Herbicides ineffective against *Sacciolepis*
9. Ranking given to *Sacciolepis* as a problem weed
10. Effect of transplanting on incidence of *Sacciolepis*
11. Approximate reduction in yield due to *Sacciolepis*
12. Approximate cost of hand weeding to remove *Sacciolepis*

RESULTS

The survey among the farmers indicated that farmers are well aware of the problems of weeds in rice with regard to the infestation. *Sacciolepis* was severe in Pallakkad tract and low in Kole area. More than 80 per cent of farmers from Kole rice tract cultivate rice in relatively large plots (2-5 acres), which is much above the average size of plots for paddy cultivation in Kerala as a whole. Majority of the farmers felt that other rice weeds *i.e. Echinochloa colona*, *Leptochloa chinensis*, *Isachne miliacea*, *Oryza rufipugon*, *Ludwigia parviflora* and *Cypreus rotundus* were more prominent weeds in fields whereas *Sacciolepis* was confined to bunds. About 60 per cent farmers of this area felt that the weed is not of much importance in the rice field but it was a problem on bunds and pathways. After harvest of rice with receipt of rains, *Sacciolepis* germinates in the field and becomes problematic, leading to high labour charges for manual removal. In areas of Palakkad, where semi-dry rice is taken up, the weed is problematic. More than 80 per cent farmers rate the weed as problematic, although control was easy. However, the weed is perennial and propagates by various methods, hence, is difficult to manage. The high regeneration capacity of the weed propagules was noticed by more than 70 per cent of farmers. Twenty per cent of farmers felt that rice yield reduction due to *Sacciolepis* was more than 20 per cent.

CONCLUSION

Sacciolepis interrupta is a serious weed problem in direct seeded rice in Kerala. The emergence pattern and growth characteristics of the weed make it a menace in rice fields. Under the present changing climatic scenario, where dry periods are becoming more frequent, the weed has potential to become a major menace.

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Evaluation of ametryn 73.15% + trifloxysulfuron 1.85% WG for the management of complex weed flora in sugarcane

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Sugarcane is one of the most important cash crop grown throughout the country. Sugarcane suffers from weed competitions which reduces its yield up to 15-75% and even more. It is well known that cultural methods of weed management is most effective to control weeds but timely availability of laborers is a problem besides increase in wages. Therefore, chemical control of weeds is considered economical in sugarcane (Kumar *et al.* 2014). Several herbicides have been tried in sugarcane with varying degree of success, but information on combined use of chemicals is scarce. Keeping this in view, the present investigation was undertaken to study the combined use of Ametryn 73.15% + Trifloxysulfuron 1.85% WG in spring planted sugarcane for the management of weeds.

METHODOLOGY

A field experiment was conducted during 2012-13 and 2013-14 at N.E. Borlaug Crop Research Centre, G.B.P.U.A. & T., Pantnagar to evaluate the bio-efficacy of ametryn 73.15% + trifloxysulfuron 1.85% WG for the control of grasses, sedge and broad leaf weeds in sugarcane. Nine treatments comprised with three doses of ametryn 73.15% + trifloxysulfuron 1.85% WG (731.5+18.5, 914.37+23.12 and 1097.25 + 27.75 g/ha), trifloxysulfuron 10 OD (30 g/ha), atrazine 50 WP (1000 g/ha), 2,4-D dimethyl amine salt 58% SL (3500 g/ha) as commercial standards as well as hand weeding thrice at 30, 60 and 90 days after planting (DAP) of sugarcane crop, weed free and weedy check with three replication was laid out in randomized block design. Three budded sets of sugarcane variety 'Co. Pant 90223' was planted on March 03, 2012 and March 06, 2013 with recommended package of practices at a row spacing of 75 cm. The data on density (no/m^2) and dry weight (g/m^2) of total grasses, sedges and broad leaved weeds were taken at 15 and 45 days after treatments and subjected to log transformation prior to statistical analysis. Yield attributes and yield (t/ha) of sugarcane was recorded at the time of harvesting.

RESULTS

The experimental field was infested mainly with *Cyperus rotundus, Ipomoea spp, Brachiaria reptans, Echinochloa colona, Digitaria sanguinalis and Dactyloctenium aegyptium*. Among the herbicidal treatments, the lowest density of total weeds were observed with ametryn 73.15% + trifloxysulfuron 1.85% WG at the dose of 1500 g/ha, though the differences were non-significant when compared with its lower dose at 1250 g/ha at 15 and 45 DAA during both the years. Application of ametryn 73.15% + trifloxysulfuron 1.85% WG at all the rates effectively controlled the *C. rotundus* (Sedge), *Ipomea* spp., *T. monogyna, D. arvensis and C. viscosa* (Broad leaf weed) and *Echinochloa spp., D. sanguinalis, D. aegyptium*, and *B. reptans* (grassy weeds) (Table 1). Application of ametryn 73.15% + trifloxysulfuron 1.85% WG at 1250 and 1500 g /ha recorded significantly lower weed dry weight over any other herbicidal treatment at 45 DAA. The highest weed control efficiency of total weeds at 45 DAA were recorded with the application of ametryn 73.15% + trifloxysulfuron 1.85% WG at 1500 g/ha which was closely followed by ametryn 73.15% + trifloxysulfuron 1.85% WG at 1250 g/ha. However, the minimum weed control efficiency was recorded with the application of 2,4-D dimethyl amine salt 58% SL 3500 g/ha at both the stages of observations. The results are in conformity with the findings of Chauhan and Srivastava (2002**)**. Application of ametryn 73.15% + trifloxysulfuron 1.85% WG at 1250 and 1500 g/ha recorded higher cane yield as compared to any other herbicidal treatment. The higher cane yield under these treatments might be due to more cane length and millable cane.

Table 1. Effect of ametryn 73.15% + trifloxysulfuron 1.85% WG on total weed density, dry weight, weed control efficiency and cane yield of sugarcane

Treatment	Total weed density at 45 DAA (no./m2)								Total weed dry weight at 45 DAA /m^2				Cane yield (t/ha)	
	C. rotundus		*Ipomoea spp.*		*D.sanguinalis*		*D. aegyptium*		2012-13	WCE%	2013-14	WCE%	2012-13	2013-14
	2012	2013	2012	2013	2012	2013	2012	2013						
Ametryn 73.15% + trifloxysulfuron1.85% WG 1000 g	2.3(9.3)	2.4(10.7)	1.0(2.7)	1.3 (2.7)	2.5(12.0)	1.9(10.7)	1.2(4.0)	1.8(5.3)	3.7(40.1)	79.62	3.7(41.9)	78.4	68.3	79.5
Ametryn 73.15% + trifloxysulfuron1.85% WG 1250 g	1.8(5.3)	1.9(6.7)	0.0(0.0)	0.5(1.3)	2.1(8.0)	1.8(5.3)	0.5(1.3)	0.5(1.3)	2.9(18.4)	90.65	2.9 18.2)	90.1	75.1	87.0
Ametryn 73.15% + trifloxysulfuron1.85% WG 1500 g	1.2(4.0)	1.3(4.0)	0.0(0.0)	0.0 (0.0)	1.2(4.0)	1.3(4.0)	0.0(0.0)	0.0(0.0)	2.2(8.2)	95.83	2.0(6.5)	96.6	82.3	95.5
Trifloxysulfuron 10 OD 300 ml	1.0(2.7)	0.5(1.3)	0.0(0.0)	0.0 (0.0)	3.1(24.0)	3.3(28.0)	0.5(1.3)	0.0(0.0)	5.0(144.9)	26.37	5.0(147.2)	24.2	51.7	64.5
Atrazine 50 WP 3000 g	2.4(25.3)	2.4(25.3)	1.0(2.7)	0.5(1.3)	1.9(6.7)	1.9(6.7)	1.0(2.7)	0.5(1.3)	3.7(41.2)	79.06	3.7(39.0)	79.9	65.9	74.0
2,4-D Dimethyl amine salt 58% SL 5000 ml	1.9(6.7)	1.7(8.0)	0.0(0.0)	0.0(0.0)	2.9(17.3)	2.2(18.7)	0.5(1.3)	0.0(0.0)	4.9(139.8)	28.96	4.9(137.8)	29.0	50.9	63.5
Hand weeding thrice	1.0(2.7)	1.8(5.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.5(0.7)	99.64	0.5(0.8)	99.6	89.8	102.9
Weed free	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0 (0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	100.0	0.0(0.0)	100.0	90.4	105.1
Untreated check	2.9(22.7)	2.4(24.0)	1.9(6.7)	1.8(5.3)	2.9 (22.7)	3.2(24.0)	2.7(24.0)	2.9(22.7)	5.3(196.8)	00.00	5.3(194.2)	00.0	34.5	41.5
LSD (P = 0.5)	NS	NS	0.9	1.0	0.8	NS	1.2	1.0	0.8	-	2.7	-	8.00	8.68

CONCLUSION

On the basis of two years field experiment, it was concluded that ametryn 73.15% + trifloxysulfuron 1.85% WG 1500 g/ha provide excellent control of weeds and it produced higher yield attributes and cane yield under north Indian conditions.

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Evaluation of mesotrione 2.27% + atrazine 22.72% w/w for the management of complex weed flora in corn

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Maize (*Zea mays* L.) is the third most important cereal crop after rice and wheat which is widely grown in the world. As the crop is heavily fertilized and sparsely grown, severe weed infestation is experienced, resulting into a drastic reduction of grain yield. In India, the presence of weeds, in general, reduces the maize yield by 27-60% depending upon the growth and persistence of weed population in maize crop (Singh *et al*. 2015). It is well known that cultural methods of weed management are most effective to control weeds but timely availability of laborers is a problem besides increase in wages.Therefore, chemical control of weeds is considered economical in maize. Several herbicides have been tried in maize with varying degree of success, but information on combined use of herbicides is scarce. Keeping this in view, the present investigation was undertaken to study the combined use of mesotrione 2.27 % + atrazine 22.72 % (Calaris Xtra 275 SC) in maize.

METHODOLOGY

A field experiment was conducted during 2013-14 and 2014-15 to evaluate the bio-efficacy of CalarisXtra 275 SC (mesotrione 2.27 % + atrazine 22.72% w/w SC) for the control of complex weeds (grasses, sedge and broad leaf weeds) in maize. Seven treatments comprised with three doses of mesotrione + atrazine (750, 875 and 1000 g/ha) and mesotrione 48 SC (120 g/ha), atrazine 50WP (1000 g/ha), 2,4-D sodium salt 80 WP (1000 g/ha) as commercial standards and weedy check with three replications was laid out in randomized block design. Mesotrione + atrazine was applied at 12 days after sowing (DAS) during first year and at 20 DAS of crop during second year, whereas atrazine was applied at 2 DAS of maize in both the years as pre-emergence. Recommended package of practices were followed to raise the crop. Observations on weed population before post-emergence application and 14 and 28 days after application (DAA) and dry weight of weeds were taken at 14 and 28 DAA. Data pertaining to density and dry weight of total grasses, sedges and broad leaf weeds were subjected to log transformation prior to statistical analysis.

RESULTS

The experimental field was infested mainly with *Echinochloa colona, Digitaria sanguinalis, Brachiaria reptans, Celosia argentia, Parthenium hysterophorus* and *Cyperus rotundus*. Among the herbicidal treatments, the highest reduction in the density of total weeds were observed with the application of mesotrione + atrazine (1000 g/ha) which was at par with its lower dose applied at 875 g/ha. Application of mesotrione + atrazine at doses 875 and 1000 g/ha completely reduced the density of *E. colona, D. sangunalis, C. argentia* and *P. hysterophorous* as compared to rest of the herbicidal treatments at both the stages of observations (14 and 28 DAA). Mesotrione 2.27% + atrazine 22.72% (1000 g/ha) also caused complete control of *C. rotundus* and *B. reptans*. Application of mesotrione + atrazine (875 g/ha) recorded the lowest dry weight being at par with its lower dose applied (750 g/ha). Complete weed control efficiency was recorded in mesotrione + atrazine (1000 g/ha) which was closely followed by its lower dose applied (875 g/ha). These findings are in conformity with the results of Hatti *et al*. (2014). The maximum grain yield was observed in mesotrione + atrazine (1000 g/ha) which figured 6.18 t/ha followed by its lower dose (875 g/ha). In both the cases yield was found at par with weed free treatment.

Table 1. Effect of mesotrione 2.27 % + atrazine 22.72 % w/w on density and dry weight of weeds at 28 DAA and grain yield of maize

Treatment	Dose (g/ha)	Total weed density(No./m2)		Total weed dry weight at 28 DAA /m^2: Grassy		BLW		Sedges		Total		WCE %		Grain yield (t/ha)	
		2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Mesotrione 2.27%+ atrazine 22.72% w/w SC (Calaris xtra 275 SC)	750	3.0 (18.8)	2.1(8.0)	2.4(10.5)	2.0(6.3)	0.0(0.0)	0.6(1.0)	1.6(4.2)	1.4(5.8)	2.8(14.7)	2.2(13.1)	94.8	89.0	5.33	5.07
Mesotrione 2.27%+ atrazine 22.72% w/w SC (Calaris xtra 275 SC)	875	1.3(4.0)	0.0(0.0)	0.7(1.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.9(1.5)	0.0(0.0)	1.2(2.5)	0.0(0.0)	99.1	100.0	6.04	5.71
Mesotrione 2.27%+ atrazine 22.72% w/w SC (calaris xtra 275 SC)	1000	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	100.0	100.0	6.18	5.83
Mesotrione 48 SC	120	3.4(30.7)	2.2(9.3)	3.6(34.7)	2.6(13.5)	1.7(4.7)	0.0(0.0)	0.0(0.0)	1.5(3.6)	3.7(39.4)	2.9(17.1)	85.9	85.69	5.21	4.29
Atrazine 50 % WP	1000	4.1(62.7)	5.2(178.7)	2.5(11.6)	2.4(10.3)	1.5(3.4)	1.5(3.5)	3.6(35.7)	2.9(17.6)	3.9(50.7)	3.5(31.4)	81.9	73.72	5.04	4.08
2,4-D Sodium Salt 80 WP	1000	5.1(170.0)	5.5(242.7)	4.8(125.2)	4.4(88.5)	1.7(4.5)	0.0(0.0)	3.4(29.1)	3.0(19.8)	5.1(158.8)	4.7(108.3)	43.5	9.37	4.93	3.93
Untreated Check	-	5.5(256.0)	5.8(322.7)	5.0(151.6)	4.5(87.8)	4.43(83.7)	2.3(9.2)	3.8(45.8)	3.1(22.5)	5.6(281.1)	4.7(119.5)	0.0	00.00	3.82	3.94
LSD (P=0.5)		1.3	0.9	0.85	0.9	0.12	0.6	0.18	1.0	0.10	1.0	-	-	0.70	0.63

CONCLUSION

On the basis of two years field experiment, it was concluded that mesotrione 2.27% + atrazine 22.72% w/w SC (CalarisXtra 275 SC) at 875-1000 g/ha could be the standard dose for post-emergence application in maize which provide excellent control of weeds and produced higher yield attributes under north Indian conditions.

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Bio-efficacy of pre- and post-emergence herbicides on weed dynamics, yield and economics in pearlmilllet

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Pearlmillet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz.] is an important short duration and drought tolerant crop. In India, pearlmillet is extensively grown during *Kharif*, by direct seeding, where weeds pose severe competition with crop resulting in yield loss upto 40% or more. Labour scarcity during the peak period for farm operations has become a major bottleneck for manual weeding operations. So, chemical weed management alone or in combination with mechanical methods has become indispensable for timely control of the weeds during *Kharif*.

METHODOLOGY

A field experiment was conducted at dryland farm of S.V. Agricultural College, Tirupati during *Kharif*, 2014 on sandy loam soil. Experiment was conducted in randomized block design with three replications and ten treatments, *viz.* pre-emergence application of atrazine 750 g/ha (T_1), pre-emergence application of oxyflourfen 100 g/ha (T_2), pre-emergence application of atrazine 750 g/ha *fb* hand weeding at 30 DAS (T_3), pre-emergence application of oxyflourfen 100 g/ha *fb* hand weeding at 30 DAS (T_4), pre-emergence application of atrazine *fb* post-emergence application of chlorimuron-ethyl 10% + metsulfuron-methyl 10% 8 g/ha (T_5), pre-emergence application of atrazine *fb* post-emergence application of ethoxysulfuron 37.5 g/ha (T_6), pre-emergence application of oxyflourfen *fb* post-emergence application of chlorimuron-ethyl 10% + metsulfuron-methyl 10% 8 g/ha (T_7), pre-emergence application of oxyflourfen *fb* post-emergence application of ethoxysulfuron 8 g/ha (T_8), hand weeding twice at 20 and 40 DAS (T_9) and weedy check (T_{10}). Recommended package of practices was followed. Atrazine and oxyflourfen were applied as pre-emergence spray and ethoxysulfuron and chlorimuron-ethyl + metsulfuron-methyl at 20 DAS. Weed density and dry weight were recorded in each plot and were subjected to square root transformation. Weed control efficiency of different weed management practices was calculated based on weed dry matter (Mani *et al.* 1973).

RESULTS

Major weed flora documented were *Cyperus rotundus* L. and *Cyperus iria* L. (17.0%) among sedges; *Digitaria sanguinalis* L. and *Echinochloa colona* L. among grasses; and *Celosia argentia* L., *Commelina benghalensis* L., *Corchorus acutangulus* L., *Phyllanthus niruri* L., *Cleome viscosa* L. and *Merremia aegyptica* among broad leaf weeds. The lowest density and dry weight of weeds was recorded with hand weeding twice at 20 and 40 DAS, which was comparable to pre-emergence application of atrazine *fb* hand weeding at 30 DAS. Pre-emergence application of oxyflourfen registered higher density and dry weight of all categories of weeds due to phytotoxic effect of oxyflourfen on pearlmillet resulted in increased weed density in vacant spaces compared to pre-emergence application of atrazine. Among the weed management practices tried, the highest WCE was registered with hand weeding twice, which was however, at par with pre-emergence application of atrazine *fb* hand weeding at 30 DAS. The highest WCE was recorded with hand weeding twice at 20 and 40 DAS (T_9), which was at par with pre-emergence application of atrazine *fb* one hand weeding at 30 DAS (T_3). These treatments registered significantly higher WCE than with pre-emergence application of atrazine alone (T_1) or in combination with post-emergence application of ethoxysulfuron (T_6) or chlorimuron-ethyl + metsulfuron-methyl (T_5), which were in parity with each other. Pre-emergence application of oxyflourfen *fb* hand weeding at 30 DAS (T_4) or post-emergence application of ethoxysulfuron (T_8) or chlorimuron-ethyl + metsulfuron-methyl (T_7) and pre-emergence application of oxyflourfen(T_2) alone recorded lower WCE than treatments consisting of atrazine. The highest grain and straw yield were recorded with hand weeding twice at 20 and 40 DAS (T_9), which were however, comparable with pre-emergence application of atrazine *fb* hand weeding at 30 DAS (T_3). These above two treatments recorded 86.5% and 83.3% higher grain yield over weedy check. These results were in line with Das *et al.* (2013). Hand weeding twice at 20 and 40 DAS resulted in the highest gross returns, which was at par with pre-emergence application of atrazine *fb* hand weeding at 30 DAS. However, the latter treatment recorded the highest net returns and benefit-cost ratio due to its lower cost of cultivation.

Table 1. Weed dynamics, weed control efficiency, yield and economics of pearlmillet as influenced by different weed management practices

Treatment	Total weed density (no./m^2)	Total Weed dry weight (g/m^2)	WCE (%)	Grain yield (kg/ha)	Straw yield (kg/ha)	Net returns (Rs./ha)
T_1	138.66 (11.81)	35.52 (6.03)	56.0 (48.4)	2289	5097	27789
T_2	174.66 (13.23)	43.73 (6.68)	45.9 (42.6)	1860	4245	19438
T_3	33.66 (5.88)	8.64 (3.10)	89.2 (70.8)	2936	6158	36115
T_4	161.33 (12.74)	40.26 (6.42)	50.1 (45.0)	2055	4646	19298
T_5	137.66 (11.76)	34.77 (5.98)	56.9 (49.0)	2339	5148	27858
T_6	133.66 (11.60)	33.71 (5.89)	58.2 (49.7)	2398	5244	28399
T_7	165.66 (12.89)	43.41 (6.66)	46.2 (42.8)	1915	4368	19634
T_8	163.33 (12.81)	40.62 (6.44)	49.7 (44.8)	2007	4556	20814
T_9	32.00 (5.73)	8.29 (3.04)	89.7 (71.3)	2976	6368	33737
T_{10} (Weedy check)	335.66 (18.33)	80.84 (9.04)	-	1595	3701	15247
LSD (P=0.05)	0.80	0.28	2.5			4042

* Values in the parenthesis are square root transformed values

CONCLUSION

In conclusion, the present study revealed that pre-emergence application of atrazine 750 g/ha *fb* hand weeding at 30 DAS (T_3) provided effective weed management, highest grain yield and maximum net returns.

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Efficacy of halosulfuron-methyl on sedges in bottle gourd

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Botttle gourd (*Langenaria siceraria* (Mol.) Standl) is a commonly grown vegetable of India and belongs to family cucurbitaceae. It is cultivated in the 0.11million ha area with a production and productivity of 1.43 million tones and 13.2 t/ha respectively (Anonymous 2011). Besides, many reason for its low productivity, poor management of weeds is the one of the most important. Due to slower early growth and close canopy structure, bottle gourd faces severe competition from weeds, particularly the perennial sedges resulting in huge yield loss. Halosulfuron methyl is known to be very effective against sedges. However, no information is available on testing of the newer herbicide on the bottle gourd in the state Odisha. The present investigation was carried out to evaluate the bioefficacy of halosulfuron methyl against perennial sedges on the bottle gourd.

METHODOLOGY

Field experiment was conducted at Central Farm OUAT, Bhubaneswar during the *Kharif* season of 2012 to evaluate the bioefficacy of halosulfuron-methyl against sedges especially *Cyperus rotundus* L. Six different treatments consisting of three different doses of halosulfuron-methyl (52.5, 67.5 and 135 g/ha) and one conventional herbicide *i.e.* pre-emergence application of metribuzin 490 g/ha along with two hand weedings (25 and 40 DAS) and one untreated control were tested in the field with a randomized block design with four replications. The bottle gourd variety 'Devagiri' was sown in pits (20×20×20 cm). All the standard packages of practices were followed. The herbicide halosulfuron-methyl was applied at 3-4 leaf stage of the *Cyperus* sps and the metribuzin was applied as pre-emergence. Data on weed growth yield and economics were recorded.

RESULTS

The crop was mainly infested with the sedges (21%) along with grasses (53%) and broad leaved weeds (26%). Among grasses were *Cynodon dactylon* and *Digtitaria sanguinallis*were dominant species. Weeds like *Chenopodium album,Melilotus indica,Ludwiga parviflora,Celosia argentia, Coronpus didymus* were dominant among broad leaved weeds and *Cyperus rotundus* among sedges. The application of halosulfuron-methyl completely controlled the sedges particularly the *Cyperus rotundus* population and dry matter irrespective of doses followed by the metribuzin treated plots where the population and dry matter recorded were 14/m^2 and 6.8 g/m^2 respectively (Table 1). However, the lowest total weed population (23/m^2) was observed in case of metribuzin application followed by the halosulfuron-methyl (135 g/ha) treated plots. Lowest weed dry weight (10.84 g/m^2) was also recorded in this treatment in comparison to all other treatments. It is evident that the grasses and other broad leaved weeds are effectively controlled by the metribuzin treatments whereas the halosulfuron methyl effectively controlled the sedge population *i.e. Cyperus rotundus*. The result was in conformity with the findings of Rathika *et al.* (2013).

Table 1. Weed growth, yield and economics of bottle gourd as affected by herbicides

Treatment	*C. rotundus* density (no/m^2) 30 DAS	*C. rotundus* dry matter (g/m^2)	Total Weed density (no/m^2) 30 DAS	Total dry matter (g/m^2)	Yield (t/ha)	Cost of cultivation (?×10^3 /ha)	B:C ratio
Halosulfuron methyl 52.5g/ha	0	0	38	19.67	21.25	13.21	2.63
Halosulfuron methyl 67.5g/ha	0	0	32	18.40	20.30	13.34	2.57
Halosulfuron methyl 135g/ha	0	0	27	14.32	18.54	13.56	2.41
Metribuzin 490 g/ha	14	6. 8	23	10.84	22.64	13.18	2.60
Two hand weedings (20 and 40 DAS)	16	7.4	42	23.41	22.87	14.52	2.13
Weedy check	37	13.6	89	42.70	14.32	12.87	1.19
LSD (P=0.05)	2.31	0.31	3.15	4.76	1.88	-	-

The highest fruit yield (22.87 t/ha) was recorded with two hand weedings followed by metribuzin treatments and the lowest (14.32 t/ha) was obtained in unweeded check. Among different doses of halosulfuron methyl, the application 37.5 g/ ha recorded 48% of yield advantage over weedy check and it was at par with the dose of 67.5 g/ha. The higher dose of 135 g/ ha significantly reduced the yield in comparison to other two lower doses. The herbicidal treatments brought about lower cost of cultivation as compared to two hand weedings (^{1} 14.52×10^3 /ha). The highest B:C ratio of 2.63 was observed in halosulfuron-methyl 52.5 g/ha, followed by metribuzin treated plots 2.60 and lowest with weedy check (1.19).

CONCLUSION

Post emergence application of halosulfuron methyl 52.5 g/ha at 3-4 leaf stages of sedges was very effective in controlling the specific weed and thereby increase the yield and profitability of the bottle gourd.

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Herbicide based weed management in groundnut

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Groundnut is an important source of quality edible oil and protein. It is viewed as an important crop to overcome protein-energy malnutrition in the world. Use of groundnut in confectionery is increasing fast throughout the world, and India earns foreign exchange worth more than Rs 4000 crores per annum from its export. The domestic and foreign demand of groundnut kernels is much more than the current production in the country. Though, it can be grown in all seasons in different parts of the country, more than 80% of the total area under groundnut is under *Kharif*/rainy session cultivation where its growth and productivity is confronted with diverse types and repeated flushes of variety of weed species (Yadav *et al.* 2014). Yield losses in groundnut due to weed competition especially during early growth stages and in bunch type varieties may be as high as 75% (Jat *et al.* 2011). At present weed management in groundnut is based mainly on manual weeding which is expensive, time consuming and occasionally not possible during rainy season and, application of commonly used pre-plant/pre-emergence herbicides (fluchloralin, pendimethalin, alachlor, trifluralin) which have limited period of efficacy and fail to control several weeds especially those emerging during subsequent growth of the crop. A field study was, therefore, carried out to study the effect of post-emergence herbicide alone or in sequence with pre-emergence herbicides on weed control vis-à-vis productivity of groundnut.

METHODOLOGY

The study comprised eight treatments, *viz.* (i) imazethapyr 75 g/ha, (ii) imazethapyr 100 g/ha, (iii) pendimethalin 750 g/ha, (iv) alachlor 2500 g/ha, (v) pendimethalin 750 g/ha *fb* imazethapyr 75 g/ha, (vi) alachlor 2500 g/ha *fb* imazethapyr 75 g/ha, (vii) two hand weedings (3 and 6 WAS) and (viii) unweeded control. Pendimethalin and alachlor were used as pre-emergence (1 DAS) and imazethapyr was applied as early post-emergence (30 DAS) with flat fan nozzle using 500 litre of water per hectare for pre-emergence and 375 litres of water per hectare for post emergence application. Spanish bunch variety of groundnut 'SG 99' was sown on June 5, 2015 at spacing of 30 cm x 15 cm and harvested at 120 days after sowing. Weed population and dry matter data were recorded from 50 x 50 cm quadrat. The weed data were subjected to square root transformation before analysis.

RESULTS

Weed flora in the field comprised mainly *Dactyloctenium aegyptiacum, Eragrostis sp, Commelina benghalensis, Acrachne racemosa, Digitaria ciliaris* among grasses, *Trianthema portulacastrum* among broadleaf weeds and *Cyperus rotundus* among sedges. All weed control treatments except pendimethalin 0.75 kg/ha at 45 DAS significantly reduced the weed intensity at 45 DAS and at maturity, and weed dry matter at maturity as compared to unweeded control. Different herbicide based weed control treatments were at par with two hand weedings with respect to intensity and dry weight of weeds. The highest pod (2.90 t/ha) and oil yield (1.42 t/ha) obtained with application of alachlor, 2.5 kg/ha + imazethapyr 0.075 kg/ha as compared to alone application of alachlor 2.5 kg/ha, imazethapyr 0.075 kg/ha and imazethapyr 0.100 kg/ha. Similarly pod yield (2872 kg/ha) and oil yield (1.39 t/ha) were higher with application of pendimethalin 0.75 kg/ha + imazethapyr 0.075 kg/ha as compared that achieved with alone herbicides treatments.

Table 1. Intensity and dry weight of weeds, plant height, shelling (%), pod and oil yield of groundnut in relation to weed management practices. Figures in parentheses indicate the number of weeds per 0.25m^2

Treatment	Weed count (no./m^2)		Weed dry weight (g/m^2) at maturity	Plant height (cm)	Shelling (%)	Pod yield (t/ha)	Oil content (%)	Oil yield (t/ha)
	45 DAS	At harvest						
Pendimethalin 0.75 kg/ha, PE	9.93 (98.0)	4.70 (21.3)	(17.77) 314.5	77.1	69.6	2.40	49.0	1.18
Alachlor, 2.5 kg/ha, pre-em	7.70 (58.7)	4.13 (16.7)	(16.33) 266.0	79.4	69.7	2.67	48.7	1.30
Imazethapyr 0.075 kg/ha, PoE 30 DAS	7.03 (48.7)	4.63 (20.7)	(14.63) 213.8)	75.3	69.4	2.66	49.0	1.30
Imazethapyr 0.100 kg/ha, PoE 30 DAS	7.13 (50.0)	4.20 (16.7)	(14.53) 212.8	75.3	68.8	2.75	48.5	1.33
Pendimethalin 0.75 kg/ha, PE + imazethapyr 0.075 kg/ha, PoE	7.73 (58.7)	4.37 (18.0)	(13.70) 187.0	75.8	69.2	2.87	48.6	1.39
Alachlor, 2.5 kg/ha, PE + imazethapyr 0.075 kg/ha, PoE	8.83 (78.0)	5.10 (25.3)	(15.67) 244.8	81.3	68.9	2.90	49.0	1.42
Hand weeding (3 and 6 WAS)	6.87 (46.7)	4.50 (19.3)	(12.47) 155.0	69.3	69.9	2.78	48.9	1.36
Unweeded control	10.87 (117.3)	7.67 (58.0)	(20.33) 413.7	65.0	69.9	1.89	48.3	0.91
LSD (P=0.05)	1.30 (21.2)	1.0 (9.5)	(2.06) 63.9	8.0	NS	0.39	NS	0.18

CONCLUSION

Pre-emergence application of alachor 2.5 kg/ha or pendimethalin 1.0 kg/ha followed by application of imazethapyr 0.075 kg/ha about one month after sowing offers season long weed control and leads to higher pod and oil yield of groundnut.

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Efficacy of post emergence herbicides in wet seeded rice

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Direct seeding of rice is widely adopted in Kerala as it is labour saving and requires less expenditure. However, high weed infestation is a major constraint in direct seeded rice (Rao *et al.* 2007). Here, effective control of weeds with pre-emergence herbicides depends to a great extent on weather conditions, particularly rainfall. Under dry seeded situation, weeds germinate simultaneously with rice and there is no water layer to suppress weed growth (Fukai 2002). Wet seeding is therefore, a more feasible option for better weed control in lowland rice cultivation. The use of broad spectrum herbicides or serial application herbicides would be an effective method to manage the diversity of weeds which commonly occur in a wetland rice field. The present investigation was undertaken to evaluate the effect of currently used and novel post emergence herbicides on weeds in direct wet seeded condition.

METHODOLOGY

The trial was conducted at the Agricultural Research Station, Mannuthy, Thrissur, Kerala. The weed problem is very severe here, and the main grass weeds are *Echinochloa glabrescens* and *Echinochloa crus-galli*, while the main sedges are *Fimbristylis miliacea* and *Cyperus iria*. Among the broad leaf weeds, the dominant ones are *Ludwigia parviflora* and *Sphenoclea zeylanica*. The experiment was laid out in a randomized block design with eight treatments and three replications during the first crop season from July 2016 to November 2016, in plots of 20 m^2 size. The treatments included pyrazosulfuron ethyl followed by bispyribac sodium, readymix of triafamone + ethoxysulfuron, penoxsulam, azimsulfuron, ethoxysulfuron, bispyribac sodium, hand weedings (20 and 40 DAS), and an unweeded check. Pyrazosulfuron-ethyl was applied 10 DAS while all other herbicides were sprayed at 20 DAS. Observations on weed count and dry matter production at 30 and 60 DAS as well as grain and straw yields of rice at harvest were recorded.

RESULTS

All the herbicides tried were effective in controlling all the types of weeds at 30 DAS (Table 1). Weed dry matter production in all herbicide treatments was at par with hand weeding and superior to unweeded control. The effects of herbicide application were more clearly visible at 60 DAS. The sedges *Cyperus iria* and *Fimbristylis miliacea* were very effectively controlled by all treatments. Penoxsulam, ethoxy sulfuron and azimsulfuron were less effective in controlling *Ludwigia parviflora*, evidenced by the high weed dry matter production in these treatments.

Table 1. Weed dry biomass and rice grain and straw yields (t/ha) as affected by post-emergence herbicides

Herbicide	Dose (kg/ha)	Weed dry biomass (30 DAS)	Weed dry biomass (60 DAS)	Grain yield	Straw yield
Pyrazosulfuron-ethyl *fb* bispyribac sodium	0.20 & 0.025	64.33^{b}	263.57^{bcd}	3.40^{bc}	3.53^{b}
Triafamone + ethoxy sulfuron	0.060 & 0.015	38.00^{b}	256.00^{cd}	3.85^{a}	3.95^{a}
Penoxsulam	0.025	41.33^{b}	327.87^{bc}	3.17^{c}	3.34^{b}
Azimsulfuron	0.035	42.67^{b}	301.13^{bcd}	3.39^{bc}	3.58^{b}
Ethoxy sulfuron	0.015	68.67^{b}	424.30^{b}	2.56^{d}	2.97^{c}
Bispyribac sodium	0.025	46.00^{b}	229.63^{cd}	3.21^{c}	3.46^{b}
Hand weeding	20 & 40 DAS	50.67^{b}	143.67^{d}	3.73^{ab}	4.12^{a}
Unweeded check	-	141.33^{a}	839.03^{a}	2.31^{d}	2.52^{d}
LSD (P=0.05)		31.979	166.948	0.33	0.34

Data on grain and straw yields (Table 1) clearly points out the beneficial effect of herbicidal application. All treatments were superior to unweeded check in grain and straw yields. Highest grain yield of 3.85 t/ha was obtained by application of pre-mix of triafamone + ethoxysulfuron. Hand weeding was at par with this treatment, recording a grain yield of 3.73 t/ha. The treatment pyrazosulfuron-ethyl followed by bispyribac sodium was next (3.40 t/ha), while azimsulfuron (3.39 t/ha) was equally effective. Yields in plots treated with bispyribac sodium and penoxsulam were at par with these treatments, though they recorded lower values. Ethoxysulfuron resulted in significantly lower grain yield (2.56 t/ha) and was at par with unweeded check (2.31 t/ha). Straw yield was highest in the hand weeded plot and in the plot treated with pre-mix of triafamone + ethoxysulfuron and lowest in the unweeded check. The other post emergence herbicides recorded values in between.

CONCLUSION

All the post emergence herbicides were effective in reducing weed growth significantly. Hand weeding (twice) was most effective in reducing weed dry matter production. Among the herbicides tried, pre-mix of triafamone + ethoxysulfuron was the best, producing grain and straw yield at par with hand weeding. Pyrazosulfuron-ethyl followed by bispyribac sodium, and azimsulfuron were the next best treatments.

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Effect of weed control measures on weed dynamics and yield of rice under rice-rice cropping system

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Weeds pose a severe problem in reducing grain yield in rice-rice cropping system. The problem of weed infestation is more severe particularly during *Kharif* due to prevalence of congenial atmosphere for weed growth. Hand weeding is effective and most common method to control weeds in this crop. However, scarcity and high wage of laborers, particularly during peak period and early crop weed competition makes this operation difficult and uneconomic. Information on integrated weed management in rice-rice system is lacking for which the present investigation was planned to study the effect of integrated weed management practices on weed dynamics, yield and economics of rice-rice cropping system in East and South Eastern coastal plain zone of Odisha.

METHODOLOGY

Field experiment was conducted consecutively for three years (2012-13 to 2014-15) in East and South Eastern coastal plain zone of Orissa at Research Farm, OUAT, Bhubaneswar taking two treatments in main plot for *Kharif* rice (Farmers' practice (2 HW at 30 and 45 DAP , Pretilachlor 0.75 kg/ha at 3 DAP) and five weed control measures in sub-plot for second rice crop (Unweeded control, two HW at 30 and 45 DAP, 2,4-D EE 0.8 kg/ha (30 DAP), butachlor 1.25 kg/ha (3 DAP) + almix 4g/ha (20 DAP), narrow spacing (15 x 10 cm) + 1 HW (30 DAP) in split plot design replicated three times. Twenty-five days old seedlings were transplanted in July during *Kharif* and third week of January during *Rabi* in all the years taking *swarna* and *lalat* as test variety during first and second season respectively. The crop was harvested during third week of November and second week of May in two the seasons, respectively. The required quantity of herbicides was applied with knapsack sprayer using a spray volume of 500 liters water/ha.

RESULTS

Weed flora of experimental plots were dominated with grasses like *Echinochloa colonum, Panicum repens, Echinochloa crus-galli, Paspalum scorbiculatum, Leptochloa chinensis;* broard leaf weeds like *Alteranthera sessilis, Ludwigia parviflora, Marsilea quadrifoliata, Cynotis cuculata. Cyperus iria, Cyperus diformis, Fimbristylis miliacea* were the dominant sedges observed in rice during *Kharif* season. It was observed during *Kharif* rice that application of pretilachlor at 0.75 kg/ha (3 DAP) reduced weed densities at 30 DAP (35.6/m^2) which was the critical period of crop weed competition although the practice of one hand weeding (farmers' practice) lowered the weed density (39.9/m^2) at harvest of crop (Table 1).

Table 1. Effect of weed control measures on weed dynamics, yield and yield attributes in rice-rice cropping system

Treatment	Weed density (m^2)		Weed biomass (g/m^2)		Panicles /m^2	Grains/ panicle	1000-grains weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest Index
	30 DAS	At harvest	30 DAS	At harvest						
Weed management followed in Kharif rice										
Farmers' practice (2 HW at 30 and 45 DAP)	34.4	54.1	21.1	26.4	270	135	21.8	3545	4360	44.8
Pretilachlor 0.75 kg/ha (3 DAP)	30.5	50.7	19.8	24.1	287	139	22.7	3814	4540	45.6
LSD (P=0.05)	1.34	1.55	0.23	1.10	9.66	NS	NS	126	NS	-
Weed management followed in Rabi rice										
Unweedy check	52.4	81.8	32.7	51.9	263	129	21.5	2707	3385	44.4
Farmers' practice (2 HW at 30 and 45 DAP)	50.9	29.5	32.5	16.3	294	145	22.9	4107	5120	44.1
2,4-DEE 0.8kg/ha (3DAP)	11.7	34.8	4.6	21.1	279	140	22.3	3796	4710	44.2
Butachlor 1.25 kg/ha (3 DAP) + almix 4g/ha (20 DAP)	11.3	33.0	4.3	19.2	285	139	22.5	4160	5170	44.6
Narrow spacing (15 x 10 cm) + 1 HW (30 DAP)	49.3	27.0	29.8	15.9	271	134	21.9	3660	4560	44.5
LSD (P=0.05)	2.34	3.63	1.07	0.66	7.05	5.78	0.56	26.35	32.41	-

Data of *Rabi* rice indicated that weed control measures applied in *Kharif* rice (main plot) on weed density of *Rabi* rice at 30 DAP and at harvest had significant effect. Application of pretilachlor 0.75 kg/ha (3 DAP) significantly reduced the weed density/m^2 (30.5 at 30 DAP and 50.7 at harvest) as compared to farmers' practices. Among various herbicides applied in *Rabi* rice, butachlor 1.25 kg/ha (3 DAP) + almix 0.8 kg/ha (20 DAP) recorded the lowest weed density of 11.3/m^2 which was at par with 2,4-DEE 0.8 kg/ha (30 DAP) whereas at harvest narrow spacing (15 x 10 cm) + one HW (30 DAP) recorded lowest density (27.0/m^2) which was at par with one HW at 40 DAP. The highest yield of *Kharif* rice in both the treatments were associated with higher panicle/m^2 (375), grains/panicle (148), 1000-grains weight (23.7g) and harvest index (46.4). It was observed in *Rabi* rice that the grain and straw yield, 1000 grain weight and grains/panicle were not significant due to weed management practices followed in *Kharif* rice. However, the maximum grain yield of 3814 kg/ha with highest HI (45.6) was obtained with the application of pretilachlor 0.75 kg/ha (3 DAP). One hand weeding at 40 DAP recorded significantly highest grain yield (4160 kg/ha) followed by application of butachlor 1.25 kg/ha (3 DAP) + almix 4 g/ha (3DAP). These observations are in agreement with the findings of Singh and Singh (2001).

CONCLUSION

Pre-emergence application of pretilachlor 0.75 kg/ha in *Kharif* rice and application of butachlor 1.25 kg/ha (3 DAP) + almix 0.8 kg/ha (20 DAP) in *Rabi* rice is found to be the effective weed management practices under rice-rice cropping system.

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Evaluation of non-chemical weed management techniques in brinjal

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Brinjal (*Solanum melongena* L.) is one of the most important vegetable crops grown all over India. Weed menace is one of the production problems associated with brinjal. Brinjal faces severe weed competition due to slow initial growth and wider spacing (Sha and Karuppaiah, 2005).

METHODOLOGY

A trial was conducted in the College of Horticulture, Kerala Agricultural University, Vellanikkara under the AICRP on Weed Management to assess the effect of various non-chemical methods of weed management including mulching materials on yield and weed control efficiency in brinjal. The crop was raised in *Kharif* season of 2016. The mulching materials included black polythene, dried leaves and coir pith. The other treatments were application of pendimethalin, hand weeding and spade weeding. An unweeded control treatment was also included.

RESULTS

As shown in Table 1, mulching with polythene recorded significantly higher fruit yield. This was followed by spade weeding and hand weeding and all the three treatments were at par. Choudhary *et al.* (2012), while studying physiological effects of polythene mulching, observed that chlorophyll content was higher and canopy temperature was lower when pepper (*Capsicum annuum* L.) was mulched with black polythene, which contributed to higher yield. Total weed count and weed dry matter production 100 days after planting are also presented in Table 1. Weed count was significantly affected by treatments and polythene mulching resulted in significantly lower weed count, followed by spade weeding and hand weeding. Spade weeding was at par with hand weeding and coir pith mulching. Highest weed count was recorded in unweeded control. This was followed by dried leaves mulching and herbicide application.

As in the case of total weed count, highest weed dry matter production was also in unweeded control. Polythene mulching was the best treatment, recording lowest dry matter production of 9.73 g/m^2. Spade weeding, which resulted in a dry matter production of 16.96 g/m^2, was at par with this treatment. This was followed by hand weeding and pendimethalin treatments which were at par with spade weeding. Weed index and weed control efficiency of different treatments were computed and the values are presented in Table 2. The lowest value for weed index and the highest weed control efficiency at 100 DAP were recorded under polythene mulching. The highest B:C ratio was recorded by chemical weed control, followed by polythene mulching. In unweeded control and coir pith mulch treatment, the ratios were less than one. Banjare *et al.* (2014) reported use of pendimethalin to be very effective in controlling weeds and enhancing yield, when followed by hand weeding. In the present trial, hand weeding was not done and that may be the reason for relatively less advantage for chemical control. However, highest return per rupee invested was with herbicide application.

Table 1. Effect of treatments on fruit yield, total weed count and weed dry matter production

Treatment	Fruit yield (tons/ha)	Total weed count 100 DAP	Weed dry matter production 100 DAP (g/m^2)
Pendimethalin 1.0 kg/ha	9.35^{bc**}	9.31^{bc} (86.67)	5.70^{c} (32.47)
Dried leaves mulch	9.08^{bc}	9.99^{b} (100.0)	10.74^{b} (115.71)
Polythene mulch	13.49^{a}	1.31^{e} (4.00)	1.95^{d} (9.727)
Coir pith mulch	8.05^{c}	8.06^{cd} (65.33)	10.18^{b} (103.85)
Hand weeding	11.48^{ab}	7.74^{d} (60.0)	4.73^{c} (23.08)
Spade weeding	11.66^{ab}	7.02^{d} (49.33)	4.08^{cd} (16.96)
Unweeded control	3.99^{d}	12.39^{a} (153.33)	15.01a (225.78)
LDS (0.05)	3.41	2.14	3.09

** Values followed by same alphabet do not differ significantly in DMRT

Table 2. Effect of treatments on weed index, weed control efficiency and B:C ratio

Treatment	WI%	WCE%		B:C ratio
		60 DAS	100 DAS	
Pendimethalin	30.7	88.8	85.6	1.54
Dried leaves mulch	32.7	82.7	48.7	1.08
Polythene mulch	0.0	92.5	95.6	1.42
Coir pith mulch	40.3	85.3	54.0	0.90
Hand weeding	14.9	93.5	89.7	1.21
Spade weeding	13.5	94.9	92.4	1.10
Unweeded control	70.4	0.0	0.0	0.69

CONCLUSION

Mulching with polythene is found to be very effective in controlling weeds in brinjal. Yield was also found to increase when polythene mulching was adopted. In the present context of labour unavailability and increasing labour charges, non-chemical weed control measures like polythene mulching are viable alternate options.

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Integrated weed control in cucurbitaceous vegetable

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Vegetables are highly prone to weed competition due to heavy manurial application, frequent irrigation and short crop period. Integration of various methods of weed control is very important in vegetable crops with respect to food safety, ecosystem concerns as well as economic factors. Hence, the present study was undertaken to arrive at an integrated weed management recommendation for a widely grown cucurbitaceous vegetable, ash gourd.

METHODOLOGY

A field experiment on weed management in ash gourd" [*Benincasa hispida* (Thunb.) Cogn.] was conducted during July to November 2013 at Krishi Vigyan Kendra farm at KAU campus, Thrissur using the variety 'KAU local'. The main objectives of the study were to compare the efficacy of cultural, physical and chemical methods of weed control and their combinations to arrive at an integrated weed management practice in ash gourd and to work out the economics of various weed management practices. The experiment was laid out in a Randomised Block Design with three replications. The treatments included pre-emergence application of oxyfluorfen 0.2 kg/ha, pendimethalin 1.5 kg/ha, and oxyfluorfen 0.2 kg/ha followed by post-emergence directed application of glyphosate 0.8 kg/ha, pre-emergence application of pendimethalin 1.5 kg/ha followed by post-emergence directed application of glyphosate 0.8 kg/ha, mulching with coconut fronds, mulching with polythene sheet, weeding using tiller, manual weeding by hoeing and no weeding.

RESULTS

Major weeds found in experimental field were dicots which comprised of *Alternanthera betzikiana*, *Borreria hispida*, *Celosia argentia* etc. *Pennisetum pedicellatum* was the dominant grass species followed by *Brachiaria* sp. Plastic mulching of the field resulted in almost 100 percent weed control efficiency. The lowest weed dry weight was recorded in plastic mulched plot which was statistically superior to all other treatments at all stages of observation. The plant growth parameters like branches/vine and leaves/ vine were significantly higher in plastic mulched plots followed by hand weeded plot. The highest fruit yield (22.68 t/ ha) was recorded in plastic mulched plots (Table 1) which was statistically superior to all other treatments. Manual weeding was the next best practice and resulted in 16.54 t/ha fruit yield and 144.12 kg/ha of seed yield. Weed competition resulted in 91.5 per cent reduction in crop yield. Awodoyin *et al.* (2007) reported that mulches are effective in weed control and weed control efficiency of the mulches ranged between 91 per cent and 100 per cent. According to Ashrafuzzaman *et al.* (2011), in vegetables, black plastic mulching resulted in the maximum number of fruits and highest yield. However, coconut frond mulching was ineffective in suppressing weeds and no net profit could be obtained. Pre-emergence herbicide alone could not take care of weed problem and hence can be recommended only for weed control during a short span of 30 days. The two pre-emergence herbicides tried *viz.* oxyfluorfen and pendimethalin had similar performance. Even a follow up spray of post emergence herbicide was found not sufficient to enhance the yield level. However, this can be integrated with other weed control methods like manual weeding or mechanical weeding.

Table 1. Effect of weed control measures on yield attributes and yield of ash gourd

Treatment	Fruit no./plant	Average fruit weight (kg)	Fruit yield (t/ha)	Seed yield (kg/ha)
Oxyfluorfen	2.50^{b}	2.30^{d}	11.21^{cd}	89.67^{d}
Pendimethalin	2.47^{b}	2.34^{cd}	11.16^{cd}	88.57^{d}
Oxyfluorfen *fb* glyphosate	2.84^{ab}	2.90^{b}	15.03^{bc}	120.20^{c}
Pendimethalin *fb* glyphosate	2.67^{ab}	2.80^{bc}	14.90^{bc}	118.70^{c}
Coconut frond mulching	2.73^{ab}	2.00^{d}	8.09^{d}	60.10^{e}
Plastic mulching	3.24^{a}	3.60^{a}	22.68^{a}	212.00^{a}
Mechanical weeding	2.49^{b}	2.81^{bc}	13.75^{bc}	124.01^{c}
Manual weeding	2.91^{ab}	3.00^{b}	16.54^{b}	144.12^{b}
Unweeded check	1.04^{c}	1.07^{e}	3.90^{e}	18.03^{f}

In a column, means followed by same letters do not differ significantly at 5% level in DMRT.

CONCLUSION

It is concluded that plastic mulching is the best method for weed control in ash gourd in areas where weed problem is very severe. A follow up directed spray of post emergence herbicide can be integrated with other weed control methods like manual weeding or mechanical weeding. In areas where weed incidence very severe, use of coconut fronds for mulching alone will not take care of weed incidence and may be integrated with a pre-emergence herbicide application.

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Effect of integrated weed management on weed growth, yield and economics of direct seeded rice

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Rice is grown under diverse ecologies ranging from irrigated to rainfed upland, lowland and deep water. Direct seeded rice (DSR) is becoming more popular as an alternative to transplanted rice, as it is more remunerative if the crop is managed properly. Aerobic edaphic conditions under non-flooded conditions in DSR stimulate germination of diverse weed species. Weeds in DSR compete for moisture, nutrients, light and space and reduce the grain yield by 50 to 91%. Ehsanullah *et al*. (2012) observed that the post-emergence application of bispyribac sodium was the most effective followed by penoxsulam in reducing the total density and dry weight over weedy check. However, to control the various flushes of weeds in DSR, integrated weed management is a good option. Therefore, present investigation was undertaken to study integration of chemical and manual weeding on weed growth, yield and profitability in DSR.

METHODOLOGY

A field experiment was conducted during the rainy (*Kharif*) season of 2015 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh to identify the best integrated weed management method for reducing density and dry weight of weeds and optimising the yield of DSR. The experiment was laid out in a randomized block design, comprising 10 treatments and replicated trice. Rice variety 'MTU-7029' was sown by zero till drill during the last week of June following the seed rate of 30 kg/ha and 20 cm row-row spacing. A recommended dose of fertilizer (150 kg N, 60 kg P_2O_5 and 60 kg K_2O) was applied using urea, single super phosphate and muriate of potash during experiment. Data on weed growth, yield performance and economics were recorded.

RESULTS

At 60 DAS, amongst the integrated weed management treatments, penoxsulam 35 g/ha at 10 DAS + 1 HW at 35 DAS recorded lower weed density and dry weight in comparison to penoxsulam 35g/ha at 20 DAS + 1 HW at 35 DAS, however, both treatments were statistically at par to each other. Bispyribac Na (12.5 g/ha) + chlorimuron-ethyl + metsulfuron-methyl (2 g/ha) at 10 DAS + 1 HW at 35 DAS had lesser weed density and dry weight in comparison to bispyribac Na 12.5 g/ha + (chlorimuron-ethyl + metsulfuron-methyl) 2 g/ha at 20 DAS + 1 HW at 35 DAS and both treatments were statistically similar to each other during experimentation. Penoxsulam 35 g/ha at 10 DAS + 1 HW at 35 DAS had higher grain and straw yield as compared to penoxsulam 35 g/ha at 20 DAS + 1 HW at 35 DAS. Consequently, the highest net return and benefit: cost ratio were observed under penoxsulam 35 g/ha at 10 DAS + 1 HW at 35 DAS (Table 1). Similar findings were also reported by Sairamesh *et al.* (2015)

Table 1. Weed growth, yield and economics of rice as influenced by integrated weed management treatments

Treatment	Weed density ($/m^2$) at 60 DAS	Weed dry weight (g/m^2) at 60 DAS	Weed index (%)	Grain yield (t/ha)	Straw yield (t/ha)	Net return (`/ha)	B:C ratio
Bispyribac Na 25g/ha at 10 DAS + 1 HW at 35 DAS	4.22^{d} (17.34)	3.28^{d} (10.27)	12.81	4.54^{d}	6.06^{a}	35024.75^{d}	1.89^{de}
Bispyribac Na 25g/ha at 20 DAS + 1 HW at 35 DAS	4.39^{b} (18.79)	3.41^{b} (11.14)	13.37	4.51^{d}	6.05^{a}	35175.72^{d}	1.91^{de}
Bispyribac Na 12.5g/ha + azimsulfuron 15g/ha at 10 DAS + 1 HW at 35 DAS	3.99^{f} (15.40)	3.10^{e} (9.09)	10.61	4.65^{bcd}	6.08^{a}	37425.72^{bcd}	1.97^{bcd}
Bispyribac Na 12.5g/ha + azimsulfuron 15g/ha at 20 DAS + 1 HW at 35 DAS	4.31^{c} (18.10)	3.36^{c} (10.76)	11.65	4.60^{cd}	6.06^{a}	36023.29^{cd}	1.92^{cde}
Bispyribac Na 12.5g/ha + (chlorimuron ethyl + metsulfuron methyl) 2g/ha at 10 DAS + 1 HW at 35 DAS	3.85^{f} (14.32)	2.98^{f} (8.36)	7.94	4.79^{bc}	5.94^{a}	40916.69^{ab}	2.11^{a}
Bispyribac Na 12.5g/ha + (chlorimuron ethyl + metsulfuron methyl) 2g/ha at 20 DAS + 1 HW at 35 DAS	4.12^{e} (16.47)	3.17^{de} (9.57)	8.99	4.74^{bcd}	6.06^{a}	39679.76^{bc}	2.06^{ab}
Penoxsulam 35g/ha at 10 DAS + 1 HW at 35 DAS	3.00^{h} (8.51)	2.39^{h} (5.22)	2.72	5.06^{a}	6.17^{a}	43974.51^{a}	2.15^{b}
Penoxsulam 35g/ha at 20 DAS + 1 HW at 35 DAS	3.13^{g} (9.29)	2.46^{g} (5.56)	6.76	4.85^{b}	6.19^{a}	40330.04^{ab}	2.04^{abc}
Hand weeding at 15 and 35 DAS	0.71^{i} (0.00)	0.71^{i} (0.00)	0.00	5.20^{a}	6.15^{a}	38255.10^{bcd}	1.83^{e}
Weedy	10.77^{a} (115.45)	8.89^{a} (78.59)	52.84	2.45^{e}	3.42^{b}	9082.08^{e}	1.29^{f}
CV (%)	2.29	2.79	-	2.68	5.63	6.08	3.55

Values in parentheses are original. Data transformed to square root transformation

CONCLUSION

It was concluded that post emergence application of penoxsulam 35g/ha at 10 DAS + 1 HW at 35 DAS was most effective for controlling weeds, improving grain yield and profitablility of DSR.

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Effect of light, temperature and burial depth on germination and emergence of *Ischaemum rugosum* Salisb. population from Northern India

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Ischaemum rugosum Salisb. (wrinkle grass) is an annual grass weed that is native to tropical Asia but has invaded rice fields in South Asia and Africa (Holm *et al*. 1977). It is highly competitive weed in rice production and can cause 23-48% yield reduction in rice (Lim *et al*. 2015). Due to labor and water scarcity, farmers in Northern India are shifting from puddled transplanted rice (PTR) to dry-seeded rice (DSR). In PTR, ponding of water serves as an effective weed control measure against emergence of wrinkle grass, but this weed control tool is missing in DSR which can make it a problematic weed. Competitiveness of any weed species in an agro-ecosystem depends on the ability of seeds to germinate in response to different environmental factors particularly temperature, light and burial depth. No such information on germination ecology has been available for wrinkle grass populations belonging Northern India.

METHODOLOGY

The seeds of wrinkle grass were collected from rice fields of Punjab Agricultural University, Ludhiana, India. Seed germination was tested in 3 replicates with seeds placed evenly on Whatman No.1filter paper in Petri dishes. The germination of seeds was tested under fluctuating day/night temperatures (12/12 h) *viz*. 15/5, 20/10, 25/15, 30/20, 35/25 and 40/30°C and different light regimes – light/dark for day/night environments (12/12 h) and continuous dark (24 h) for completely no light environment. For continuous dark treatment, Petri dishes were wrapped in double layers of aluminum foil to prevent light penetration and were covered immediately after recording data. Germination counts were made at 24-h intervals for 15 days after start of the experiment with the criterion for germination being visible protrusion of the radicle. Effect of burial depth was studied in plastic pots placed under field conditions during months of June to August. The weed seeds were sown on the soil surface in pots and covered to a depth of 0, 1, 2, 4, 6, 8 and 10 cm as per treatment. The emergence of wrinkle grass was recorded over a period of one month.

RESULTS

The seeds of wrinkle grass germinated under complete darkness showing that germination of this weed was independent of light. The seedlings germinated under complete darkness were etiolated having elongated and chlorotic shoots. The wrinkle grass seeds exhibited the highest germination in the temperature regime of 30/20°C; however, seeds were able to germinate under wide temperature range of 15/5 to 35/25°C. The highest germination speed and seedling vigor index were exhibited at day/night temperature regime of 30/20°C. The weed did not germinate at 40/30°C. The wrinkle grass seeds recorded the highest emergence from 0-1 cm depth. When placed at 4cm depth, the emergence was reduced by about 50% compared to surface placed seeds. The emergence was >20% when placed at 6 cm depth and no emergence was recorded when seeds were buried at e" 8 cm. Apparently, this weed has capacity to germinate from deeper soil layers

CONCLUSION

The optimum temperature for germination of wrinkle grass was found to be 30/20°C and optimum sowing depth 0-1cm. The germination of this weed was independent of light.

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Effect of weed management and sulphur nutrition on quality parameters in clusterbean

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Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] popularly known as 'Guar' is being cultivated in India since ancient time for various purposes *viz.* vegetables, green fodder, green manuring and seeds. Among leguminous crops, it is comparatively more drought tolerant which is grown during rainy season in semi-arid and arid regions of India. In the recent years, besides its conventional uses, it has emerged as an industrial crop due to presence of natural hydrocolloids (galactomannan). The guar seed consists of three parts seed coat (14-17%) endosperm (35-42%) and germ (43-47%). The spherical shaped endosperm contains 28-33% gum. Guar gum is a natural nano-particle and its derivatives are used as crucial ingredients in about 98 products over diversified applications (Goldstein and Alter, 1959). Guar gum is used as an important ingredient in producing food emulsifier, food additive, food thickener, gelling, filming agent and non-calorific fibrous food. Being a rainy season crop, it suffers badly due to severe competition by mixed weed flora. Looking to its industrial importance, it was felt necessary to find out the effect of weed management and sulphur nutrition on quality parameters in terms of protein, gum and chlorophyll content.

METHODOLOGY

Field experiment was conducted during *Kharif* season of 2013 and 2014 at Instructional Farm of Department of Agronomy, Rajasthan college of Agriculture, MPUAT Udaipur. The soil of experimental site was clay loam in texture, alkaline in reaction, medium in available nitrogen, phosphorus high in potassium and low in available sulphur. The experiment consisted of eight weed management treatments (weedy check, one hand weeding at 20 DAS, two hand weeding at 20 and 40 DAS, pre-emergence application of pendimethalin 1.0 kg/ha, post-emergence application of imazethapyr 0.1 kg/ha, post-emergence application of quizalofop-ethyl 0.05 kg/ha, pre-emergence application of pendimethalin 0.75 kg/ ha *fb* post-emergence imazethapyr 0.075 kg/ha, and pre-emergence pendimethalin 0.75 kg/ ha *fb* post-emergence quizalofop-ethyl 0.04 kg/ha) and four levels of sulphur (control, 15, 30 and 45 kg/ha), thereby making 32 treatments combinations. Sulphur was supplied through mineral gypsum. The experiment laid out in split plot design with weed management treatments assigned in main plots and sulphur in sub plots and replicated thrice. Clusterbean variety 'RGC-1017' was used as test crop and raised according to package of practices recommended for this agro-climatic zone. Treatments were evaluated following standard procedures.

RESULTS

Various weed control treatments did not significantly influence protein content of clusterbean. Maximum gum content in clusterbean seed was recorded by weed control through two hand weedings, closely followed by sequential application of pendimethalin with imazethapyr. Next in order of superiority was pendimethalin *fb* quizalofop-ethyl. Analysis of data further reveal that effect of imazethapyr, pendimethalin and one hand weeding were found superior over quizalofop-ethyl and weedy check, but at par to each other. Two hand weedings gave 19.84 per cent higher gum content than weedy check (24.94%). Two hand weeding treatment recorded the highest (1.76 mg/g fresh weight of leaves) chlorophyll content, its effect was at par to pendimethalin *fb* imazethapyr. On pooled basis, two hand weeding, pendimethalin *fb* imazethapyr and pendimethalin *fb* quizalofop-ethyl recorded significantly higher chlorophyll content over weedy check (1.30 mg g^{-1} fresh weight of leaves) and registered 35.38, 33.85 and 30.00 per cent enhancement in chlorophyll content, respectively. The increase in gum and chlorophyll content under the influence of weed management treatments is possibly due to the fact that reduced crop weed competition provides congenial atmosphere to the crop which in turn had the positive impact on these parameters which is evident from the weed dry matter under the influence of different weed control treatments.

Table 1. Effect of weed management and sulphur nutrition on quality parameters in clusterbean (pooled data)

Treatment	Weed dry matter (kg/ha)	Protein content (%)	Gum content (%)	Chlorophyll content (mg/g fresh weight of leaves) 75 DAS
Weed management				
Weedy check	3439	24.64	24.24	1.30
One hand weeding	1791	24.71	25.81	1.50
Two hand weeding	524	25.07	29.05	1.76
Pendimethalin	1723	24.95	26.02	1.53
Imazethapyr	1005	25.07	26.22	1.61
Quizalofop-ethyl	2232	24.78	24.48	1.40
Pendimethalin *fb* imazethapyr	580	25.13	28.88	1.74
Pendimethalin *fb* quizalofop-ethyl	1283	25.13	27.49	1.69
LSD (P=0.05)	75	NS	0.57	0.03
Sulphur (kg/ha)				
Control	1555	24.21	25.25	1.40
15	1566	24.63	26.39	1.56
30	1581	25.29	27.06	1.64
45	1586	25.61	27.40	1.66
LSD (P=0.05)	NS	0.21	0.22	0.02

Protein content was increased significantly up to 45 kg S/ha which was 5.78, 3.98 and 1.27 per cent higher over control, 15 and 30 kg S/ha, respectively. Enhancing sulphur dose from control to 15, 15 to 30 and 30 to 45 kg/ha was associated with 4.51, 2.54 and 1.26 per cent increase in gum content, respectively. Data indicate that application of 45 kg S/ha was associated with 18.57, 6.41 and 1.22 per cent increase over control, 15 and 30 kg S/ha, respectively in chlorophyll content. Protein content in clusterbean seed with sulphur application can be ascribed to the fact that sulphur deficiency hinders the full utilization of carbohydrates. The increase in gum content of seed might be due to boldness of seed and endosperm thereby more accumulation of carbohydrates.

CONCLUSION

Based on quality parameters, hand weeding twice as well as pendimethalin *fb* imazethapyr was found beneficial as compared to other treatments. Application of 45 kg S/ha was found better in enhancing quality parameters like seed protein and gum content.

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Control of mixed weed flora in garden pea with imidazolinone herbicides

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Peas are considered as weak competitors of weeds like other grain legumes. Such lower competitive ability is attributed to plant factors such as slow initial growth, higher energetic cost of nodule formation and activity, and agronomic factors such as lower plant density and fewer and costly herbicide options (Corre-Hellou *et al.* 2011). Imidazolinone herbicides which are acetolactate synthase inhibitors with their broad-spectrum action on both grass and broadleaf weeds, have been employed both in pre and post emergence window timings. This flexibility in application timings, make these herbicides particularly selective for weed control in legumes such as peas. Sikkema *et al.* (2005) observed effective weed control in pea with imazethapyr application both as pre- and post-emergence herbicide options. Keeping this in mind, this experiment was designed to assess the comparative efficacy of imidazolinone herbicides for controlling weeds in pea.

METHODOLOGY

A field experiment was conducted at Agronomy Research Farm, Punjab Agricultural University, Ludhiana during *Rabi* 2015-16. Sowing of garden pea cultivar 'Punjab 89' was done in randomized complete block design with four replications comprising 12 weed control treatments including imazethapyr 50, 60, 70 g/ha as post-emergence (POST); pre-mix of pendimethalin + imazethapyr 800, 900, 1000 g/ha as pre-emergence (PRE); pre-mix of imazethapyr + imazamox 50, 60, 70 g/ha as POST, along with unsprayed weedy, weed free and pendimethalin 1000 g/ha as PRE. The PRE herbicides were sprayed at 1 days after sowing (DAS) using 500 L water and POST were sprayed at 25 days after sowing (DAS) with 375 L water/ha using knapsack sprayer. The crop was raised as per local recommendations except weed control treatments and was harvested in end of the February. The data on weed biomass was recorded at 60 DAS, and green pod yield at crop harvest. The comparisons were made at 5 per cent level of significance.

RESULTS

Pendimethalin 750 g/ha resulted in poor weed control of *Medicago denticulata* and *Oenothera laciniata*, resulting in more weed biomass and poor weed control efficiency (55 % WCE) at 60 DAS and at harvest (26 % WCE). Premix of pendimethalin + imazethapyr applied as pre-emergence resulted in 100% weed control of all grass weeds, and partial control of *M. denticulata* (Table 1), resulting in 96% WCE for broadleaved weeds. Premix of imazethapyr + imazamox (66-83, 56-75% WCE) was superior in controlling the weeds than alone imazethapyr (59-69, 43-59% WCE) at 60 DAS and at harvest, respectively. All weed control treatments yielded significantly more pod yield than unsprayed weedy check. The maximum green pod yield was obtained with premix of pendimethalin + imazethapyr 800-1000 g/ha which was statistically at par with 60-70 g/ha of imazethapyr and premix of imazethapyr + imazamox, and weed free plots. Imazethapyr and premix of Imazethapyr + imazamox 50 g/ha yielded similar yields as obtained with pendimethalin 750 g/ha.

Table 1. Effect of different weed control treatments on weeds and crop yield and yield attributes

Treatments (Dose in g/ha)	Weed biomass (g/m^2) at 60 DAS*		Weed biomass (g/m^2) at harvest*		Green pod yield (t/ha)
	Grasses	Broadleaved	Grasses	Broadleaved	
Pendimethalin 750	1.0 (0)	11.9 (141)	1.0 (0)	20.1 (406)	13.16
Pendimethalin + imazethapyr 800	1.0 (0)	3.7 (12)	1.0 (0)	9.7 (94)	16.59
Pendimethalin + imazethapyr 900	1.0 (0)	3.4 (10)	1.0 (0)	8.1 (64)	16.50
Pendimethalin + imazethapyr 1000	1.0 (0)	3.2 (10)	1.0 (0)	6.4 (40)	16.75
Imazethapyr 50	1.8 (2)	11.4 (129)	5.4 (28)	17.7 (312)	14.11
Imazethapyr 60	1.6 (2)	10.1 (101)	4.3 (17)	16.1 (258)	15.71
Imazethapyr 70	1.4 (1)	9.8 (96)	3.6 (12)	15.0 (223)	16.16
Imazethapyr + imazamox 50	1.0 (0)	10.3 (106)	3.2 (9)	15.6 (244)	14.00
Imazethapyr + imazamox 60	1.0 (0)	10.0 (99)	1.0 (0)	13.4 (178)	15.52
Imazethapyr + imazamox 70	1.0 (0)	7.4 (54)	1.0 (0)	11.6 (134)	15.47
Weedfree	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	16.30
Unsprayed/weedy	3.1 (9)	17.8 (317)	5.2 (27)	23.6 (554)	9.68
LSD (P=0.05)	0.37	1.16	0.51	1.25	1.41

*Data is subjected to square root transformation. Figures in parenthesis are means of original values

CONCLUSION

Pre-emergence (premix of pendimethalin + imazethapyr 800-1000 g/ha) and post-emergence imidazolinone herbicides (imazethapyr and premix of Imazethapyr + imazamox 60-70 g/ha) could be adopted for broad-spectrum control of weeds in garden pea.

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Influence of sowing methods and herbicides on weed seed bank dynamics and productivity of direct seeded rice

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Direct seeded rice (DSR) is infested with diverse weed flora and is more susceptible to weed competition as compared to puddle transplanted rice (Bhullar *et al.* 2016). The weed flora in direct seeded rice germinates in several flushes, and the initial flushes are more problematic. Herbicides are the primary tool used for weed control, however, herbicides alone have not been able to prevent the yield losses caused by weeds in case of DSR. There is an urgent need to deplete the soil weed seed bank which is the source of the weed infestation in a field. The present study evaluated the effects of sowing methods and weed control on soil weed seed bank dynamics and grain yield of DSR in Punjab.

METHODOLOGY

A field study was carried out on a sandy loam field in 2014 and 2015 at Ludhiana, India. Three rice sowing methods (without stale seedbed, stale seedbed with glyphosate 1 kg/ ha, stale seedbed with shallow tillage (5 cm) in main-plots and four weed control treatments viz. unsprayed control, pendimethalin 750 g, bispyribac-sodium 25 g and pendimethalin 750 g followed by bispyribac-sodium 25 g/ha in sub-plots were evaluated in split-plot design. In stale seedbed plots, one extra irrigation was given for weeds to germinate, and germinated weed seedlings were killed with shallow tillage or glyphosate. Rice was sown in moist bed in 20 cm spaced rows with rice seed drill in first week of June. Pendimethalin was sprayed on the day of sowing and bispyribac at 20 days after sowing. Weed seed bank studies were carried out from 0-5 cm soil depth before start of study, before crop sowing and after harvest. The crop was harvested in October in both years.

RESULTS

Among sowing methods, stale bed with glyphosate and tillage reduced viable weed seedbank count by 43-57% before sowing, and 17-35% at crop harvest compared to conventional sowing in 2014 and 2015 (Table 1). Both stale seedbed methods recorded significantly lower weed density and biomass, and significantly higher rice grain yield than without stale seedbed in both years; in 2014, stale seedbed

Table 1. Effect on sowing methods and weed control on weed seedbank dynamics and rice grain yield during 2014 and 2015 at Ludhiana

Treatment	Soil weed seedbank dynamics at 0-5cm depth (%)[x]				Weed density (no./m^2)[y]		Weed biomass (g/m^2)[y]		Rice grain yield (t/ha)	
	Before sowing		At harvest		45 DAS		45 DAS			
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Sowing method										
Without stale seedbed (conventional sowing)	-	-	-	-	10.34	13.51	6.36	8.42	3.005	2.913
Stale seedbed (with herbicide)	- 43.7	- 57.6	-16.9	- 30.4	9.07	10.92	6.25	6.97	3.235	3.854
Stale seedbed (with shallow tillage)	- 45.6	- 56.1	-22.3	- 34.9	9.14	10.53	5.87	7.06	4.156	4.163
LSD (P=0.05)	-	-	-	-	0.31	0.47	0.48	0.34	0.417	0.321
Weed control										
Unsprayed control	-	-	+ 42.3	+48.7	11.52	13.93	9.23	9.85	1.226	1.846
Pendimethalin 750 g/ha	-	-	+ 65.6 (+16)	+76.6 (+19)	9.07	12.38	5.62	7.61	3.164	3.491
Bispyribac sodium 25 g/ha	-	-	-3.8 (-32)	+3.1 (-31)	9.80	12.22	5.81	8.07	2.896	2.884
Pendimethalin 750 g fb bispyribac-sodium 25 g/ha	-	-	-53.1 (-67)	-59.9 (-73)	7.69	8.09	3.99	4.41	6.575	6.353
LSD (P=0.05)	-	-	-	-	0.33	0.57	0.44	0.40	0.226	0.322

[x]In case of sowing methods, it is percent change in seedbank compared to conventional sowing. In weed control, it is percent change compared to original seedbank before sowing (parentheses are percent change compared to unsprayed control).

[y]Data subjected to square root transformation $(\sqrt{x+1})$; values are transformed means.

with shallow tillage recorded significantly higher yield than stale seedbed with glyphosate. Among weed control, sequential application of pendimethalin and bispyribac recorded highest decrease in seedbank count (53-59%) compared to original, and by 67-73% compared to unsprayed control. In contrast, pendimethalin recorded increase in seed bank count (65-77%) compared to original seed bank, and 16-19% higher than even unsprayed control. Sequence application of pendimethalin and bispyribac recorded significantly lower weed biomass and provided significantly higher grain yield than other treatments in both years.

CONCLUSION

The adoption of combination of stale seedbed with shallow tillage or with glyphosate and, application of pre- and post-emergence herbicides seems to be the best way for depleting soil weed seed bank and enhanced rice productivity.

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Comparative efficiency of new herbicides in managing resurging weeds in wheat

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Weeds are known to be a major biotic constraint in agricultural production systems. Estimates reveal that more than one-third of the total field losses are caused by weeds alone which often go unnoticed due to their multipronged hidden effects on plant growth. Weeds have better adaptability to the changing environments by virtue of greater genetic diversity in comparison to crops. Weed management is likely to become more complex in future due to increase in their invasiveness, weed shifts, herbicides resistance in weeds and their residue hazards under changing climate. Increasing interest towards conservation agricultural and shortage of labour due to implementation of different development programme in the country are increasing the acceptance of herbicides to tackle the dynamic problem of weed management.

METHODOLOGY

A field experiment was conducted at research farm, RARI, Durgapura for two consecutive years during *Rabi* and *Kharif* seasons 2013-14 and 2014-15 in loamy sand soil. The experiment consisted of eleven weed control treatments *i.e.* weedy check, hand weeding, 2,4-D ester (0.5 kg/ha), sulfosulfuran (25 g/ha), metsulfuran-methyl (4 g/ha), sulfosulfuran 75% + metsulfuran-methyl 5 WG (32 g/ha), piroxofop-propargyl 15% WP (60 g/ha), clodinafop-propanyl 15% + metsulfuran-methyl 1% (64 g/ha), carfentrazone-ethyl 40% DF (20 g/ha), pendimethalin pre-emergence, and weedy free. These treatments were evaluated in randomized block design with four replications. Wheat variety 'Raj 4079' was used as test crop.

RESULTS

Results revealed that highest reduction in weed density at 25 DAS was recorded in the plots treated with pendimethalin pre-emergence (0.750 kg/ha) but at 50 DAS with 2,4-D ester (0.5 kg/ha) followed by clodinafop-propanyl 15% + metsulfuran-methyl 1% (64 g/ha) and metsulfuran-methyl (4 g/ha). Significant reduction in weed dry matter and the highest weed control efficiency of 89.41 per cent at harvest was recorded by hand weeding at 30–35 DAS. The yield attributes (effective tiller per metre row length, number of grains per spike, length of spike and test weight) and grain, straw and biological yields were significantly higher in weed free treatment but almost the same as those under hand weeding. The uptake of N and P by wheat was also significantly higher in weed free treatment. Significantly higher net returns and B:C ratio were obtained with hand weeding.

CONCLUSION

Based on the results of two years experimentation, it is concluded that conventional method of hand weeding is the most effective and remunerative weed control measure in wheat securing the highest net returns and B:C ratio. The next best option is use of clodinafop-propargyl 15% + metsulfuran-methyl 1% (64 g/ha) or sulfosulfuran 75% + metsulfuran-methyl 5 WG (32 g/ha) under labour shortage conditions. The ready mixtures proved superior as compared to existing single herbicides.

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Sequential herbicides for control of complex weed flora in dry direct-seeded rice in TBP command area of Karnataka

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Rice (*Oryza sativa* L.) is main staple food for human consumption all over the world. Recently, there is trend towards direct seeded rice because of labour and water scarcity. In DSR (direct seeded rice-dry and wet) weeds are the main biological constraint. As the weeds and rice emerge simultaneously in DSR, the proper time and method of weed control remains a complex phenomenon (Khaliq and Matloob 2011). Use of sequential herbicides is vital tool for effective and cost efficient weed control in DSR, which encounters weed competition from the day of germination.

METHODOLOGY

Field experiment was conducted at Agricultural Research Station, Gangavathi, University of Agricultural Sciences, Raichur, Karnataka, during *Kharif*, 2015 in medium deep black clay soil with twelve different weed management practices and variety '*GNV-05-01*' sown at 20 cm row spacing for all the treatments except for treatment comprising mechanical weeding for which 25 cm row spacing was followed. Fertilizer dose of 150:75:75 kg N, P_2O_5 and K_2O/ha along with 20 kg $ZnSO_4$ was applied. The gross and net plot sizes were 5.0 m x 5.0 m and 4.2 m X 4.2 m, respectively. These treatment combinations were replicated thrice in Randomized Block Design.

RESULTS

At 60 DAS, among different herbicides, sequential application of pyrazosulfuron-ethyl 20 g/ha at 3 DAS *fb* bispyribac-sodium 10 SC 25 g/ha at 25 DAS recorded lower total weed density (52.56%), dry weight (47.04 %), weed control efficiency (78.46), lower weed index (4.73), higher grain and straw yield (4.04 and 5.05 t/ha, respectively), increased returns (Rs. 26816) over weedy check and benefit cost ratio (2.07). Follow-up spray of bispyribac after pyrazosulfuron-ethyl resulted in significantly lower weed dry matter than alone application of pre-emergence herbicides (Kaur and Singh 2015).

Table 1. Effect of herbicide mixtures on weed density, dry weight weed control efficiency at 60 DAS, grain, straw yield, weed index, net returns and benefit cost ratio in direct-seeded rice

Treatment	Weed density (no. /m^2)	Weed dry wt (g//m^2)	WCE (%)	Grain yield (t/ha)	Straw yield (t/ha)	NR (Rs/ha)	B:C
Bispyribac-sodium 10 SC 25 g/ha – 20 DAS	6.70 (44.32)	5.13 (25.94)	63.63	3.48	4.35	23442	1.77
Pendimethlain 38.7 CS 1000 g/ha (2 DAS) *fb* bispyribac 10 SC 25 g/ha – 25 DAS	5.49 (29.84)	4.37 (18.63)	73.41	3.99	4.98	29225	1.94
Oxadiargyl 80 WP 100 g/ha – 2 DAS *fb* bispyribac-sodium 10 SC 25 g/ha – 25 DAS	5.75 (32.68	4.52 (19.91)	71.60	3.84	4.80	28171	1.90
Pyrazosulfuron ethyl 20 g/ha – 3 DAS *fb* bispyribac-sodium 10 SC 25 g/ha – 25 DAS	5.12 (40.98)	3.97 (15.33)	78.46	4.04	5.05	33231	2.07
Pendimethlain 38.7 CS 1000 g/ha (2 DAS) *fb* bispyribac 10 SC 25 g/ha – 20 DAS *fb* manual weeding – 45 DAS	4.64 (21.04)	3.56 (12.22)	82.84	4.16	5.20	24557	1.64
Pendimethlain 38.7 CS1000 g/ha (2 DAS) *fb* manual weeding -25 DAS	6.22 (38.21)	4.96 (24.22)	65.83	3.70	4.63	21376	1.60
Bispyribac-sodium 10 SC 25 g/ha – 20 DAS + chlorimuron-ethyl + metsulfuron-methyl 20 WP 4 g/ha -20 DAS	6.03 (35.89)	4.75 (22.13)	68.79	3.71	4.64	26434	1.85
Mechanical weeding (passing conoweeder – 20, 40 and 60 DAS)	5.72 (32.35)	4.51 (19.91)	71.59	3.82	4.77	23569	1.66
Hand Weeding (20, 40 and 60 DAS)	3.99 (15.45)	3.19 (9.69)	86.15	4.25	5.31	25299	1.62
Weedy check	9.74 (94.69)	8.44 (70.89)	0.00	2.25	2.81	6415	1.23
Butachlor 50 EC 1250 g/ha- 6DAS *fb* bispyribac 10 SC 25 g/ha – 25 DAS	6.43 (40.86)	5.03 (24.93)	65.01	3.53	4.41	23417	1.75
Penoxsulam+ cyhalofop 6% OD (RM) 135 g/ha – 15 DAS	5.33 (27.91)	4.20 (17.18)	75.47	3.90	4.88	32672	2.12
LSD (P=0.05)	0.66	0.55	5.38	0.37	0.73	7063	0.28

Data within the parentheses are original values; Transformed values square root of (X+0.50); DAS = Days after sowing, WCE-weed control efficiency

CONCLUSION

Among different herbicide combinations application pyrazosulfuron ethyl 20 g/ha at 3 DAS *fb* bispyribac-sodium 10 SC (25 g/ha) at 25 DAS.

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Effect of brown manuring on weeds, productivity and profitability of maize and soil nutrients

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The rice-wheat system has encountered numerous challenges (Gupta *et al.* 2003), which pose threats to its sustainability in recent years. The maize-wheat system could be a viable alternative to rice-wheat system (Humphreys *et al.* 2010). The productivity of maize (~2.44 t/ha) is low due to a host of factors including weeds. Brown manuring by growing *Sesbania aculeata* L. co-culture with crops offers multiple benefits including weed management, but hardly studied in maize. Maize being is a non-tillering crop, may experience yield losses through initial reductions in population and vigour due to smothering by *Sesbania* plants (Susha *et al.* 2014). Therefore, these experiments were conducted in the field for four years (2011-2014) to appraise and optimize brown manuring method through *Sesbania* seed rate, and the time and dose of application of 2,4-D for killing *Sesbania* plants in maize.

METHODOLOGY

The experiment I involved 6 treatments laid out in a RBD with 4 replications. The experiment II involved three factors at two levels laid out in a FRBD with three replications. The factors were *Sesbania* seed rates (~15, 25 kg/ha), and doses (~0.25, 0.50 kg/ha) and times of applications of 2,4-D (~25, 35 DAS) and 2 controls [unweeded control (UWC) and weed-free control (WFC)]. For brown manuring, *Sesbania* seeds 10, 15 or 25 kg/ha (as applicable) were uniformly broadcast over the entire plot at the time of sowing of maize. The 2,4-D 0.25 and 0.50 kg/ha was applied at 25 and 35 DAS for killing *Sesbania* plants, which gradually dried up and served as mulch for the initial 35-40 DAS. Atrazine and pendimethalin at required quantities were mixed in the spray-tank and applied as pre-emergent tank-mixture at 2 DAS. All herbicides were applied with 400 l/ha water using a knapsack sprayer fitted with a flat fan nozzle.

RESULTS

Weed flora comprised of grasses: *Acrachne racemosa* Heyne ex Roem and Ohwi, *Dactyloctenium aegyptium* (L.) P. Beauv., *Setaria glauca* (L.) Beauv.; sedges: *Cyperus rotundus* L.; and broad leaved weeds: *Trianthema portulacastrum* L., *Commelina benghalensis* L. and *Digera arvensis* (L) Forsk. The experiment I showed that brown manuring with 15 kg *Sesbania* seed/ha, and 2,4-D applied 0.50 kg/ha at 30 DAS provided higher weed control efficiency (~70%) than the recommended pre-emergent tank-mix application of atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha. It resulted in similar weed control index (~70%) and weed index (~7%) with the tank-mix. The brown manuring resulted in better suppression of *Cyperus rotundus* L. than this tank-mixture. The experiment II conducted for three years showed that weed densities and dry weights were significantly lower and maize grain yields were significantly higher due to 15 than 25 kg/ha *Sesbania* seeds; and due to 2,4-D applied 0.50 than 0.25 kg/ha at 25 than at 35 DAS. A combination involving 15 kg/ha *Sesbania* seed, and 2, 4-D applied with 0.50 kg/ha at 25 DAS resulted in better weed control through significant reductions in weed densities and dry weights and gave significantly higher maize grain yields consecutively for three years. This combination inflicted least reduction (3.4-7.0%) in maize yield due to weeds, and resulted in significantly higher net returns than all other treatments including weed-free control, and was most remunerative. It, however, led to lower accumulation of C and N in soil compared to the combinations of 25 kg/ha *Sesbania* seed and 2,4-D applied at 35 DAS with 0.50 or 0.25 kg/ha, which improved soil organic carbon by 6.8-7.0% and total soil nitrogen by 2.8-3.6% over a period of three years.

CONCLUSION

A combination of 15 kg/ha *Sesbania* seed and 2,4-D applied with 0.50 kg/ha at 25 DAS for killing *Sesbania* and weeds would be an effective brown manuring practice in maize. It may suppress noxious weed *Cyperus rotundus* as well. This would sequester C and N in soil, and sustain maize yield and farm income over the years.

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Integrated weed management in spring maize

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Maize is one of the most versatile promising crops having wider adaptability under varied agro-climatic conditions. It is cultivated in *Kharif* season in 6000 ha with production of 17,000 tonnes and productivity of 2,833 kg/ha in Haryana (Anonymous 2015). The area under spring maize is increasing in Northern Haryana due to higher yields in this season. Weed being a serious negative factor in crop production are responsible for marketable loss (29-100%) in crop yield (Pandey *et al.* 2001). The weed flora changes with change in agro-climatic conditions and crop rotation followed in that area. The crop sequence for spring maize in Haryana is Paddy- Potato- Spring maize. Almost all types of weeds, *viz.* grassy, sedges and BLWs infest the maize fields during this season. Considering these facts, the present study was undertaken to evaluate the new and old herbicide as pre and post emergence application in spring maize against different type of weeds in spring maize.

METHODOLOGY

A field experiment was conducted at Regional Research Station, Uchani, Karnal of CCSHAU Hisar, Haryana on sandy loam soils having pH 7.8, low in organic carbon, medium in phosphorus and potash during *spring* 2016. The experiment consisting of eighteen treatments were laid out in randomized block design with three replications. The herbicides *i.e.* atrazine, alachlor, tembotrione, 2,4 D and metribuzin were compared in alone or in combination or in mixture with three hoeings, weed free and weedy check treatments. *'HQPM-1'* variety of maize was used in the experiment with row of 70 X 20 cm. The crop was fertilized with 150-60-60 NPK kg/ha. The crop was raised as per package of practices of CCSHAU, Hisar. Data on weed growth, weed control efficiency, weed index and yield was recorded.

RESULTS

The prominent weeds were *Cyperus rotundus* among sedges (23.9%), *Anagallis arvensis*, *Eclipta alba*, *Ageratum conyzodies*, *Coronopus didymus* among broad leaf weeds (53.2%), *Brachiaria reptans* and *Dactyloctenium aegyptium as* grassy weeds (22.9%) recorded at 60 DAS. Among herbicide treatments, lowest weed density (9.7/m^2) and dry matter (29.9 g/m^2) was recorded with the application of alachlor 2000 g/ha as PRE *fb* tembotrione 120 g/ha at 25 DAS + S. Maximum weed control efficiency was also recorded in the same treatment. Among the herbicide treatments, alachlor 2000 g/ha as PRE *fb* tembotrione 120 g/ha at 25 DAS + S, atrazine 750 g/haas PRE *fb* tembotrione 120 g/ha at 25DAS + S, tembotrione 140 g/ha + S, tembotrione 120 g/ha + S being at par resulted in lower weed index *i.e.* 2.0, 4.1, 7.0 and 7.8% respectively, in comparison to rest of the treatments.

Table 1. Weed growth, yield and weed index of maize as influenced by different herbicidal treatments

Treatment	Dose (g/ha)	Time of application	Weed density (no./m^2)	Weed dry matter (g/m^2)	WCE (%)	Weed index (%)	Grain yield (kg/ha)
Atrazine	750	PRE	10.2(103.3)	16.6(275.8)	49.6	33.7	5153
Atrazine *fb* 2,4-D	750 and 500	PRE & 30 DAS	9.1(82.4)	14.6(214.6)	60.8	29.3	5523
Atrazine *fb* one hoeing	750	PRE & 30 DAS	8.1(64.7)	11.4(128.5)	76.5	22.6	6027
One hoeing *fb* atrazine	500	20 & 30 DAS	8.3(69.0)	11.9(143.2)	73.8	26.1	5813
Alachlor	2000	PRE	4.7(21.7)	8.6(73.0)	86.7	16.7	6497
Alachlor *fb* hoeing	2000	PRE & 30 DAS	4.4(18.7)	7.8(61.4)	88.8	12.2	6887
Alachlor *fb* 2,4-D	1000 and 500	PRE & 30 DAS	4.8(22.7)	8.8(77.1)	85.9	19.1	6306
Atrazine + alachlor	375 and 1000	PRE	5.0(24.7)	8.5(72.1)	86.8	12.8	6792
Tembotrione + surfactant	120 + 1000	25 DAS	4.4(18.7)	7.2(51.5)	90.6	7.8	7214
Tembotrione + surfactant	140 + 1000	25 DAS	4.1(16.3)	6.6(43.8)	92.0	7.0	7283
Alachlor *fb* tembotrione + S	2000 and 120	PRE & 25 DAS	3.2(9.7)	5.5(29.9)	94.5	2.0	7648
Metribuzin	400	PRE	8.9(78.3)	14.3(205.2)	62.5	37.8	4878
Metribuzin	500	PRE	8.6(74.3)	13.7(189.4)	65.4	37.8	4819
Atrazine *fb* tembotrione+ S	750 and 120	PRE & 25 DAS	4.2(16.7)	6.5(42.1)	92.3	4.1	7521
Manual hoeing		20 & 40 DAS	7.9(61.7)	11.4(128.5)	76.5	26.3	5744
Mechanical hoeing		20 & 40 DAS	8.1(65.0)	11.8(138.5)	74.7	27.3	5663
Weedy check			12.9(167.3)	23.4(547.3)	0.0	47.2	4101
Weed free			1.0(0.0)	1.0(0.0)	100.0	0.0	7853

Original data given in parenthesis were subjected to square root $\sqrt{(x+1)}$ transformation before analysis

CONCLUSION

It is concluded that pre emergence application of alachlor 2000 ml/ha *fb* tembotrione120 g/ha applied at 20-25 DAS found to be very promising in controlling all type weeds and enhancement of grain yield in spring maize.

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Weed control in maize with sequential application of herbicides under conservation agriculture

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Among the various factors of low productivity of crops, competition by weeds is major one. If weeds are not controlled during critical periods of crop-weed competition, there is reduction in the yields of maize, to the tune of 68.9% depending upon the types and intensity of weeds (Walia *et al.* 2007). Therefore, it is necessary to find out the effective methods of weed control for reducing the weed load during early growth period of crops to get economical yields. Literature indicates that no single method is effective and economical for a crop or for a whole cropping system. Thus, management of weeds through integration of tillage methods with herbicides can increase the productivity of maize by decreasing the biomass and nutrient removal by the weeds.

METHODOLOGY

A field experiment was conducted at ICAR-Directorate of Weed Research, Jabalpur during *Kharif* 2015 in order to control weeds in maize-mustard-greengram cropping system with tillage practices and application of herbicides. The experiment was laid out in split plot design with five main plot or tillage and residue management treatments, *viz.* conventional tillage- conventional tillage (CT-CT), conventional tillage-zero tillage- zero tillage (CT-ZT-ZT), zero tillage + greengram residue-zero tillage-zero tillage + mustard residue (ZT + GR-ZT-ZT + MsR), zero tillage-zero tillage + maize residue-zero tillage + mustard residue, (ZT-ZT + MR-ZT + MsR), zero tillage + greengram residue- zero tillage + maize residue-zero tillage + mustard residue (ZT + GR- ZT + MR- ZT + MsR); and three sub-plot treatments of weed management; *viz.* atrazine + pendimethalin (500 g + 500 g/ha) (PE) *fb* tembotrione (100 g/ha) (PoE), atrazine + pendimethalin (500 g + 500 g/ha) (PE) *fb* 2,4-D (500 g/ha) (PoE), atrazine + pendimethalin (500 g + 500 g/ha) (PE) *fb* 1 HW at 25 DAS, unweeded control under zero tillage was alone maintained as additional. Maize Hybrid-4212 was grown with row spacing of 70 cm and a plant to plant spacing of nearly 25-30 cm during 2015. Total weed population and biomass/m^2 were recorded besides the growth and yield parameters of maize crop.

RESULTS

Among different tillage practices, the density of weeds was maximum in CT-CT treatments, while the lowest density of these weeds was recorded in ZT + GR- ZT + MR- ZT + MsR. Pre-emergence (PE) application of pendimethalin (500 g/ha) + atrazine (500 g/ha) reduced the density of weeds. Post-emergent application of tembotrione (100 g/ha) effectively controlled the grassy, sedges and broad-leaves weeds (BLWs) except *Commelina benghalensis.* It caused only bleaching symptom on *C. benghalensis* and after sometimes the plants regenerated. Post emergence application of 2,4-D was effective in controlling the BLWs. Pre-emergence application of pendimethalin (500 g/ha) + atrazine (500 g/ha) *fb* 1 hand weeding effectively checked the density of all weeds and attained 77.5% weed control index.

Table 1. Influence of tillage and weed management on weeds and yield of maize during 2015

Treatment	Total weed density (no./m^2)	Total weed biomass (g/m^2)	Weed control efficiency (%)	Weed control index (%)	Grain yield (t/ha)
T_1 CT-CT	97.7 (16.1)	197.3 (22.1)	66.4	67.6	3.89
T^2 CT-ZT-ZT	77.1 (14.2)	163.6 (19.8)	73.2	73.1	4.67
T_3 ZT + GR-ZT-ZT + MsR	68.4 (13.0)	133.1 (17.7)	77.1	78.1	5.11
T_4 ZT-ZT + MR-ZT + MsR	49.7 (11.1)	101.3 (15.3)	84.3	83.4	5.18
T_5 ZT + GR-ZT + MR + ZT + Msr	30.8 (8.8)	67.9 (12.6)	90.1	88.8	5.44
LSD (P=0.05)	3.23	7.5	-	-	0.83
W_1 Atrazine + pendimethalin 500 g + 500 g/ha (PE) *fb* Tembotrion 100 g/ha	63.1 (12.5)	165.3 (17.8)	78.9	72.9	5.07
W_2 Atrazine + pendimethalin 500 g + 500 g/ha (PE) *fb* 2,4-D 500 g/ha (PoE)	65.3 (13.0)	175.9 (21.0)	78.3	71.1	4.39
W_3 Atrazine + pendimethalin 500 g + 500 g/ha (PE) *fb* 1 HW at 25 DAS	65.8 (12.8)	56.7 (11.9)	77.4	90.7	5.12
Unweeded (control)	304.2 (29.8)	356.0 (27.2)	0.0	0.0	3.67
LSD (P=0.05)	2.01	2.90	-	-	0.42

Among different tillage practices, the weeds biomass was maximum under CT-CT treatment, while minimum biomass of weeds were observed under ZT + GR- ZT + MR-ZT + MsR The biomass of weeds was higher in plot treated with W_1 treatment while minimum biomass of weeds were observed in W_3 (98.70 % WCI) (Table 1).

Among different tillage practices, minimum grain yield (3.89 t/ha) was recorded under T_1 while maximum grain in T_5 treatments which was at par with T_2, T_3 and T_4. Among different weed management treatments, minimum grain yield (4.38 t/ha) was observed in W_2. Maximum grain (5.11 t/ha) was recorded in W_3.

CONCLUSION

ZT + GR-ZT + MR + ZT + MsR with atrazine + pendimethalin (500 g + 500 g/ha) as a pre-emergence *fb* tembotrione 100 g/ha as a post-emergence was the most effective strategies for controlling weeds and increasing the yield of maize.

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Enhancing efficacy of pre- and post-emergence herbicides through spray technology for weed management in direct seeded rice-wheat production system in Punjab

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Weeds have been one of the major biological production constraints in direct seeded rice-wheat production systemin Punjab (Bhullar *et al.* 2016a, 2016b). The herbicides form the most important tool for weed management in this cropping system in the region. Generally, farmers report differential results with pre- and post-emergence herbicides, which many times are attributed to inappropriate spray technology like use of lower volume of water, use of unspecified nozzles, improper dose of herbicide, wrong time of application with regard to crop and weed stages adopted by the farmers. Hence, there is need to create awareness among farmers regarding appropriate spray technology for getting the best efficacy from applied herbicides. The present study was aimed to enhance the efficacy of pre- and post-emergence herbicides through improved spraying technology for weed management in direct seeded rice-wheat system at farmers' field.

METHODOLOGY

A total of 109 demonstrations (each 4000 m^2) in wheat in 2015-16 and 60 in direct seeded rice in 2016 wereconducted at farmers' field in six districts- Bathinda, Sri Muktsar Sahib, Moga, Patiala, Amritsar and Jalandhar in different agro-climatic zones in Punjab. The improved spray technology consisting of using multi-boom nozzles sprayer fitted with tractor was compared to conventional spraying (hand operated knapsack sprayers or tractor operated gun sprayers). Pendimethalin as pre- and clodinafop + metsulfuron and sulfosulfuron + metsulfuron as post-emergence were demonstrated in wheat, and pre-emergence pendimethalin and pendimethalin + pyrazosulfuron were demonstrated in direct seeded rice. The wheat crop was sown in November 2015 and harvested in April 2016. Direct seeded rice was sown in June 2016 and harvested in October 2016

RESULTS

In wheat, averaged over 109 locations in six districts, improved spray technology recorded 9.2% higher weed control, provided 4.3% higher wheat grain yield and Rs. 3627/ha higher net returns than conventional spraying (Table 1). The best benefit of improved spray technology was recorded in district Patiala where the improved technology provided 16% higher weed control and 0.75 t/ha higher wheat grain yield compared to conventional spray. The problem of herbicide resistance in *Phalaris minor* is more in this district primarily being under rice-wheat system and incidences of herbicide failures are quite common in this district. In case of direct seeded rice, averaged over 60 locations in five districts, improved spray technology recorded 16% higher weed control, provided 6.2% higher rice grain yield and Rs. 5500/ha higher net returns than conventional spay technology. In this crop, the best benefit of improved spray technology were recorded from districts Bathinda and Amritsar, in which the spray technology improved weed control by 18-25% and rice grain yield by 0.5 t/ha compared to conventional spray. The farmers were fully satisfied with the demonstrated technology both in rice and wheat crops. The study indicated the potential of improved spray technology in enhancing weed control and crop yield in rice-wheat production system in the region.

Table 1.Effect of improved spray technology on weed control and crop yield in direct seeded rice-wheat production system at farmers' field in Punjab. (Size of demo=4000 m^2; No. of demos: Wheat-109; Rice-60)

Name of the district	Wheat (2015-16)				Direct seeded rice (2016)			
	Weed control(%)		Wheat grain yield (t/ha)		Weed control (%)		Rice grain yield (t/ha)	
	Improved spray technology	Conventional spray technology	Improved spray technology	Conventional spray technology	Improved spray technology	Conventional spray technology	Improved spray technology	Conventional spray technology
Bathinda	90	84	5.25	5.25	88	63	7.25	6.75
Patiala	89	63	4.75	4.00	74	67	7.00	6.75
Sri Muktsar Sahib	91	90	5.00	5.00	78	71	4.75	4.75
Jalandhar	95	92	4.50	4.25	81	75	5.50	5.25
Moga	89	78	5.50	5.50	-	-	-	-
Amritsar	96	95	5.25	5.00	88	70	5.50	5.00
Mean	91	82	5.09	4.88	84	68	6.16	5.80
STDEV	3.08	11.8	0.37	0.58	6.2	4.5	1.08	0.97

CONCLUSION

The improved spray technology using multi-boom tractor operator sprayer enhanced weed control, crop yield and economic returns than conventional spraying in direct seeded rice-wheat production system; its adoption will enhance the judicious use of herbicides in the region.

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Herbicide combinations for control of complex weed flora in wheat

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Effective weed management in wheat will produce optimum yields. Among different weed management practices chemical weed control is preferred (Marwat *et al*. 2008) because of less labor involvement and no mechanical damage to the crop that happens during manual weeding. Moreover, the control is more effective as the weeds even within the rows are killed which invariably escape, because of morphological similarity to wheat, during mechanical control. Keeping these in view, the present study was designed with the objectives to find out the efficacy of different herbicides on wheat productivity and profitability.

METHODOLOGY

A field experiment was conducted in agronomical research farm of Birsa Agricultural University, Ranchi, during winter season of 2014-15 and 2015-16 to find out the effect of herbicides on weed dynamics and productivity of wheat under Jharkhand situation. The treatment comprised of pre emergence application of pendimethalin 0.75kg/ha, metribuzin0.021kg/ha, pendimethalin + metribuzin 1 kg/ha + 0.175 kg/ha, pendimethalin 1.0 kg/ha *fb* sulfosulfuron 0.018 kg/ha post-emergence, post-emergence application of sulfosulfuron 0.025kg/ha, clodinafop 0.06 kg/ha, sulfosulfuron75% + metsulfuron 20% (total) 0.03 + 0.002 kg/ha 5 WAS, metsulfuron0.004 kg/ha 5 WAS, mesosulfuron3%+iodosulfuron0.6% (atlantis) 0.012 + 0.0024kg/ha 5 WAS, Clodinafop 15% + metsulfuron1% (Vesta) 0.06 + 0.004 kg/ha 5 WAS, 2 Hand weeding 30 and 60 DAS and weedy check. The experiment was laid out in randomized block design with three replications. Crop was sown on 05th and 19th December, 2014 and 2015 and harvested on 12th and 24th April, 2015 and 2016 respectively.

RESULTS

Two hand weeding performed in wheat crop at 30 and 60 DAS recorded significantly reduced weed density and weed dry matter of broad leaf, grassy, sedges and total weeds at 30 and 60 DAS and was similar to clodinafop 0.06 kg/ha post-emergence and pendimethalin + metribuzin 1kg/ha+0.175 kg/ha pre-emergence during 2014-15 and 2015-16 and also when data were pooled. This resulting maximum total and effective tillers, grain and straw yield, net return and B:C ratio compared to other herbicides application.

Table 1. Effect of herbicide combinations on weed dry matter, yield and economics of wheat production (pool of 2014-15 and 2015-16)

Treatment	Weed dry matter (pooled)		Grain yield (t/ha)	Straw (t/ha)	Net (?/ha) Return	B:C
	30 DAS	60 DAS				
Pendimethalin 38.7%	16.28 (266.9)	20.72 (438.07)	2.56b	4.86b	23859	0.99
Sulfosulfuron 75%	18.88 (359.48)	16.19 (262.54)	2.32	4.80b	21405	0.93
Metribuzin 70%	16.19 (268.62)	16.87 (287.59)	2.52	4.81b	23584	1.00
Clodinafop	8.34 (71.7)	9.98 (99.69)	3.08b	5.37ab	32019 b	1.33a
Pendimethalin 38.7% + metribuzin 70%	9.13 (86.07)	13.15 (180.33)	2.97b	5.01a	28298	1.12
Pendimethalin 38.7% *fb* sulfosulfuron75%	20.96 (454.72)	19.58 (385.55)	2.67b	4.97a	24703	0.99
Sulfosulfuron75% + metsulfuron 20%(Total)	21.21 (455.61)	22.99 (536.93)	2.26	4.59	20100	0.87
Metsulfuron	21.93 (508.29)	27.07 (741.5)	2.18	4.47	18370	0.79
Mesosulfuron 3%+ iodosulfuron 0.6%(Atlantis)	12.08 (152.2)	15.84 (274.63)	2.58b	4.90a	22298	0.86
Clodinafop 15%+ metsulfuron 1% (Premix) (Vesta)	17.87 (327.89)	20.51 (432.72)	2.12	4.28	14776	0.58
2 Hand weeding	6.61 (43.59)	7.38 (54.62)	3.96a	5.65a	39632 a	1.38a
Unweeded control	28.61 (829.13)	32.23 (1067.76)	2.03	3.99	15590	0.69
LSD (P=0.05)	5.48	5.92	0.65	0.76	8978	0.37
CV%	29.23	25.56	0.014	0.009	22.60	22.80

CONCLUSION

On the basis of two years experiment it can be concluded that application of clodinafop 0.06 kg/ha post emergence is as good as two hand weeding in wheat at 30 and 60 DAS for higher productivity and profitability.

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Management of complex weed flora in maize through tank mix application of new herbicides and atrazine in Odisha

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Kharif maize suffers from heavy weed infestation, which may cause yield losses ranging from 28-100% depending upon the intensity and nature of infestation (Das *et al.* 2016). There are a few herbicides options available for weed management in maize in India. Sole application of atrazine does not always provide effective and desirable level of control of many weeds like *Cyperus rotundus, Xanthium* spp. *etc.* in *Kharif* season throughout the critical period of crop-weed competition. Tembotrione, topramezone and halosulfuron are new selective post emergence herbicides introduced recently against weeds in maize. But it is essential to study the efficacy of these herbicides against different weed species in maize either alone or in combination with atrazine. With this background the present experiment was conducted to study the efficacy of tank mix application of new herbicides and atrazine in managing weed species in the *Kharif* maize.

METHODOLOGY

The field experiment comprising of twelve weed management treatments, which were carried out in a randomized block design with three replications at farmer's field, Kashipal village (Mayurbhanj district, Odisha) during *Kharif*, 2015. The hybrid maize *'P 3441'* was cultivated in the experiment with fertilization rate of N: P_2O_5: K_2O at 160:100:80 kg/ha. All other agronomic practices were followed as per recommendations. Species wise, total weed density and dry weight were recorded at 45 DAS. The data were analyzed through square root transformation.

RESULTS

The experimental field was infested with 12 weed species out of which *Lindernia ciliata* among broadleaved, *Echinochloa colona* among grasses and *Cyperus iria* among sedges were predominant. Application of tembotrione at 90 g/ha + surfactant, topramezone at 80 g /ha + surfactant and halosulfuron at 67.5 g/ha as tank mix with atrazine at 500 g/ha at 20 DAS effectively controlled the grassy weed *E. colona* and *Cynodon dactylon*, broadleaved weed *Evolvulus numularis* and *L. ciliata*, sedge *C. iria* and *Fimbristylis miliacea* and also the total weed. These treatments also registered higher grain yield of maize and were at par with atrazine at 625 g/ha pre-emergence + one manual weeding at 25 DAS (Table 1). Effective weed management by these treatments facilitated better growth in maize resulting in higher values of yield attributes and yield.

Table 1. Effect of treatments on weed density and grain yield of maize

Treatment	Weed density (no. m^{-2}) at 45 DAS							Grain yield (t/ha)
	Grass		Broad-leaved		Sedge		Total weed	
	E. colona	*C. dactylon*	*E. numularius*	*L. ciliata*	*C. iria*	*F. miliacea*		
Atrazine at 625 g/ha PE	1.71 (2.47)	2.32 (4.87)	1.97 (3.39)	1.66 (2.26)	2.47 (5.61)	2.26 (4.61)	5.22 (26.74)	5.65
Atrazine at 500 g /ha at 20 DAS	1.58 (2.00)	2.38 (5.18)	2.00 (3.48)	1.68 (2.32)	2.62 (6.36)	2.40 (5.27)	5.44 (29.06)	5.36
Tembotrione at 100 g/ha at 20 DAS	1.13 (0.77)	1.88 (3.03)	1.86 (2.97)	0.71 (0.00)	1.49 (1.72)	1.76 (2.60)	3.63 (12.68)	5.73
Tembotrione at 90 g/ha + atrazine at 500g /ha at 20 DAS	0.71 (0.00)	0.96 (0.43)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.96 (0.43)	7.15
Topramezone at 90 g/ha at 20 DAS	1.02 (0.53)	2.06 (3.76)	1.80 (2.73)	0.71 (0.00)	1.46 (1.64)	1.87 (3.00)	3.70 (13.19)	5.68
Topramezone at 80 g /ha + atrazine at 500 g/ha at 20 DAS	0.71 (0.00)	0.95 (0.39)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.95 (0.39)	7.10
Halosulfuron at 67.5 g/ha+ atrazine 500 g/ha at 20 DAS	0.71 (0.00)	1.02 (0.53)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	1.02 (0.53)	7.06
Atrazine at 625 g/ha PE + one manual weeding at 25 DAS	0.71 (0.00)	1.48 (1.68)	0.71 (0.00)	1.44 (1.57)	1.29 (1.17)	1.15 (0.83)	2.65 (6.50)	7.04
Current farmers' practice	1.47 (1.67)	2.57 (6.09)	2.11 (3.96)	2.63 (6.41)	2.75 (7.05)	2.86 (7.68)	6.76 (45.21)	5.35
Manual weeding at 20 and 40 DAS	0.71 (0.00)	1.40 (1.46)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	1.40 (1.46)	6.93
Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	7.35
Unweeded control	2.84 (7.61)	3.61 (12.54)	3.05 (8.79)	2.97 (8.30)	3.44 (11.37)	3.32 (10.50)	9.37 (87.26)	4.76
LSD (P=0.5)	0.20	0.29	0.24	0.22	0.25	0.28	0.37	0.67

* Figures in parentheses are the original values. The data was transformed to SQRT ($\sqrt{x+0.5}$)

CONCLUSION

Tank mix application of tembotrione at 90 g/ha or topramezone at 80 g/ha or halosulfuron at 67.5 g/ha with atrazine at 500 g/ha appeared to be the promising tool for effective control of wide spectrum of weed flora and obtaining higher grain yield of *Kharif* maize.

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Weed flora and weed density of groundnut in the North Eastern region of Karnataka

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India is one of the biggest producer of oilseed crops in the world and has achieved self-sufficiency in oilseed production. Among oilseed crops groundnut (*Arachis hypogaea* L.) is known as 'King of Oilseed Crops' and is believed to be native of Brazil (South America). The low yields of groundnut are attributed to numerous factors. Among them the many fold losses caused by weeds are of serious nature. Chemical weed control using herbicides in the cultivated agricultural crops has opened new vistas. Certain herbicides could be applied pre- or post-emergence, which helps in checking the weed growth in early stages of crop growth. The efficiency of herbicide can be improved when it is used in conjunction with tillage and other agronomic practices.

METHODOLOGY

A field experiment was conducted during *Kharif* 2013 in the farm lands of College of Agriculture, Raichur, Karnataka. The soil of the experimental site was red sandy loam in texture and pH was neutral (7.2). The soil was low in available nitrogen (212 kg/ha) and medium in phosphorus (30 kg/ha) and available potassium (328 kg/ha). 'R-2001-2', a long duration (115 to 130 days) bunch type and high yielding variety (2.5-3.0 t/ha), was sown on July 14th, 2013 following recommended package of practices. The data on weed flora, weed density and weed dry weight were recorded at 20 and 40 days after seeding (DAS).

RESULTS

Important observed in the experiment were *Cynodon dactylon* (L.) Pers., *Panicum* spp., *Dactyloctenium aegyptium*, *Erogrostis gangetica*, *Digitaria marginata*, *Phyllanthus niruri*, *Tribulus terrestris*, *Abutilon indicum*, *Euphorbia hirta*, *Trichodesma* spp., *Portulaca oleracea*, *Lagasca mollis*, *Tridax procumbens*, *Amaranthus viridis*, *Parthenium hysterophorus*, *Mimosa pudica* L, *Digeria arvensis*, *Leucus aspera* and *Cyperus rotundus*. All the weed control treatments had significantly lower weed population than weedy check at 20 and 40 DAS which received the application of herbicides with cultural practices. Whereas at 40 DAS, pendimethalin 1000 g/ha *fb* 2 intercultivation at 25 and 35 DAS followed by pendimethalin 1000 g/ha *fb* imazethapyr 75 g/ha recorded significantly lower weed density for extended period compared to unweeded check. This is because imazethapyr is very effective on control of dicot weeds. Similarly, other treatments listed above receiving sequential application recorded lower weed count due to inhibitory action of monocot weeds by quizalofop-ethyl. At 20 and 40 DAS weed free check recorded lesser weed dry weight when compared to all other treatments which was mainly because of maintenance of minimum weeds throughout the crop growth enabled the crop to utilize the nutrients, moisture, space and light effectively compared to rest of the treatments. Similar results were obtained by Kori *et al.* (2000).

Table 1. Weed density (m^2) and weed dry weight in groundnut as influenced by weed control treatments

Treatment	Weed density (m^2)		Weed dry weight ($g\ m^2$)	
	20 DAS	40 DAS	20 DAS	40 DAS
Pendimethalin (38.7% EC) 1000 g/ha *fb* 2 intercultivation at 25 and 35 DAS	5.18 (26.67)*	7.04 (43.33)	1.00 (8.27)*	0.99 (7.70)
Imazethapyr (10% SL) 75 g/ha at 20-25 DAS	8.89 (78.00)	8.23 (60.00)	1.26 (16.20)	1.36 (21.20)
Quizalofop-ethyl (5% EC) 45 g/ha at 20-25 DAS	9.14 (83.33)	8.85 (61.33)	1.31 (18.40)	1.52 (31.55)
Imazethapyr (10% SL) 75 g/ha + quizalofop-ethyl (5% EC) 45 g/ha at 20-25 DAS	10.08 (100.67)	9.60 (75.67)	1.37 (21.67)	1.52 (31.55)
Pendimethalin (38.7% EC) 1000 g/ha *fb* imazethapyr (10% SL) 75 g/ha at 20-25 DAS	6.94 (47.33)	7.76 (52.33)	1.20 (14.00)	1.29 (31.00)
Pendimethalin (38.7% EC) 1000 g/ha fb Quizalofop-ethyl (5% EC) 45 g/ha at 20-25 DAS	6.85 (46.00)	8.14 (53.00)	1.17 (12.87)	1.36 (17.63)
Pendimethalin (38.7% EC) 1000 g/ha *fb* Imazethapyr (10% SL) 75 g/ha *fb* 1 intercultivation at 35 DAS	4.31 (17.67)	5.38 (29.67)	1.06 (10.13)	0.97 (21.20)
Pendimethalin (38.7% EC) 1000 g/ha fb quizalofop-ethyl (5% EC) 45 g/ha at 20-25 DAS *fb* 1 intercultivation at 35 DAS	5.89 (33.67)	7.90 (53.33)	1.10 (10.67)	1.15 (12.73)
Weed free check (interculture at 15, 30 and 40 Days after sowing) + 1 Hand weeding at 25 Days after sowing	1.14 (0.33)	1.42 (2.00)	0.72 (3.47)	0.85 (5.51)
Weedy check	11.24 (125.33)	13.06 (173.67)	1.56 (34.27)	1.82 (64.60)
LSD (P=0.05)	0.85	0.03	0.15	0.14

Original monocot weed count (x) data were transformed in to $(\sqrt{x+1})$ ½ * Figures in parenthesis indicate original values. Weed dry weight (x) data were transformed in to Log (x+2)* Figures in parenthesis indicate original values

CONCLUSION

Weed free check registered significantly lower weed density and dry weight; whereas weedy check recorded higher weed density and dry weight. The integrated treatments such as pendimethalin (38.7% CS) 1000 g/ha *fb* imazethapyr (10% SL) 75 g/ha *fb* 1 intercultivation at 35 DAS and pendimethalin (38.7% CS) 1000 g/ha *fb* 2 intercultivation at 25 and 35 DAS were on par with each other and recorded significantly lower weed density and dry weight.

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Performance of organic manures and weed control methods on weed parameters of winter irrigated cotton

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Cotton is one of the principal commercial crops in India. A few decades ago, most of the cotton cultivated in India was 'ecofriendly' with little or no use of toxic chemicals in its production (Blaise *et al*. 2004). Weeds are responsible for heavy yield losses, even to the extent of complete crop loss under extreme conditions. Soil fertility and weed control are the principal challenges associated with organic cotton production. Successful weed management in organic crop production system requires an understanding of plant characteristics in relation to specific field conditions.

METHODOLOGY

Field experiment was conducted at Eastern Block farm, Tamil Nadu Agricultural University, Coimbatore during winter irrigated season, 2015-16. The experiment was laid out in the strip plot design. The treatments, *viz*. farmyard manure, vermin-compost, goat manure and composted poultry manure were assigned to main plot; while hand weeding, twin wheel hoe weeding, power weeding and weedy check were assigned to sub plots and replicated thrice. The organic manures on equal nitrogen basis were applied to respective treatment plots. Two weeding at 20 and 40 DAS with twin wheel hoe weeder and power weeder in between rows was done and within the rows weeds were removed by manually. Weed density was recorded species-wise using 0.25 m^2 quadrat from four randomly fixed places in each plot and expressed as number of weeds/m^2. From the data, weed control efficiency (WCE) was calculated.

RESULTS

Grasses were more dominant (51.75%) than the broad leaved weeds (44.59%) and sedges (3.66%). Weed flora mainly consisted of *Trianthema portulacastrum*, *Cleome viscosa*, *Digera muricata*, *Boerhavia diffusa*, *Cynodon dactylon*, *Chloris barbata* and *Cyperus rotundus*.

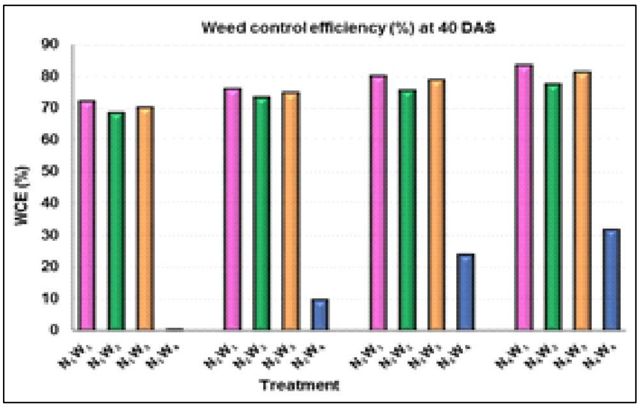

Fig. 1. Effect of organic manure and weed control methods on WCE (%) of cotton

Table 1. Weed parameters of cotton as influenced by organic manures and weed control methods at 40 DAS

Treatment	Grasses (no./m^2)	Sedges (no./m^2)	Broad leaved weeds (no./m^2)	Total weed density (no./m^2)	Weed dry weight (g/m^2)
Main plot: Organic manures					
100 % RDN through Farm yard manure	7.71 (56.92)	2.28 (4.92)	7.32 (56.66)	10.45 (118.5)	8.46 (78.10)
100 % RDN through vermicompost	6.84 (52.00)	2.08 (4.00)	6.72 (48.30)	9.76 (104.8)	7.11 (55.24)
100 % RDN through goat manure	6.39 (44.95)	1.87 (3.13)	6.17 40.69)	9.02 (88.76)	5.92 (38.16)
100 % RDN through composted poultry manure	6.05 (40.34)	1.70 (2.49)	5.80 (36.09)	8.50 (78.93)	4.79 (25.08)
LSD (P=0.05)	0.49	0.12	0.42	0.61	0.43
Sub plot: Weed control methods					
Hand weeding at 20 & 40 DAS	5.16 (26.31)	1.64 (2.26)	5.18 (26.7)	7.43 (55.24)	5.07 (26.57)
Twin wheel hoe weeding at 20 & 40 DAS	5.52 (30.07)	1.89 (3.09)	5.74 32.67)	8.13 (65.83)	5.61 (32.07)
Power weeding at 20 & 40 DAS	5.26 (27.33)	1.73 (2.55)	5.45 29.49)	7.71 (59.36)	5.40 (30.04)
Weedy check	10.51 (110.5)	2.66 (6.67)	9.64 (92.88)	14.47 (210.0)	10.21 (107.9)
LSD (P=0.05)	0.44	0.13	0.43	0.63	0.48
Interaction	0.83	0.24	0.80	1.18	0.85

Composted poultry manure significantly recorded lower weed density of grasses, sedges, broad leaf weeds, total weed density and dry weight (4.34, 2.49, 36.09 78.93 no./m^2 and 25.08 g/m^2 respectively at 40 DAS) which was at par with goat manure. With respect to weed control efficiency, not much difference was observed in all the organic manures (Fig 1). Lower weed density of grasses, sedges, broad leaf weeds; and total weed density, and dry weight (26.31, 2.26, 26.7, 55.24 no./m^2 and 26.57 g/m^2 respectively) and high weed control efficiency of 83.53 % were obtained with hand weeding at 20 and 40 DAS and followed by power weeding at 20 and 40 DAS (Table 1). Mechanical or manual weeding in controlling the weeds at critical crop-weed competition of cotton might be the reason for better crop growth (Sumachandrika *et al*. 2002).

CONCLUSION

Application of composted poultry manure, along with hand weeding or power weeding on 20 and 40 DAS is the key to sustainable crop production throughout the world and will remain the mainstay for weed control for the foreseeable future.

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Efficacy of different herbicide combination on weed management and productivity of *Kharif* maize

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Maize (*Zea mays* L.) is an amazing crop and perhaps nature's one of the most important gifts to the mankind. It is source for a large number of industrial products, *viz.* corn starch, corn oil, baby corn, popcorn, dairy feed, poultry feed, piggery, agro industries, etc. The huge potential for export has added the demand for maize all over the world. Globally, maize is cultivated in 132 m hectares with a production of 570 m tonnes. However, FAO predicts that an additional 60 m tonnes of maize grain will be needed from the annual global harvest by 2030. The demand for maize as an animal feed will continue to grow faster than the demand for its use as a human food, particularly in Asia, where a doubling of production is expected from the present level of 165 m tonnes to almost 400 m tonnes in 2030 (Paliwal *et al.* 2000). In India currently maize is cultivated over 9.23 m ha area with 23.67 m t production with average yield of 25.64 q/ha (Govt. of India, 2015). The average productivity of crop is very low mainly on account of lack of appropriate weed management. Hence the present investigation was under taken.

METHODOLOGY

A field experiment was conducted during *Kharif* 2015 with ten weed management practices (Control weedy, weed free, atrazine 1.0 kg/ha, atrazine 0.75 kg/ha + Pendimethalin 0.75. kg/ha, atrazine 0.75 kg/ha *fb* 2-4 D 0.5 kg/ha at 25 DAS, halosulfuron 0.60 kg/ha 25 DAS, atrazine 1.5 kg/ha *fb* halosulfuron 0.60 kg/ha 25 DAS, tembotrione 0.12 kg/ha POE at 25 DAS, pendimethalin 1.0 kg/ha PE *fb* atrazine 0.75 kg/ha + 2,4-D 0.5 kg/ha at 25 DAS, and atrazine 1.5 kg/ha PE *fb* tembotrione 0.12 kg/ha 25 DAS) and replicated three times. The field was prepared by giving one ploughing with tractor drawn M.B. plough followed by two cross harrowing and planking. After opening furrow at 60 cm, sowing was done manually by placing seeds at 25 cm spacing in each row. Thinning was done at 15 days after sowing in order to remove extra plants. Maize variety *'PHEM-2'* was used as test variety. As per treatments, herbicides were prayed using knapsack sprayer using fitted with flat fan nozzle. The plastic sheets were used on both side of plot to avoid shifting of spray droplets in adjoining plots. Total weed count recorded at 50 DAS and at harvest and expressed as number/m^2. The data were subjected to square root transformations to normalize their distribution. Weeds collected at harvest were dried at 70 ^oC for 24 h and weighed. The crop was raised under irrigated condition. As per recommendation 90 kg N and 40 kg P_2O_5/ha was applied to crop. The crop was harvested when more than 90 per cent crop became yellow. Before harvesting the plants under each experimental unit, border row were harvested and removed from experimental field. After through drying the cobs collected from net area were threshed, weighed and expressed grain yield in t/ha.

RESULTS

Amongst different weed management practices lowest weed intensity at 50 DAS, at harvest and weed dry matter at harvest were recorded under weed free followed by pre-emergence application of atrazine 0.75 kg/ha + pendemathalin 0.75 kg/ha. Consequently, the highest grain (4.14 t/ha) and stover (6.43 t/ha) yield were recorded under weed free condition which was statistically at par with that of grain (4.03 t/ha) and stover (6.23 t/ha) yield were recorded under pre-emergence application of atrazine 0.75 kg/ha + pendemathalin 0.75 kg/ha and both of these practices proved significantly superior over rest of weed management practices.

Table 1. Effect of weed management practices on weed dynamics and yield of *Kharif* maize

Treatment	Weed intensity (m^2)		Weed dry matter (t/ha)	Yield (t/ha)	
	50 DAS	At harvest		Grain	Stover
Control weedy	237 (15.4)	225 (15.0)	8.32	1.03	1.24
Weed free	27 (5.2)	25 (5.1)	1.00	4.14	6.43
Atrazine 1.0 kg/ha	71 (8.5)	65 (8.1)	2.23	3.25	6.08
Atrazine 0.75 kg/ha + Pendimethalin 0.75. kg/ha	39 (6.3)	34 (5.9)	1.19	4.03	6.23
Atrazine 0.75 kg/ha *fb* 2-4 D 0.5 kg/ha at 25 DAS	81 (9.0)	70 (8.4)	2.71	3.33	5.02
Atrazine 0.75 kg/ha *fb* 2-4 D 0.5 kg/ha at 25 DAS	182 (13.5)	165 (12.9)	6.39	1.35	1.76
Atrazine 1.5 kg/ha *fb* halosulfuron 0.60 kg/ha 25 DAS	53 (7.3)	40 (6.4)	1.80	3.33	5.04
Tembotrione 0.12 kg/ha POE at 25 DAS	187 (13.7)	168 (13.0)	6.46	1.51	2.04
pendimethaline 1.0 kg/ha PE *fb* atrazine 0.75 kg/ha + 2,4-D 0.5 kg/ha at 25 DAS	189 (13.7)	169 (13.0)	6.37	3.03	4.55
Atrazine 1.5 kg/ha PE *fb* tembotrione 0.12 kg/ha 25 DAS	64 (8.0)	55 (7.4)	2.60	3.25	4.94
LSD (P=0.05)	0.41	0.41	0.27	0.27	0.33

*Values in parentheses are square root transformation of original vale

CONCLUSION

On basis of one year findings it is concluded that for weed minimization and higher yield of *Kharif* maize, pre-emergence application of atrazine 0.75 kg/ha + pendemathalin 0.75 kg/ha proved best practice.

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Effect of propaquizafop and imazethapyr mixture on weeds, crop growth and yield of soybean

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Soybean [*Glycine max* (L.) Merill] is a crop of global importance having multiple qualities as it is both a pulse and an oil seed crop. Being a rainy season crop it suffers severely due to competition from weeds, which results in reduction of yield up to 77% (Tiwari and Kurchania 1990). Weed management through manual weeding and hoeing though effective, is not free from several limitations such as unavailability of adequate labourers during weeding peaks and difficulty in the use of mechanical weeders in heavy soils due to incessant rains. The only alternative, therefore, seems to be application of suitable herbicides. Imezethapyr is used in soybean to control a wide spectrum of weed species to a level of satisfaction (Sondhia 2008). However, its efficacy has not been tested with propaquizafop for broad spectrum weed control in soybean. Thus the present experiment was conducted to find out suitable dose of propaquizafop and imazethapyr mixture for effective control of weeds and its effects on growth parameters and productivity of soybean.

METHODOLOGY

A field experiment was carried out during *Kharif* season 2014 in Product Testing Unit of JNKVV, Jabalpur. Nine treatments, *viz.* four doses of propaquizafop+ imazethapyr mixture (47 + 70, 50 + 75, 53 + 80 and 56 + 85 g/ha), alone application of propaquizafop (75 g/ha) and imazethapyr (100 g/ha) as post-emergence at 15 DAS and pendimethalin (1000 g/ha) as pre emergence at 2 DAS hand weeding twice at 20 and 40 DAS including weedy check were laid out in randomized block design with three replications. Soybean variety *'JK 97-52'* was line sown using 80 kg seed/ha with recommended package of practices. Data on weeds, crop growth at various stages, yield and economics were recorded using standard techniques.

RESULTS

In soybean grassy weeds were predominant (65.15%) compared to broad-leaved (23.51%) and sedges (11.34%). Among these *Echinochloa colona* (33.90%) was the rampant weed closely followed by *Dinebra retroflexa* (23.90%). Propaquizafop (75 g/ha) alone gave effective control of grassy weeds but failed to curb broad-leaved weeds. However, its efficacy was improved when applied in combination with imazethapyr being maximum at 53 + 80g/ha or higher rate (56 + 85 g/ha) which reduced weed density and biomass to the tune of 74.14 and 85.19% respectively. However, none of the herbicidal treatments, whether applied alone or in combination, surpassed the manual hand weeding twice which curbed the weed growth to the maximum extent (98.87%). Similar trend was observed for crop biomass which was the highest in hand weeded plot (490.10 g/m^2) closely followed by plots treated with propaquizafop + imazethapyr at 56 + 85g/ha and 53 + 80 g/ha. The unchecked weed growth throughout the season, caused 63.06 % reduction in yield of soybean, which was checked appreciably (6.89 and 7.95%) when propaquizafop was applied along with imazethapyr at 53+80 g/ha or at higher dose (56+85g/ha) and these proved practically at par to that of hand weeding twice (20 and 40 DAS). Seed yields, HI and B: C ratio of soybean was minimum when weeds were not controlled throughout the crop season. However, these parameters were superior under propaquizafop and imazethapyr mixture applied at the rate of 53 + 80 g/ha and proved significantly superior over weedy check, alone application of propaquizafop (75 g/ha), imazethapyr (100 g/ha), pendimethalin (1000 g/ha) and lower doses of propaquizafop + imazethapyr (47 + 70 and 50+75 g/ha) but found at par to higher dose of propaquizafop + imazethapyr (56 + 85 g/ha) including hand weeding twice.

Table 1. Weed growth, yield and economics of soybean as influenced by different weed control treatments

Treatment	Dose (g/ha)	Weed density (no./m^2)	Weed biomass (g/m^2)	Weed control Efficiency (%)	Weed Index	Crop biomass (g/m^2)	Seed yield (t/ha)	Harvest index (%)	B:C ratio
Propaquizafop + imazethapyr	47+70	11.62(134.67)*	14.41(207.08)*	61.34	33.00	284.61	1.59	31.46	2.15
Propaquizafop + imazethapyr	50+75	10.81(116.33)	13.25 (175.13)	67.30	22.86	371.16	1.83	31.50	2.46
Propaquizafop + imazethapyr	53+80	9.63(92.33)	11.79(138.53)	74.14	7.95	455.19	2.19	33.59	2.91
Propaquizafop + imazethapyr	56+85	8.15(66.33)	9.95(98.60)	81.59	6.89	468.40	2.21	33.73	2.92
Propaquizafop	75	11.71(136.67)	14.19(200.99)	62.48	41.44	270.59	1.39	30.60	1.97
Imazethapyr	100	11.14(123.67)	14.04(196.71)	63.27	37.54	328.50	1.48	30.74	2.02
Pendimethalin	1000	13.04(169.67)	15.77(248.16)	53.67	50.28	240.80	1.18	30.35	1.58
Hand weeding	At(20&4DAS)	4.05(16.00)	2.56(6.07)	98.87	0.00	490.10	2.38	34.23	2.23
Weedy check	-	16.73(279.33)	23.15(535.63)	0.00	63.06	190.78	0.88	26.37	1.32
LSD (P=0.05)	-	0.36	0.28	-	-	24.26	4.40	-	-

*Values in parantheses are original. Data transformed to square root transformation.

CONCLUSION

It was concluded that post-emergence application of propaquizafop + imazethapyr mixture at 53+80g/ha was most remunerative for controlling weeds in soybean.

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Bio-efficacy of different post emergence herbicides for control of *Phalaris minor* in sub mountainous area of Punjab

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Wheat is one of the premiere cereal crops of Punjab and is badly infested with *Phalaris minor* Retz (little seed canary grass) which is a major weed of wheat crop in northern parts of India. The crop suffers a yield loss of 25-30 per cent due to infestation of this weed (Yadav and Malik 2005) and is very difficult to distinguish it from wheat plant in its early growth stages. The weed evolved insensitivity to isoproturon after its continuous use for over 15 yrs. So, alternative herbicides were recommended for its management but the newly introduced herbicides for the control of *Phalaris minor* are also rapidly losing their effectiveness at many farms. It is due to that some farmers have started using higher than the recommend doses or tank-mix of these herbicides to achieve control of *P. minor* in wheat.

METHODOLOGY

A field experiment was carried out during *Rabi* season of 2015 at four different locations in district Pathankot and Gurdaspur. The experiment was laid out in randomized complete block design. Each location was considered as one block and replication. The weed control treatments thus replicated at different locations consisted isoproturon 75 WP 1250 g/ha, clodinafop 15 WP 400 g/ha, pinoxaden 5 EC 1000 ml/ha, fenoxaprop-p-ethyl 10 EC 1000 m/ ha, sulfosulfuron 10 WG 32.5 g/ha and untreated control. The drill sowing of wheat cv. HD 2967 was done at 22.5 cm row spacing after seed treatment at the seed rate of 100 kg/ha during first fortnight of November at all the locations. The crop was raised with recommended package of practices, developed by Punjab Agricultural University, Ludhiana except weed control treatments. Data on weed growth and yield was recorded to draw valid conclusions

RESULTS

The chosen field was infested with *Phalaris minor*-a major grass weed of rice-wheat cropping system which have shown resistance to isoproturon. At 60 DAS, population of *Phalaris minor* was significantly controlled with all the herbicides except isoproturon and unweeded check. The results indicated that clodinafop, pinoxaden, fenoxaprop-p-pethyl and sulfosulfuron gave effective control of *Phalaris minor* (Table 1). At 60 DAS, weed count was significantly affected by herbicide application. All the herbicidal formulations recorded statistically at par weed count per m^2 and was significantly lower than unsprayed check and isoproturon. The data in table 1 also indicated significant differences among various weed control treatments w.r.t. weed index. Among herbicidal treatments isoproturon recorded maximum weed index (22.3) followed by fenoxaprop-p-ethyl (7.9), clodinafop (5.1), pinoxaden (3.7) and least with sulfosulfuron (2.3). This indicates that sulfosulfuron, pinoxaden, clodinafop and fenoxaprop-p-ethyl have controlled the resistant population of *Phalaris minor* very effectively. Singh *et al*. 2002 also reported that clodinafop provides effective control of isoproturon resistant *Phalaris minor* biotypes.

Weed control treatments have direct effect on growth and grain yield of wheat crop. Sulfosulfuron, pinoxaden, clodinafop and fenoxaprop-p-ethyl recorded significantly taller plants (87.5, 86.2, 83.0 and 84.5 cm), with more effective tillers (369.5, 369.5, 364.7 and 368.0 per m^2,) and which led to higher grain yield (5.2, 5.2, 5.1 and 4.9 t/ha), respectively as compared to unweeded control and isoproturon (4.0 and 4.2 t/ ha), respectively. Due to better weed control in sulfosulfuron, pinoxaden, clodinafop and fenoxaprop-p-ethyl treated plots, the crop grows luxuriantly. Therefore, it can be concluded that weeds do not compete with crop for light, moisture, space etc. and ultimately this was reflected in crop growth and grain yield.

Table 1. Growth, yield of wheat and weed growth as influenced by different herbicides for control of *Phalaris minor*.

Treatment	Plant Height (cm)	Effective Tillers (per m^2)	Grain Yield (t/ha)	No of weeds (per m^2)	Weed Index
Unweeded check	65.5	239.5	4.0	4.0 (15.5)*	25.7
Isoproturon 1250 g/ha	71.2	242.0	4.2	3.9 (14.5)	22.3
Clodinafop 400 g/ha	83.0	364.7	5.1	1.7 (2.0)	5.1
Pinoxaden 1000 ml/ha	86.2	369.5	5.2	1.6 (1.7)	3.7
Fenoxaprop-p-ethyl 1000 ml/ha	84.5	368.0	4.9	1.8 (2.2)	7.9
Sulfosulfuron 32.5 g/ha	87.5	369.5	5.2	1.6 (1.7)	2.3
Weed Free	87.7	368.5	5.3	1.1 (0.2)	-
LSD (P=0.05)	6.6	10.9	0.4	0.5	-

*Values in parenthesis are original. Data transformed to square root transformation.

CONCLUSION

The study revealed that sulfosulfuron, pinoxaden, clodinafop and fenoxaprop-p-ethyl were statistically at par to earlier recommended isoproturon with respect to weed control and wheat grain yield. Post emergence application of these herbicides after 30-35 days after sowing provided effective control of *Phalaris minor.* Further rotational use of different herbicide groups or ready mix herbicide combination can further delay the occurrence of resistance in *Phalaris minor*. Utmost care should be taken before selecting a particular herbicide for weed control depending upon cultivar being grown, cropping system to be followed, soil type and type of weed flora present.

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Weed management in direct seeded finger millet

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Finger millet [*Eleusine coracana* (L.) *Gaertn.*] is an important staple and nourishing food as well as valuable source of carbohydrate (76.32%), protein (9.2 per cent), calcium (0.33%) and minerals (2.24%), besides vitamins A and B and phosphorus in trace quantities. Slow releasing glucose nature of its diet is preferred for the diabetic patients. Weeds compete with the direct seeded finger millet crop as the weeds and crop seeds germinate simultaneously. The critical period of weed competition in finger millet is identified to be around 30 to 45 days after sowing and further delay in the control of weeds leads to severe reduction in the grain yield ranging from 60 to 70% (Prasad *et al.* 1991 and Singh and Arya 1999). Hence the present investigation was undertaken to evolve suitable weed management practice for profitable cultivation of direct seeded finger millet.

METHODOLOGY

The experiment was laid out in a Randomized Complete Block Design (RCBD) with twelve treatments and three replications. The treatments consisted of five pre-emergence herbicides (butachlor 50 EC, oxyflourfen 23.5 EC, oxadiargyl 80 WP, isoproturon 75 WP and pendimethalin 30 EC) and combination of these pre-emergence herbicides with one post-emergence herbicide (bispyribac sodium 10 SC), compared with farmer's practice of two hand weeding (20 and 45 DAS) and weedy check.

RESULTS

Among herbicide combinations, oxadiargyl 80 WP *fb* bispyribac sodium 10%, oxyfluorfen 23.5 EC fb bispyribac sodium 10%, pendimethalin 30 EC *fb* bispyribac sodium 10% were better in controlling weeds upto 60 DAS and were on par with the hand weeding under present scenario of labour shortage (Table 1). These treatments gave significantly higher effective tillers /hill and grain yields compared to application of only pre-emergence herbicides and weedy check. These findings are in confirmatory with the work of Prashanth kumar *et al.* 2015.

CONCLUSION

The results of the present investigation indicated that the pre-emergence herbicides (butachlor 50 EC, oxyflourfen 23.5 EC, oxadiargyl 80 WP, isoproturon 75 WP and pendimethalin 30 EC) can be combined with post-emergence herbicide (bispyribac sodium 10 SC) in direct seeded finger millet without any phytotoxicity effect. These results will help the farming community as they are facing severe shortage of labour for manual weeding and also previously recommended pre-emergence herbicide isoproturon 75 WP is not available in the market in Karnataka. So combination of pre-emergence herbicides oxadiargyl 80 WP, oxyflourfen 23.5 EC and pendimethalin 30 EC with bispyribac sodium 10% SC results in efficient weed management with profitable direct seeded finger millet cultivation.

Table 1. Grain yield, effective tillers/hill and WCE (%) in direct seeded finger millet as influenced by weed management practices

Treatment	Time of application (DAS)	Effective tillers / hill	Grain yield (t/ha)	WCE (%)
T1: Butachlor 50 EC	2	3.6	2.43	66.0
T2: Oxyfluorfen 23.5 EC	2	4.2	2.90	74.4
T3: Oxadiargyl 80 WP	2	4.1	2.91	79.5
T4: Isoproturon 75 WP	2	4.1	2.74	71.8
T5: Pendimethalin 30 EC	2	2.9	2.05	57.1
T6: Butachlor 50 EC fb bispyribac sodium 10%	2 *fb* 30	4.3	3.00	88.0
T7: Oxyfluorfen 23.5 EC *fb* bispyribac sodium 10%	2 *fb* 30	4.8	3.25	92.2
T8: Oxadiargyl 80 WP *fb* bispyribac sodium 10%	2 *fb* 30	4.8	3.36	92.8
T9: Isoproturon 75 WP *fb* bispyribac sodium 10%	2 *fb* 30	4.6	3.07	89.8
T10: Pendimethalin 30 EC *fb* bispyribac sodium 10%	2 *fb* 30	4.5	3.11	90.5
T11: Two hand weeding (20 and 45 DAS)	20 and 45	5.4	3.74	95.9
T12: Weedy check		1.8	1.45	0.0
LSD (P=0.05)		1.03	0.76	
CV (%)		14.8	15.9	

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Evaluation of sulfentrazone 48% SC on productivity of soybean and its residual effect on succeeding *Rabi* crops

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Soybean is a miracle "golden bean" of 21st century because it contains 38-42 per cent good quality protein and 18-20 per cent oil, which is rich in polyunsaturated fatty acids (Linoleic and oleic acid) along with good amount of minerals (Ca, P, Mg, Fe and K). Losses due to weeds have been one of the major limiting factors in soybean production. The grain yield reduction due to weed infestation in soybean ranges between 35-80 per cent depending upon weed flora and weed intensity (Gupta *et al.* 2006). Most of yield reduction due to weed competition occurs during the first 4-5 weeks after sowing. Therefore, major emphasis on weed control should be given during this period. Considering the present day labour scarcity and their high wages for cultural and mechanical weed control, it was felt necessary to evaluate the performance of some newer herbicide molecules like sulfentrazone and imazethapyr for controlling various weeds in soybean and their residual effect on succeeding *rabi* crops.

METHODOLOGY

A field experiment was carried out at Instructional Farm of Rajasthan College of Agriculture, Udaipur during *Kharif*, 2015 to evaluate the performance of sulfentrazone on soybean and its residual effect on the succeeding *Rabi* crops of this zone *i.e.* wheat, mustard and gram. The experimental soil was clay loam, alkaline, medium in nitrogen and phosphorus and high in potassium. The experiment consisted of 7 weed control treatments, *viz.* sulfentrazone (48% w/v SC) at doses 300, 360, 410 and 720g/ha, imazethapyr 100g/ha, hand weeding (farmers' practice) and weedy check. Sulfentrazone was applied as pre-emergence whereas, imazethapyr was applied as early post-emergence while in farmers practice two hoeing and weeding at 20 and 40 DAS were done. The experiment was laid out in randomized block design with four replications. Soybean variety 'JS-9560' was sown following standard package of this zone. After harvesting of soybean the field was prepared precisely with minimum disturbance of soil with the help of power operated hand tiller on the same layout of soybean crop. Each plot was equally divided into three equal parts and sowing of mustard (var. Bio-902), gram (var. GNG-1581) and wheat (var. Raj-4037) were done at recommended row to row spacing of respective crops.

RESULTS

Data presented in Table 1 indicate that all the weed control treatments significantly increased the seed yield of soybean compared to weedy check. Data further show that all the treatments under test were found statistically at par with reference to seed yield of this crop. Among different doses of sulfentrazone, the significant improvement in yield was obtain up to application of sulfentrazone 360 g/ha and further increase in its dose failed to record significant improvement in seed yield of this crop. The per cent increase in seed yield under sulfentrazone 360, 410 and 720 g/ha, imazethapyr 100 g/ha and farmers practice was 250.84, 178.13, 202.15, 252.52 and 263.87 compared to weedy check. It is an established fact that least crop weed competition as evident from weed control efficiency ranging from 51.46 to 79.1 per cent under different treatments during the phase of crop growth exerts an important regulatory function on complex process of yield formation due to better availability of water, space and nutrients to the crop plant. The residues of sulfentrazone at different doses as well as imazethapyr did not influence the yield of wheat, gram and mustard and was found statistically at par with each other. The yield of wheat, mustard and gram under the influence of residual effect of different weed control treatments ranged between 4.16 to 4.29, 0.91 to 1.11 and 0.73 to 0.84 t/ha, respectively.

Table 1. Effect of weed management practices on weed control efficiency, seed yield of soybean and succeeding *Rabi* crops

Treatment	Weed control efficiency (%) 60 DAT	Soybean seed yield (kg /ha)	Yield of succeeding crop (t/ha)		
			Wheat	Gram	Mustard
Sulfentrazone 300 g/ha PE	51.46	951	4.25	0.77	0.96
Sulfentrazone 360 g/ha PE	74.56	1670	4.18	0.81	1.11
Sulfentrazone 410 g/ha PE	76.77	1717	4.26	0.84	0.99
Sulfentrazone 720 g/ha PE	78.36	1752	4.29	0.80	1.02
Imazethapyr 100 g ha^{-1} POE	76.06	1678	4.19	0.73	1.03
Hand weeding (farmers practice)	79.10	1732	4.16	0.76	0.91
Weedy check	-	476	4.24	0.78	1.06
LSD (P=0.05)	-	266	NS	NS	NS

CONCLUSION

On the basis of one year experimentation, it is concluded that application of sulfentrazone 360 g/ha as pre-emergence is found suitable in enhancing seed yield of soybean with comparable yield level as obtained under farmers practice and application of early post-emergence of imazethapyr. Residual effect of different weed control treatments was not found significant in influencing yield of wheat, mustard and gram.

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Weed management in turmeric

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Turmeric is an important commercial crop and fetches higher returns to farmers. Weeds compete with turmeric in the initial stages due to its slow initial growth and shallow root system. Weeds compete with turmeric for nutrients, light, moisture and space and result in yield loss to the tune of 35-75% (Krishnamurthy and Ayyaswamy 2000). So the present investigation was undertaken to screen few pre- and post-emergence herbicides in combination with other methods for better management of weeds in turmeric.

METHODOLOGY

The field experiment was conducted during *Kharif*, 2014 at the Agricultural Horticultural Research Station, Kathalgere, Davanagere district to know the bio-efficacy of different pre-emergence herbicides (metribuzin, Pendimethalin, atrazine and oxyfluorfen) alone and in combination with fenoxaprop + metsulfuron) against weeds, and their effect on growth and yield of turmeric, apart from knowing the phyto-toxic effect, if any. The soil type was sandy clay loam with average fertility level. Fifteen treatments were replicated thrice in RCBD.

RESULTS

The plot treated with pendimethalin 1.0 kg/ha 0-5 DAP fb 2 HW 45 and 75 DAP(23.2 t/ha), oxyfluorfen 0.30 kg/ha-0-5 DAP fb two HW-45 and 75 DAP(22.5t/ha), atrazine 0.75 kg/ha 0-5 DAP fb two HW-45 and 75 DAP(22.3 t/ha), metribuzin fb 2 hand weeding 0.7 kg/ha 0-5 DAP fb two HW-45 and 75 DAP(21.4 t/ha),oxadiargyl 0.25 kg/ha- 0-5 DAP fb two HW-45 and 75 DAP(21.1 t/ha) and glyphosate7.5 ml/lit - 25DAP fb *2* HW fb 45 and 75 DAP(20.7 t/ha) have reduced the weed density and dry weight and resulted in higher fresh rhizome yield which was on par with pendimethalin 1.0 kg/ha 2 HW 45 and 75 DAP(23.2 t/ha) (Table 1). Unweeded control gave the lowest fresh rhizome yield (6.4 t/ha), owing to severe competition from all types of weeds .Similar trend was noticed with respect to plant height and number of leaves which attributed to yield. The results are in line with the findings of Gill *et al.* 2000.

Table 1. Effect of weed management practices on turmeric plant height, number of leaves, fresh rhizome yield and weed control efficiency in turmeric crop during *Kharif*, 2014

Treatment	Plant height (cm)75 DAP	No. of leaves at 75 DAP	Fresh rhizome yield (t/ha)	Weed control efficiency (%)
PE metribuzin at 0.7 kg/ha *fb* two HW on 45 and 75 DAP	80	19	21.4	82.6
PE metribuzin at 0.7 kg/ha *fb* POE fenoxaprop at 67 g/ha + metsulfuron at 4 g/ha on 45 DAP	65	15	13.8	67.5
PE metribuzin at 0.7 kg/ha *fb* straw mulch at 10 t/ha on 10 DAP *fb* one HW on 75 DAP	74	17	19.7	76.4
PE pendimethalin at 1.0 kg/ha *fb* two HW on 45 and 75 DAP	87	20	23.2	89.6
PE pendimethalin at 1.0 kg/ha *fb* POE fenoxaprop at 67 g/ha + metsulfuron at 4 g/ha on 45 DAP	65	14	12.0	62.4
PE pendimethalin at 1.0 kg/ha *fb* straw mulch at 10 t/ha on 10 DAP *fb* one HW on	73	17	17.4	74.2
PE atrazine at 0.75 kg/ha *fb* two HW on 45 and 75 DAP	81	19	22.3	84.9
PE atrazine at 0.75 kg/ha *fb* POE fenoxaprop at 67 g/ha + metsulfuron at 4 g/ha on 45 DAP	61	14	11.5	58.4
PE atrazine at 0.75 kg/ha *fb* straw mulch at 10 t/ha on 10 DAP *fb* one HW on 75 DAP	69	16	15.6	72.5
PE oxyfluorfen at 0.30 kg/ha *fb* two HW on 45 and 75 DAP	83	20	22.5	87.2
PE oxadiargyl at 0.25 kg/ha *fb* two HW on 45 and 75 DAP	79	18	21.1	80.9
POE glyphosate at 5.0 ml/lit on 25 DAP *fb* HW on 45 and 75 DAP	66	15	14.8	69.3
POE glyphosate at 7.5 ml/lit on 25 DAP *fb* two HW on 45 and 75 DAP	78	19	20.7	79.2
Hand weeding at 25, 45 and 75 DAP	77	18	19.9	77.2
Unweeded check	58	11	6.4	0.0
LSD (P=0.05)	10.9	4.7	5.8	

CONCLUSION

Among weed management practices, pendimethalin 1.0 kg/ha 0-5 DAP fb 2 HW 45 and 75 DAP, oxyfluorfen0.30 kg/ha-0-5 DAP fb two HW-45 and 75 DAP, atrazine 0.75 kg/ha 0-5 DAP fb two HW-45 and 75 DAP, metribuzin fb *2* hand weeding 0.7 kg/ha 0-5 DAP fb two HW-45 and 75 DAP and oxadiargyl 0.25 kg/ha- 0-5 DAP fb two HW-45 and 75 DAP were better in controlling weeds, resulted in rhizome yield on par with hand weeding treatment but higher yield than other herbicide treatment and unweeded control.

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Efficacy of herbicidal weed control and sulphur on soybean production

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Soybean is frequently subjected to heavy infestation of weeds comprising narrow and broad-leaved ones and sedges. The much practiced manual weeding by farmers is strenuous, time-consuming and costly. Also unpredictable weather conditions during monsoon season make it difficult to plan manual weeding with precise periodicity. Therefore, use of herbicides is inevitable to control weeds in soybean. However, their application needs to be integrated with physical means for acceptable weed control. Sulphur deficiency in most parts of India is not uncommon due to continuous use of S-free fertilizers, and intensification of agriculture with high yielding varieties. A number of studies have reported relatively high requirement of sulphur for soybean, which could be attributed to its high protein and oil content (Dange *et al*. 2014). Therefore, an experiment was conducted to adjudge the effect of weed control and rate of sulphur application on the productivity of soybean.

METHODOLOGY

Experiments were carried during rainy season of 2011 and 2012 at Rajasthan College of Agriculture, MPUA&T, Udaipur. Soil of the experimental site was clay loam in texture, alkaline in reaction (pH 8.0 and 8.1), medium in available nitrogen and phosphorus, and high in available potassium. While the available sulphur content of the soil (9.4 and 9.6 ppm of SO_4^{-2}) indicated its deficiency. The study involved twenty-eight treatment combinations comprising seven weed control treatments viz. weedy check, pre-emergence (PE) application of pendimethalin (1000 g/ha), post-emergence application of quizalofop-ethyl (50 g/ha) and imazethapyr (100 g/ha) at 15 days after sowing (DAS) alone and followed by hoeing and weeding at 30 DAS; and four levels of sulphur. *viz*. control, 20, 40 and 60 kg/ha. The experiment was laid out in split plot design, assigning weed management to main plots and sulphur nutrition to sub-plots. The soybean variety *"JS-335"* was sown manually in furrows opened 30 cm apart in each plot measuring 5 x 3 m using seed rate of 80 kg/ha. A uniform dose of 20 kg N and 40 kg P_2O_5 /ha along with sulphur (as per treatment) with supplementation of mineral gypsum 5 cm below the seeding zone. The herbicides were applied as per treatment by knapsack sprayer fitted with flat fan nozzle using 500 liters of water. The weeds under 0.25 m^2 area were removed and dry weight was taken.

RESULTS

Major weeds present in the experimental site were *Amarathus viridis* L., *Digera arvensis* Forsk., *Commelina benghalensis* L., *Parthenium hysterophorus* L., *Phyllanthus niruri* Hook F., *Cynodon dactylon* (L) Pers., *Cyperus rotundus* L,, *Echinochloa colonum* (L.) Link, *Echinochloa crusgali* (L.) Beauv, *Convolvulus arvensis* L., *Setaria glauca* (L.) Beauv. and *Portulaca oleraceae* L. The broad leaf weeds dominated the weed flora by accounting for 61.0% dry matter of the total weed dry matter in the weedy plots (Table 1). Application of all three herbicides under test brought about significant decrease in the dry matter of weeds at 50 DAS, through the extent of decrease varied. Pendimethalin pre-emergence was superior over remaining two herbicides whereas imazethapyr post-emergence was significantly superior over quizalofop-ethyl post-emergence in controlling broad-leaf. For controlling narrow leaf weeds, quizalofop-ethyl was significantly superior over pendimathalin and imazethapyr. The efficiency of these herbicides was increased when followed by hoeing and weeding at 30 DAS. The order of superiority remained the same when these three herbicides were supplemented by hoeing and weeding. Pendimethalin, imazethapyr and quizalofop-ethyl, all *fb* HW at 30 DAS resulted in 90.16, 84.96 and 77.52% reduction in total weed dry matter at 50 DAS. The seed yield and the net return from soybean crop were significantly influenced due to weed control. Corollary to the extent of reduction in weed dry matter, the highest seed yield (2.17 t/ha) and thereby the net return (' 40682/ha) were obtained by pendimethalin *fb* HW. Increase in sulphur application up to 40 kg/ha resulted in significant increase in soybean yield and net return.

Table 1. Effect of weed control and sulphur on weed dry matter of at 50 DAS, soybean seed yield and net return

Treatment	Weed dry matter (g/m^2)			Seed yield (t/ha)	Net return (`/ha)
	Broad leaf	Narrow leaf	Total		
Weed control					
Weedy check	464.72	296.90	761.62	0.80	4822
Pendimethalin at 1000 g/ha PE	77.60	66.16	143.76	1.65	27957
Quizalofop-ethyl at 50 g/ha POE	213.09	51.02	264.11	1.31	18394
Imazethapyr at 100 g/ha POE	91.45	80.26	171.70	1.48	22720
Pendimethalin PE *fb* HW	37.85	37.06	74.91	2.17	40682
Quizalofop-ethyl POE *fb* HW	146.16	25.01	171.16	1.83	31063
Imazethapyr POE *fb* HW	59.77	54.76	114.53	2.00	35293
LSD (P=0.05)	9.90	5.87	15.70	0.11	3204
Sulphur (kg/ha)					
00	155.27	86.76	242.02	1.04	9858
20	155.59	87.07	242.66	1.59	25342
40	155.98	87.50	243.48	1.89	33970
60	156.38	87.91	244.29	1.91	34218
LSD (P=0.05)	NS	NS	NS	0.05	1533

CONCLUSION

In soybean, pre-emergence application of pendimethalin (1 kg/ha) followed by hoeing or hand weeding at 30 days after sowing provide effective control of broad spectrum weeds. Supplementation of sulphur (40kg/ha) provides higher yield and net profit.

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Bio-efficacy of PlatForm 385 for the control of weeds in wheat

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Wheat (*Triticum aestivum L.*) is one of the most important and widely cultivated cereal crop of India and occupies a prime position among the food crops in terms of production and consumption. Among the various factors responsible for low yield of wheat crop, weeds are one of the major factor responsible for low yield because they compete with crop plants for light, moisture, nutrients and space. The average yield losses caused by weeds in different wheat growing zone ranges from 20 to 32%. (Mongia *et al.* 2005). The losses depend on weed species, weed density, time of emergence, wheat cultivar, row spacing, soil and environmental factors (Chhokar and Malik 2002). Chemical weed control is widely adopted by the farmers of the state to control weeds in wheat. Herbicides viz. clodinafop, sulfosulfuron, fenoxaprop have also provided some relief over the years after the isoproturon resistance but with time these herbicides also show resistance in *P. minor* in Punjab. Considering these facts in view, some new herbicide molecules are to be tested to study their bio efficacy. In this context bioefficacy of Plat form 385 was tested to control weeds in wheat.

METHODOLOGY

A field experiment was carried out during *Rabi* 2014-15 in Department of Agronomy, Punjab Agricultural University, Ludhiana (Punjab) to evaluate the bio-efficacy of Platform 385 for the control of weeds in wheat crop. Wheat variety PBW 621 was sown in well ploughed plots in rows at a distance of 22.5 cm. Eleven treatments consisting of Platform- 385 2.0, 2.5 and 3.0 litre/ha, sulfosulfuron 33.3 g/ha, metribuzin 0.25 g/ha, pendimethalin 4.2 l t/ha, hand weeding and weedy check was kept in randomized block design experiment replicated three times. The herbicides were applied viz. Platform- 385 2.0, 2.5 and 3.0 l t/ha as pre- and early post emergence (10 DAS), pendimethalin as pre-emergence, sulfosulfuron and metribuzin as post-emergence. Recommended package of practices by Punjab Agricultural University were followed to raise the crop. The observations for weed density was recorded at 75 DAS of crop and grain yield was recorded at harvest.

RESULTS

All the herbicide treatments recorded significantly lower weed density of *P. minor* as compared to unsprayed control. Efficacy of Platform 385 against *P. minor* population was highly increased with increase in dose from 2.0 to 3.0 lt/ha, however slight less efficacy was recorded when it was applied early post (10 DAS) which was better than application of sulfosulfuron, metribuzin and pendimethalin at their respective recommended doses. Sulfosulfuron was poor on *P. minor* as compared to even lower dose of Plat Form 2.0 l t/ha. Significantly more weed density was recorded in sulfosulfuron, metribuzin and pendimethalin at 75 DAS than Platform at 2.5-3.0 l t/ha herbicide. PlatForm at 2.5l t/ha significantly reduced population of *P. minor* as compared to its lower dose of 2.0 lt/ha and at par with 3.0 l t/ha as pre emergence and performed better than already recommended herbicides *i.e.* sulfosulfuron 33.3 g/ha, metribuzin 0.25kg/ha and pendimethalin 4.2 l t/ha and unweeded control (Table 1).

Table 1. Effect of different herbicide treatments on weed density at 75 DAS in wheat during *Rabi* 2014-15

Treatment	Dose (l t/ha)	Application time	Weed density (no./m^2)				Grain yield (t/ha)
			P. minor	*M. denticulata*	*R. dentatus*	*C. didymus*	
Plat form – 385	2.0	PRE	4.91 (23)	4.31 (18)	3.87 (14)	2.57 (6)	6.32
Plat form – 385	2.5	PRE	3.11 (9)	3.54 (12)	2.88 (7)	1.78 (2)	6.57
Plat form – 385	3.0	PRE	2.91 (8)	1.41 (1)	1.41 (1)	1.52 (1)	6.64
Plat form – 385	2.0	10 DAS	5.11 (25)	4.04 (15)	3.78 (13)	2.74 (7)	6.26
Plat form – 385	2.5	10 DAS	3.30 (10)	3.27 (10)	2.82 (7)	2.08 (3)	6.56
Plat form – 385	3.0	10 DAS	3.09 (9)	1.33 (1)	1.41 (1)	1.41 (1)	6.63
Sulfosulfuron 75% WG	33.3	POST	6.81 (45)	4.19 (17)	5.57 (30)	2.08 (3)	6.22
Metribuzin 70% WP	0.25	POST	5.33 (27)	3.11 (9)	3.36 (10)	2.77 (7)	6.37
Pendimethalin 30% EC	4.2	PRE	5.70 (32)	3.78 (13)	3.87 (14)	3.08 (9)	6.49
Weed free	-	-	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	6.62
Weedy check	-	-	9.72 (94)	4.68 (58)	6.70 (44)	4.91 (23)	4.61
LSD (P=0.05)			0.22	0.50	0.49	0.20	0.81

*Data is subjected to square root transformation. Figures in parenthesis are original values

CONCLUSION

Pre-emergence application of Platform 385 2.5- 3 l t/ha was most effective for controlling weeds and improved grain yield of wheat.

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Assessment of various herbicides in berseem crop under sub-mountaineous conditions of Punjab

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Berseem (*Trifolium alexandrinum* L) is one of the prominent winter season forage crop. It is a fast growing annual legume which provides high quality green forage, rich in protein (15-25%), minerals (11-19%) and carotene (Sharma and Murdia 1974). Common weeds found in berseem are *Cichorium intybus*, *Chenopodium album*, *Amaranthus viridus*, *Rumex dentatus*, *Melilotus indica*, *Medicago denticulata*, *Lathyrus aphaca*, *Spergula arvensis* among broadleaf weeds and *Poa annua, Polypogon monspeliensis* among the grassy weeds. Weeds pose competition to the main crop for essential plant nutrients, light, moisture and space. Weed infestation reduces normally 25-35% green fodder and seed yield. Weeds decrease the acceptability of the fodder and also pose problems in harvesting of the crop (Walia 2003). Being a dense crop (broadcast seeding) manual weeding is not practicable in removing weeds. Herbicides offer a scope to control weeds, but not all herbicides are selective to berseem and effective against infesting weed species. Keeping in the view the facts, the current study was explored to assess various pre-plant, pre-emergence and post-emergence weedicides in berseem to evaluate their efficacy on weeds and crop selectivity.

METHODOLOGY

The field experiment was conducted at farmer's field of district Gurdaspur during the *Rabi* season of 2014-15 and 2015-16 in sub-mountaineous region of Punjab (Latitude- 31Ë%562 43.4" N, Longitude- 75Ë%132 39.5" E and Altitude - 265.17 m from msl). The experimental site was clay loam in texture, medium in organic carbon (0.72%), high in available phosphorus (35 kg/ha) and low in potassium (80 kg/ ha) at 0-15 cm soil depth. The soil was neutral in reaction (pH - 7.1) with normal electrical conductivity (0.61 ds/m). The experiment was laid out in randomized block design having three replications and comprised eight treatments, *viz.* fluchloralin 0.45 kg/ha, pendimethalin 0.75 kg/ha, imazethapyr 0.075 kg/ha, oxyfluorfen 0.1 kg/ha, fluchloralin 0.45 kg/ha followed by imazethapyr 0.075 kg/ha, pendimethalin 0.75 kg/ ha followed by imazethapyr 0.075 kg/ha, oxyfluorfen 0.1 kg/ha followed by imazethapyr 0.075 kg/ha and a weedy check. The data on weed density/m^2 and dry matter of weeds (g/m^2) were recorded before first cutting of berseem. Weed control efficiency (%) of different weedicides alone and in combination, was also calculated. The data on yield attributes, green fodder and seed yield of berseem crop were recorded at harvest.

RESULTS

The results revealed that all the weed control treatments caused significant reduction in weed density and dry weight of weeds as compared to weedy check. The lowest weed density (13.5 weeds/ m^2) and dry weight of weeds (10.2 g/m^2) were observed under fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha closely followed by application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha, which were significantly lower than all other herbicidal treatments. The results are in conformity with the findings of Kumar and Shivadhar (2008). However, the application of pendimethalin 0.75 kg/ha *fb* imazethapyr 0.075 kg/ha, and imazethapyr 0.075 kg/ha alone, being at par with each other, registered significantly lower weed density and dry weight of weeds than Fluchloralin 0.45 kg/ha, Oxyfluorfen 0.1 kg/ha and pendimethalin 0.75 kg/ha. Moreover, application of fluchloralin 0.45 kg/ha which was statistically at par with oxyfluorfen 0.1 kg/ha caused significantly higher reduction in weed density and dry weight of weeds than pendimethalin 0.75 kg/ha. Pre-plant application of fluchloralin followed by post-emergence application of imazethapyr 0.075 kg/ha recorded maximum weed control efficiency (82.8%) which was closely followed by application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha (77.5%).

The herbicidal treatments did not show significant effect on plant height of berseem at first cutting. Among the herbicidal treatments, fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha, being at par with oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha recorded significantly more number of tillers as compared to all other herbicidal treatments. This indicates that effective weed control might have created favourable environment for the development of tillers which led to increase in green fodder and seed yield. The maximum pooled green fodder (98.64 t/ha) and pooled seed yield (7.0 q/ ha) were recorded with fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha which was closely followed by application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha. These results were in agreement with the findings of Pathan *et al.* (2013). However, pendimethalin 0.75 kg/ha fb imazethapyr 0.075 kg/ha and imazethapyr 0.075 kg/ha caused significant enhancement in green fodder and seed yield as compared to remaining herbicidal treatments. Significantly superior green fodder and seed yield were noticed under fluchloralin 0.45 kg/ ha and oxyfluorfen 0.1 kg/ha as compared to the application of pendimethalin 0.75 kg/ha.

CONCLUSION

The present study indicated that application of fluchloralin 0.45 kg/ha *fb* imazethapyr 0.075 kg/ha closely followed by oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.075 kg/ha appeared to be productive for effective weed control in berseem which resulted in maximum green fodder and seed yield.

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Efficacy of imazethapyr and its ready mix on weed growth and yields of blackgram

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Blackgram (*Vigna Mungo* L.) is one of the most *important* pulses crop grown across *India*. In *Kharif* season grown blackgram, weed causes maximum damage initially during 25 to 35 days after sowing (Randhawa *et al.* 2002) and the heavy weed infestation during rainy season is the main reason for low productivity of blackgram (Aggarwal *et al.* 2014). In blackgram, weeds could be controlled by hand weeding or by use of herbicides as pre- and post-emergence herbicides. At present, talone application of herbicides are less effective in diversified weed flora. Recently, the ready mix herbicides combinations with imazethapyr are being marketed with the assurance of selective broad spectrum weed control in blackgram. Therefore, in the present study, effect of different doses and combinations of imazethapyr and its ready mix were compared with application of herbicides alone for evaluating the reduction in weed dry weight and productivity of blackgram.

METHODOLOGY

A field experiment was carried out during *Kharif* season of 2015 at Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur. Twelve treatments including weedy check were replicated thrice in a randomised block design. Blackgram variety '*PU-31*' was used in the experiment. The data on weed density and dry weight were recorded at 45 DAS. Weed control efficiency was also computed using the dry weight of weeds. Seed yield and yield components of blackgram were recorded at harvest.

RESULTS

Prominent weed species were *Echinochloa colona* (47.6%), *Commelina bengalensis* (18.4%), *Trianthama portalacastrum* (19.4%), *Digera arvens* (3.6%), *Parthanium hysterophorus* (4.5%) and *Cyperus rotundus* (6.5%). All the weed species were effectively controlled by pre-mix PoE herbicides like imazethapyr + imazamox and pre-mix PE pendimethalin+ imazethapyr as compared to alone application of herbicides. The lowest weed count (1.56) and dry matter (1.36) at 45 DAS of weeds was registered under post emergence at 13 DAS application of ready mix of Imazethapyr + Imazamox 80 g/ha which was significantly superior over rest of the treatments. It was followed by pre-emergence application of imazethapyr + pendimethalin 1000 g/ha and then ready mix imazethapyr + imazamox 70 g/ha (Table 1). Similar findings were also reported by Aggarwal *et al.* (2014). Maximum weed control efficiency 95.2% was recorded under ready mix application of imazethapyr + imazamox 80 g/ha, which was followed by pre-emergence application of imazethapyr + pendimethalin 1000 g/ha (92.91%) and post emergence application of imazethapyr + imazamox at 70 g/ha (92.86%) at 45 DAS stage of crop growth (Table 1).

Table 1. Effect of treatments on weed growth, weed control efficiency (WCE), yield attributes and yield of black gram

Treatment	At 45 DAS			Branches per plant	Seeds per pod	Pods per plant	Test weight (g)	Seed yield (kg/ha)	Haulm yield (kg/ha)
	Weed count (no./ m^2)	Weed dry matter (g/m^2)	WCE (%)						
Imazethapyr70 g/ha PE	5.81(33.30	4.32(18.19)	34.93	4.7	4.7	34.1	47.6	593	1.02
Imazethapyr 80 g/haPE	6.01(35.60)	4.37(18.56)	33.60	5.2	5.7	35.8	47.7	584	1.02
Imazethapyr 80 g/ha PoE	5.18(26.32)	3.61(12.56)	55.07	4.6	4.9	34.4	48.7	618	1.11
Imazethapyr 80 g/ha PoE	5.64(31.33)	3.80(13.98)	49.91	4.7	4.2	31.6	47.1	683	1.16
Imazethapyr + imazamox (RM) 70 g/ha PE	5.46(29.33)	3.96(15.20)	45.51	4.9	5.0	33.6	48.3	674	1.16
Imazethapyr + imazamox (RM) 80 g/ha PE	6.26(38.67)	3.72(13.37)	52.17	4.2	5.6	30.4	48.0	652	1.10
Imazethapyr + imazamox (RM) 70 g/ha PoE	2.80(7.33)	1.74(1.63)	92.86	5.2	4.9	32.8	49.4	808	1.38
Imazethapyr + imazamox (RM) 80 g/ha PoE	1.56(1.93)	1.36(1.35)	95.16	4.7	4.7	32.2	48.7	794	1.37
Pendimethalin 1000 g/ha PE	3.55(12.09)	2.91(7.98)	71.40	4.8	3.6	31.6	47.5	575	0.98
Imazethapyr + pendimethalin (RM) 1000 g/ha PE	2.49(5.69)	1.57(1.98)	92.91	5.6	4.5	34.9	48.6	774	1.29
Two hoeing at 20 and 40 DAS	3.58(12.33)	2.47(5.62)	79.89	5.6	4.3	40.1	48.2	742	1.30
Weedy check	8.21(67.00)	5.34(28.00)	0.00	3.3	4.7	26.0	44.2	366	0.59
LSD (P = 0.05)	0.30	0.13	-	1.2	0.7	6.4	2.3	165	0.28

* Data transformed to square root transformation and figures in parenthesis are original

Maximum number of pods per plant (40.1) were observed with hoeing at 20 and 40 DAS, followed by pre-emergence ready mix application of imazethapyr + pendimethalin 1000 g/ha (Table 2). Maximum seed yield (808 kg/ha) was recorded with post-emergence application of ready mix combination of imazethapyr + imazamox 70 g/ha which was statistically at par with ready mix of imazethapyr + imazamox 80 g/ha as pre- and post-emergence, pre-emergence application of ready mix imazethapyr + pendimethalin 1000 g/ha and two hoeing operations. Post-emergence application of ready mix imazethapyr + imazamox at either 80 g/ha or 70 g/ha showed mild phytotoxicity on blackgram.

CONCLUSION

It is concluded that post-emergence application of ready mix combination of imazethapyr + imazamox 70 g/ha at 3-4 leaf stage appeared to be a promising weed management practice for managing broad spectrum weeds and obtaining higher seed yield and profitability of *Kharif* blackgram.

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Economic feasibility of herbicide for weed control in rice under northern dry zone of Karnataka

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Rice is cultivated in area of 44.0 million hectares with an annual production of 104.3 million tons in India. However, its productivity in India is very low (2.37 t/ha) as compared to other rice growing countries like Japan (6.35 t/ha), Australia (6.22 t/ha), Spain (6.16 t/ha), Egypt (5.0 t/ha) and China (5.2 t/ha). There are several reasons for its low productivity but the losses due to weeds are one of the most important. In general, weeds problem in transplanted rice is lower than that of direct seeded rice because of puddling and stagnation of water in transplanted rice during early growth stage of crop. According to Singh *et al.* (2005), weeds can reduce the grain yield of dry-seeded rice by 75.8%, wet seeded rice by 70.6%, and transplanted rice by 62.6%. Flufenacet is a post emergent herbicide and mainly used for the control of grasses and sedges in transplanted rice. Therefore, keeping these points in view, present study was carried out to find out suitable method of weed control/herbicide and their dose for controlling weeds in transplanted rice.

METHODOLOGY

A field study was conducted during *Kharif* 2013 and 2014 on deep black soil of Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka. The experiment was laid out in randomized complete block design consisted of nine treatments with three replications. The soil of the experimental site was deep black, neutral in pH (8.04), EC (0.47 dS/m) and medium in organic carbon content (0.41%), low in nitrogen (189 kg/ha), medium in phosphorus (58.5 kg/ha) and potassium (287.5 kg/ha). All recommended agronomic practices were followed. Pretilachlor 50% EC was sprayed on one or two day of transplanting as pre-emergence treatment and different doses of Flufenacet 50% SC (150 ml/ha, 240, 340 and 480 ml/ha) was sprayed at 1-2 leaf stage as early post-emergence treatment. Weed population were recorded before spraying, 40 and 60 days after application of herbicide. Further, total dry weight of weeds were recorded and used for calculating weed control efficiency (WCE). The data on weed density and dry weight were transformed using square root transformation and analyzed statistically. The cost of inputs, labour charges and prevailing market rates of farm produce were taken into consideration for working out cost of cultivation, gross and net returns per hectare.

RESULTS

The major weeds observed in the experimental fields were *Ludwigia parviflora, Leptochloa chinensis, Echinichloa colona, Panicum repens, Cynodon doctylon, Digitaria longifolia and Cyperus sp.* Application of Flufenacet 50% SC at 480 ml/ha recorded significantly higher weed control efficiency at 40 and 60 days after application (75.2 and 78.6%, respectively) and which was at par with the application of bispyribac-sodium 10% SC at 250 ml/ha (74.8 and 78.4, respectively) followed by flufenacet 50% SC at 350 ml/ha (74.4 and 77.5%) and 240 ml/ha (71.9 and 75.6) compared to other weed control treatments (Table 1). Among all herbicide treatments, application of Flufenacet 50% SC at 480 ml/ha at 2-3 leaf stage as early postemergence treatment recorded maximum gross returns (Rs. 94812/ha), net returns (Rs. 59236/ha) and B:C ratio (2.67) and it was at par with the application of flufenacet 50% SC at 350 ml/ha followed by bispyribac sodium 10% SC at 250 ml/ha and flufenacet 50% SC at 240 ml/ha.

Table 1. Weed control efficiency, grain and straw yield and economics of rice as influenced by weed management practices

Treatment	Weed control efficiency (%)		Yield (t/ha)		Economics (10^3 `/ha)			
	40 DAS	60 DAS	Grain	Straw	Cost of cultivation	Gross returns	Net returns	B:C
Flufenacet 50% SC at 150 ml/ha	70.4	74.5	5.21	5.59	35.18	86.17	50.99	2.45
Flufenacet 50% SC at 240 ml/ha	71.9	75.6	5.29	6.06	35.29	87.73	52.44	2.49
Flufenacet 50% SC at 350 ml/ha	74.4	77.5	5.62	6.48	35.30	93.18	57.88	2.64
Flufenacet 50% SC at 480 ml/ha	75.2	78.6	5.71	6.81	35.58	94.81	59.24	2.67
Pretilachlor 50% EC at 1500 ml/ha	67.7	63.3	5.19	5.58	35.43	85.83	50.40	2.42
2, 4-D Na salt 80% WP at 2500 g/ha	65.5	65.9	5.17	5.54	35.79	83.17	47.38	2.32
Bispyribac-sodium 10% SC at 250 ml/ha	74.8	78.4	5.68	6.74	36.87	92.01	55.14	2.50
Weed free check	100.0	100.0	6.49	7.79	38.00	107.75	69.75	2.84
Weedy check	0.0	0.0	3.29	4.17	35.00	54.74	24.74	1.82
LSD (P=0.05)	3.33	3.30	0.44	0.81	-	7.086	-	0.18

CONCLUSION

The results of Flufenacet 50% SC at 480, 350 and 240 ml/ha and bispyribac-sodium 10% SC at 250 ml/ha or 25 g/ha were statistically at par with each other. Therefore, bispyribac-sodium 10% SC at 250 ml/ha (25 g/ha) and flufenacet 50% SC 240 ml/ha (120 g/ha) can be recommended for effective control of grass weeds and sedges in transplanted rice.

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Effect of crop establishment methods and weed management practices on productivity and profitability of chickpea in upland rainfed ecology of Bihar

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In pulses, crop losses due to weeds ranging from 60-70 percent at farmers' field are common. In addition, weeds also deteriorate the quality of the produce coupled with poor resource use efficiency. Weed problem gets more intensified due to increasing problem of immense labour shortage during peak periods. Chickpea is short stature crop and has slow growth at initial stage which favour heavy weed infestation. Under given circumstances, farmers need alternate weed management system using chemicals which is more efficient, less labor-intensive and shows quick response enabling farmers produce more at less costs. Thus, chemical weed control seems to be pre-requisite for improved chickpea productivity and production using new molecules of herbicides. Therefore, an experiment has been conducted to find out most suitable and economically viable herbicide(s) under different methods of crop establishments for chickpea.

METHODOLOGY

A field experiment was conducted at Research Farm of Bihar Agricultural University, Sabour, Bhagalpur during *Rabi* season of 2014-15 and 2015-16. The experimental site was rainfed upland and having loamy soil. It is under sub-tropical climatic condition characterized with hot desiccating summer, cold winter and moderate rainfall. Sowing of crop was done during third week on November after harvesting of rainfed rice during both the years. Two crop establishment methods, zero till planting and conventional planting was adopted in main plots and nine weed management practices were accommodated in sub plots with three replications. The variety of chickpea was *'PG-186'* and sown in row opened manually by hand plough at 30 cm apart.

RESULTS

The data presented in Table 1 revealed that weed free condition and weedy check recorded the maximum and minimum seed yield of chickpea ie.1461 and 663 kg/ha, respectively. The application of pendimethalin alone and with other herbicides was more or less equally effective in controlling the weeds in chickpea. Application of pendimethalin 750 g/ha with imazethpyr 20 g/ha suppressed the weed growth significantly over pedimethalin applied alone. However, integrated option of weed control with pendimethalin alone or combined with imezethpyr recorded significantly higher values of growth and yield. Among the herbicidal option, application of pendimethalin 750 g/ha with imazethpyr 20 g/ha as pre emergence followed by one hand weeding recorded significantly higher seed yield of chickpea (1.38 kg/ha) over other herbicidal treatments. Application of pendimethalin 750 g/ha with imazethpyr 20 g/ha as pre-emergence followed by one hand weeding at 45 DAS recorded significantly higher weed control efficiency (83.6%) as compared to other herbicidal treatments. Uncontrolled growth of weeds reduced 54.7% seed yield of chickpea. Weed control efficiency was also lower in conventional tillage over zero tillage condition. Application of pendimethalin 750 g/ha with imazethpyr 20 g/ha as pre-emergence followed by one hand weeding at 45 DAS was the best option as it fetched a high B:C ratio of 2.18. Yadav *et al*. (2013) reported lowest density and dry weight of weeds due to pendimethalin as pre-emergence plus one hand weeding, which was more economical but statistically at par with pendimethalin in producing seed yield of lentil.

Table 1. Effect of tillage and weed management practices on seed yield, weed control efficiency weed index and benefit: cost ratio in chickpea

Treatment	Seed yield (kg/ha)	WCE (%)	Weed index (%)	B: C ratio
Tillage				
Zero Tillage	1,143	61.3	25.0	2.02
Conventional Tillage	1,065	58.9	23.7	1.72
LSD (P=0.05)	NS	0.7	NS	0.13
Weed management practices				
Pendimethalin (1000 g/ha PE)	979	32.4	32.7	1.79
Pendimethalin (750 g/ha) PE + 1HW at 45DAS	1299	74.2	11.05	2.13
Imazethapyr (40 g/ha) at 15DAS	1020	66.7	30.1	1.88
Imazethapyr (40 g/ha) at 30DAS	1015	71.3	30.4	1.84
Pendimethalin + imazethapyr (750 + 20 g/ha) PE	1095	42.6	25.1	1.96
Pendimethalin *fb* quizalofop-ethyl (750 + 50 g/ha) PE/POE	1015	70.6	30.45	1.71
Pendimethalin + imazethapyr (750+20 g/ha) PE *fb* 1 HW at 45 DAS	1385	83.6	4.95	2.18
Weedy check	663	0	54.7	1.30
Weed free	1461	100	0	2.05
LSD(P=0.05)	137.9	4.3	5.7	0.22

CONCLUSION

It was concluded that zero till planting proved its superiority over conventional planting in terms of yield of chickpea and reduced weed infestation. Application of pendimethalin 750 g/ha with imazethpyr 20 g/ha as pre emergence followed by one hand weeding provided higher yield and profit with better weed control option in chickpea under upland rainfed ecology.

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Evaluation of bio-efficacy of herbicides on weed flora in wheat

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Wheat is one of the most important crops of India not only in terms of acreage, but also in terms of its versatility for adoption under wide range of agro-climatic conditions and crop growing situations. For millennia, wheat has provided dietary sustenance for large proportion of world's population. It is produced in wide range of climatic environments and geographic regions (Dixon *et al.* 2009). It provides 21 per cent of the food calories and 20 per cent protein for more than 4.5 billion people in 94 developing countries (Braun *et al.* 2010). Among several constraints of wheat production, weed infestation is a major one (Zimdahl 2004). Weed interference is one of the most important but less noticed factors, contributing towards considerable reduction in yield of wheat. Weeds not only reduce the crop yield, but also deteriorate the quality of farm produce and trim down the market value of crop (Hussain *et al.* 2012).

METHODOLGY

A field experiment was conducted at Instructional farm, Rajasthan College of Agriculture, MPUAT, Udaipur (Rajasthan) during the *Rabi* seasons of 2011-12 and 2012-13 to evaluate the performance of herbicides and their tank mixtures for control of broad-leaved weed flora in wheat crop. The wheat variety '*Raj 4037*' was used in experiment. Ten treatments, *viz*. 2,4-D, carfentrazone, metsulfuron, metsulfuron + carfentrazone, 2,4-D + 0.2% NIS, carfentrazone + 0.2% NIS, metsulfuron + 0.2% NIS, metsulfuron + carfentrazone + 0.2% NIS, weedy check and weed free were taken for weed management. The herbicides were sprayed by Knapsack sprayer at 32 DAS. The experiment was laid out in randomized block design and it was replicated three times.

RESULTS

The results revealed that the tank mixture of metsulfuron + carfentrazone + 0.2% NIS recorded the minimum weed density (3.54 no./0.5 m^2) and weed dry matter accumulation (12.15 g/0.5 m^2) at 60 DAS and it reduced the weed density and weed dry matter accumulation by 46.36 and 78.31 per cent , respectively over weedy check. Due to the highest controlling of broad-leaved weed flora, treatment metsulfuron + carfentrazone + 0.2% NIS gave the highest weed control efficiency *i.e.* 78.30 per cent and lowest weed index (2.81) at 60 DAS. Further, data showed that tank mixture of metsulfuron + carfentrazone + 0.2% NIS recorded the maximum grain yield (54.97 q/ha) because of higher weed control efficiency and due to this more space, sunlight and nutrients available to crop plants and in lights of this facts number of tillers (491.78 0.5/m^2) and test weight (45.53 g) of wheat crop was also higher compared to other treatments. However, minimum days to maturity were observed with weedy check.

Table 1. Effect of herbicide on weed dynamics, yield attributing characters and yield of wheat

Treatment	Weed density (no. 0.5/m^2)	Weed dry matter (g 0.5/m^2)	WCE (%)	Weed Index	Tillers/m^2	Days to maturity	Test weight (g)	Grain yield (t/ha)
2,4-D	14.00 (3.81)	12.72	77.33	13.01	470.00	133.83	44.54	4.91
Carfentrazone	14.00 (3.81)	12.88	77.00	19.03	470.67	132.83	44.45	4.57
Metsulfuron	15.33 (3.96)	13.43	76.05	23.74	432.83	132.67	44.44	4.31
Metsulfuron + carfentrazon	13.50 (3.73)	12.68	77.35	10.74	440.29	133.83	45.11	5.03
2,4-D + 0.2% NIS	13.67 (3.76)	12.53	77.63	10.11	462.83	134.67	45.26	5.07
Carfentrazone + 0.2% NIS	12.67 (3.63)	12.37	77.91	6.86	463.41	134.83	45.29	5.26
Metsulfuron + 0.2% NIS	12.33 (3.58)	12.23	78.16	6.59	479.46	134.83	45.44	5.28
Metsulfuron + carfentrazone 0.2% NIS	12.00 (3.54)	12.15	78.30	2.81	491.78	135.67	45.53	550
Weedy check	43.00 (6.60)	56.02	0.00	23.97	410.35	130.67	44.02	4.30
Weed free	0.00 (0.71)	0.00	100.00	0.00	516.83	136.17	46.24	5.66
LSD (P=0.05)	0.68	0.67	1.18	2.53	17.41	2.58	1.31	0.15

CONCLUSION

It was concluded that post-emergence use of metsulfuron + carfentrazone + 0.2% NIS was most effective to control the broad-leaved weed flora in wheat crop and produce the highest grain yield.

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Effect of weed and nutrient management in maize

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Maize (*Zea mays* L.) has becoming very popular cereal crop in India because of the increasing market price and high production potential in both irrigated as well as rainfed conditions. Poor productivity of maize is mainly because of inadequate attention towards weed and nutrient management. It is well known fact that weeds through competition with crop, deprive crops of limited essential resources. Thus, the extent of reduction in grain yield of maize has been reported up to 60 per cent owing to wider row spacing and coincidence of crop with rains (Sunitha and Lakshmi 2012). Moreover, weeds grow faster than the crop plants and absorb the nutrients earlier resulting into lack of nutrient for the growth of crop plants. Thus, nutrient drain by weeds assumed significance in the present context of fertilizer crisis. Control of weeds is vitally important not only to check the yield losses caused by them but also to increase the fertilizer use efficiency. The present investigation was therefore undertaken to study the extent of nutrient depletion by crop and weeds under various weed and nutrient management systems and to minimize these losses by controlling weeds.

METHODOLOGY

A field experiment was carried out at Instructional farm of the Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur during *Kharif* 2011 and 2012 to investigate weed and nutrient management on the nutrient uptake studies using variety *'HQPM-5'*. The experiment consisted of 6 weed management treatments (weedy check, atrazine 0.5 kg/ha pre-emergence + hoeing and weeding 30 DAS, metribuzin 0.25 kg/ha pre-emergence + hoeing and weeding 30 DAS, oxyfluorfen 0.15 kg/ha pre-emergence + hoeing and weeding 30 DAS, two hoeing and weeding 15 and 30 DAS and weed free up to 60 days stage of crop) and 4 fertility levels (75, 100, 125 and 150 per cent RDF) thereby making 24 treatment combinations. Experiment was conducted in split plot design keeping weed management in main block and nutrient management in sub blocks with three replications. The recommended dose of nitrogen and phosphorus was used as 120 and 40 kg/ha, respectively. To obtain uptake of nutrients weed dry matter was multiplied with the respective nutrient content and divided by 100. The crop was raised by adopting the full package of practices for this zone.

RESULTS

All weed management practices significantly decreased nitrogen and phosphorus uptake by weeds as compared to weedy check. The minimum N and P uptake by weeds was obtained under oxyfluorfen in combination with one hoeing and weeding which was statistically at par with metribuzin + one hoeing and weeding treatment. This treatment reduced N and P by the weeds to the tune of 75.55 and 13.02 kg/ha, respectively at harvest compared to weedy check wherein the corresponding uptake of these nutrients at this stage was 97.90 and 16.87 kg/ha. Weed management treatments increased N and P uptake by the crop significantly over weedy check. On pooled basis maximum total N and P (116.69 and 25.62 kg/ha, respectively) uptake by the crop was registered under oxyfluorfen + HW 30 DAS treatment which was closely followed by metribuzin + HW treatment. The superiority of pre-emergence application of oxyfluorfen + hand weeding 30 DAS was because of the fact that the emergence of early growth of weeds was inhibited by pre-emergence application of this soil applied herbicide and later emerging weeds were effectively controlled by hoeing and weeding performed at 30 DAS, thus, this treatment provided longer weed free period compared to their application alone. Amongst fertility levels, maximum N and P uptake by weeds at harvest was recorded when soil was enriched with 150 % RDF which was statistically at par with 125 per cent RDF. The uptake of N and P by the crop and weeds could be mainly attributed to the extent of their dry matter production which is evident from the inverse relationship between uptake of nutrients by weeds and crop.

Table 1. Effect of weed and nutrient management on nutrient uptake of weeds and crop (pooled data)

Treatment	Weed dry matter (g/m^2)	Nutrient uptake by weeds N	Nutrient uptake by weeds P	Biological yield (kg/ha)	Nutrient uptake by crops (kg/ha) N	Nutrient uptake by crops (kg/ha) P
Weed management						
Weedy check	644.37	97.90	16.87	4957	43.91	9.11
Atrazine *fb* HW 30 DAS	202.24	31.51	5.45	9029	90.31	19.31
Metribuzin *fb* HW 30 DAS	150.83	24.07	4.14	10148	107.03	23.64
Oxyflourfen *fb* HW 30 DAS	139.08	22.35	3.85	10660	116.69	25.62
HW 15 and 30 DAS	225.08	34.83	6.06	8704	86.04	18.46
Weed free	26.80	4.47	0.75	11072	123.37	27.29
LSD (P=0.05)	17.95	1.81	0.28	508	7.73	1.59
Nutrient management						
75% RDF	207.29	31.53	5.46	7762	73.06	16.30
100% RDF	226.77	35.07	6.05	8845	90.38	19.62
125% RDF	243.20	37.93	6.54	9760	105.23	22.70
150% RDF	248.36	38.89	6.70	10014	109.56	23.66
LSD (P=0.05)	12.84	1.23	0.19	348	4.53	1.22

CONCLUSION

It is concluded that application of pre-emergence application of oxyfluorfen followed y hoeing or weeding was found superior and saved N and P drain through weeds to the tune of 77.17 and 77.18 per cent, respectively compared to weedy check.

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Influence of weed management practices on growth of mustard under different fertility levels

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Mustard is one of the most important crops adopted by the farmers in the arid and semi-arid region of India. Since, these crops are cultivated mainly in the rainfed and resource scarce regions of the country, their contribution to livelihood security of the small and marginal farmers in these regions is also very important. Mustard crop offers immense scope for further yield enhancement. As this crop is grown in poor soils with poor management practices, weed infestation is one of the major causes of low productivity. Nutrient management is also the key technology in maintaining and sustaining the production potential of rapeseed-mustard. Balanced fertilization is more essential even at low levels of fertilizer usage for maintaining long-term fertility.

METHODOLOGY

The field experiment was conducted at research farm, RARI, Jaipur for two consecutive years during *Rabi* seasons 2014-15 and 2015-16 on loamy sand soil. The twenty four treatment combinations consisting of 3 fertility levels {100% RDF; 100% RDF+K+Zn and 125% (RDF+K +Zn)} and 8 herbicides (weedy check, weed free, pendimethalin 30 EC pre-emergence 750 g/ha, pendimethalin 38.7 CS pre-emergence 750 g/ha, pyrazosulfuron-ethyl 10 WP pre-emergence 150 g/ha, oxydiargyl 6 EC pre-emergence 90 g/ha, propaquizafop 10% EC 100 g/ha at 20-25 DAS and Fluazifop-p-butyl 13.4% EC 134 g/ha at 20-25 DAS were tested in factorial randomized block design with three replications.

RESULTS

After weed free, the density of *Argemone maxicana*, *Chenopodium album*, *Heliotropium ovalifolium* and other minor weeds at 30 DAS was recorded lowest under pendimethalin 38.7 CS. *Portulaca procumbense* at 30 DAS was completely controlled by pendimethalin 38.7 CS, pendimethalin 30 EC and oxydiargyl 6 EC. *Tithonia diversifolia* was most effectively controlled by oxydiargyl 6 EC. *Cynodon dactylon* in propaquizafop 10% EC treatment and *Cyperus rotundus* in fluazifop-p-butyl 13.4% EC at 30 DAS recorded the lowest density. The plant height of all the herbicidal treatments was significantly superior over pyrazosulfuron-ethyl 10 WP treatment. There was no significant variation found in number of branches per plant due to herbicides. Data further revealed that due to fertility levels there was no significant variation in the density of any of the weed species at 30 DAS. Plant height and number of branches per plant increases with the increase in fertility levels. Maximum plant height and number of branches per plant were recorded under 125 % (RDF + K + Zn) treatment.

Table 1. Effect of treatments on the density of different weeds at 30 DAS

Treatment	*Argemone maxicana*	*Chenopodium album*	*Cynodon dactylon*	*Cyperus rotundus*	*Heliotropium ovalifolium*	*Portulaca oleraceae*	*Tithonia diversifolia*	Other minor weeds
Fertility levels								
100 % RDF*	2.13 (4.17)	2.15 (4.82)	2.61 (7.17)	2.31 (5.36)	2.00 (3.36)	2.02 (4.04)	2.48 (6.09)	2.02 (3.44)
100 % RDF + K + Zn	2.17 (4.37)	2.09 (4.42)	2.77 (7.97)	2.24 (4.56)	2.01 (3.4)	2.00 (4.07)	2.63 (7.01)	2.03 (3.49)
125 % RDF + K + Zn	2.13 (4.24)	2.17 (4.64)	2.78 (8.18)	2.24 (4.73)	2.04 (3.46)	2.02 (4.14)	2.67 (7.04)	2.06 (3.62)
LSD (P=0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Herbicides								
Weedy check	3.25 (9.60)	3.60 (12.00)	4.13 (16.09)	3.61 (12.09)	2.82 (6.93)	3.35 (10.23)	3.77 (13.25)	2.61 (5.82)
Weed free	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Pendimethalin 30 EC pre-emergence 750 g/ha	1.63 (1.78)	1.74 (0.58)	2.99 (7.91)	2.30 (4.35)	1.54 (1.42)	1.00 (0.00)	2.01 (3.25)	1.66 (1.78)
Pendimethalin 38.7 CS pre-emergence 750 g/ha	1.55 (1.51)	1.08 (0.18)	2.93 (7.60)	2.31 (4.44)	1.51 (1.33)	1.00 (0.00)	2.12 (3.56)	1.48 (1.25)
Pyrazosulfuron-ethyl 10 WP pre-emergence 150 g/ha.	3.25 (9.60)	3.41 (10.67)	4.04 (15.29)	3.23 (9.6)	2.59 (5.69)	3.13 (8.80)	3.94 (14.54)	2.97 (7.78)
Oxydiargyl 6 EC pre-emergence 90 g/ha.	1.58 (1.60)	1.42 (1.17)	3.67 (12.45)	2.6 (5.77)	2.11 (3.46)	1.00 (0.00)	1.94 (2.94)	1.89 (2.58)
Propaquizafop 10% EC 100 g/ha at 20-25 DAS	2.51 (5.34)	2.73 (6.49)	1.46 (1.29)	1.59 (1.64)	2.43 (4.89)	3.00 (8.00)	2.9 (7.47)	2.25 (4.10)
Fluazifop-p-butyl 13.4% EC134 g/ha at 20-25 DAS	2.37 (4.63)	2.61 (5.91)	1.56 (1.52)	1.44 (1.2)	2.13 (3.55)	2.52 (5.34)	3.07 (8.45)	2.41 (4.80)
LSD (P=0.05)	0.233	0.220	0.195	0.27	0.147	0.121	0.287	0.134

Data in parentheses indicate the original weed density per m^2.Square root transformation " (x + 0.5) was applied; * Recommended Dose of Fertilizer: 60 kg N + 30 kg P_2O_5 + 40 kg S per hectare. 30 kg K_2O + 20 kg $ZnSO_4$ per hectare was also applied in second treatment of fertility level.

CONCLUSION

Most effective herbicides in controlling most of the weeds is Pendimethalin 38.7 CS, followed by Pendimethalin 30 EC and Oxydiargyl 6EC. Propaquizafop 10% EC and Fluazifop-p-butyl 13.4% EC were found more effective in controlling grassy weeds. 125 % RDF + K + Zn treatment was observed best as it gave maximum plant height and number of branches per plant in crop.

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Effect of crop-weed competition on growth and yield of niger under rainfed condition of Jharkhand

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Niger (*Guizotia abyssinica (L.f.) cass*.) is an important traditional oilseed crop. India is the largest producer of niger in the world which was grown over an area of 2.77 lakh hectare with a production of 0.89 lakh tones and productivity of 321 kg/ha (Anonymous 2015). In Jharkhand, niger production is confined to the area of 4.6,000 ha with production of 1.57,000 tonnes and productivity is about 342 kg/ha (Anonymous 2011-12). Niger although considered minor oilseed crop, is important in terms of its 32 to 40 per cent of quality oil with 18 to 24% protein in seed. It is also used as an oilseed crop in India where it provides about 03 % of the edible oil requirement of the country (Getinet and Sharma 1996). Productivity of niger indicates a declining trends during 2012-13 and 2013-14 in India as well as in Jharkhand. It is a very primitive crop of Jharkhand state and mostly grown in tribal belts on marginal and sub-marginal lands without much care and use of negligible agro-inputs under rainfed situation during *Kharif* season. Among the various factors responsible for low yields of niger, infestation of weeds is the one of the most important constraint under rainfed upland situation. For making sound weed management decision, it is very important to generate data regarding impact of weeds on growth and yield of crop at different growth stages. Thus, timely control of weeds during critical period of crop–weed competition is necessary for minimizing the yield losses. However, there is very scanty information pertaining to critical period of weed competition in the crop raised during *Kharif* season. Therefore, identifying and establishing the critical period of crop-weed competition in niger is essential to develop effective and economical weed control measures.

METHODOLOGY

A field experiment was conducted on niger with variety *'Birsa Niger-1'* at research farm of BAU Kanke, Ranchi during *Kharif* season for three years (2009-11). The soil of the experimental field was clay loam in texture, acidic in reaction (pH 5.5-6.0) with low in available N (185 kg/ha), P (16 kg/ha) and available K is medium (240 kg/ha). A set of ten treatments of different weed management practices viz., weedy check to weeding at 15, 30, 45 and 60 DAS and weed free throughout the crop period were tested in randomized block design replicated thrice. The sowing of seeds was done on first fortnight of September in rows of 30 cm. The recommended dose of fertilizers (20:20:20:: N:P:K) was applied through urea, single super phosphate & muriate of potash to all the treatments. The rest of management practices were followed in accordance with the recommended package of practices. The data on weed density and weed dry weight were recorded from two randomly selected quadrants (0.25m) in each plots and data pertaining to growth parameters, yield attributes and yield were also recorded. The crop was harvested in second fortnight of December. Weed control efficiency (WCE) and economic indices viz. gross monetary returns (GMR), net monetary returns (NMR) and benefit: cost ratio (B:C ratio) were computed on the basis of cost involved in the cultivation and value realized from the produce per unit area under various treatments.

RESULTS

There was progressive increase in the population of all the weeds species with increase in duration of weed infestation and reduction in weed population was registered when weed infestation was checked periodically. Significant reduction in weed population was recorded when weed free situation was existed up to 40 DAS. Significant decrease in dry matter accumulation of weeds was recorded when weed free situation prolonged from 20-40 DAS and throughout crop growth period. The minimum weed dry weight (8.3 g/m^2) and maximum WCE (82.6%) was recorded when crop was kept weed free throughout the crop period. Seed yield was significantly influenced due to different weeding methods. Keeping the crop weed free throughout the crop season produced highest seed yield (438 kg /ha) which is 51 and 50% higher as compared to weeding at 60 DAS & weedy check, respectively. This might be due to efficient utilization of available resources *viz*., space, nutrients water etc. by the crop. Maximum NMR of Rs.6632/ha was recorded when crop was kept weed free throughout the crop growth period. There is no significant difference was recorded between treatments regarding B:C ratio due to differences in cost of cultivation. These results are in conformity with the findings of Sheoran *et al.* (2008).

CONCLUSION

It is concluded that critical period of crop -weed competition was found to be between 40 - 60 days after sowing of niger crop and keeping the crop weed free throughout the crop growth period is more productive and remunerative under rainfed upland situation.

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Sequential application of herbicides to control complex weed flora in direct seeded rice

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Weeds are the most significant biological constraint and major threat to the production and adoption of DSR systems (Chauhan 2012). Success of DSR depends largely on weed control especially with chemical methods as mechanical weed control is labour intensive and not cost effective. Various herbicides have been used for controlling weeds in DSR but efficiency of chemical methods based on single herbicide treatment may be unsatisfactory because of their narrow spectrum of weed control. Therefore, application of several herbicides in combination or in sequence can be more useful (Chauhan and Yadav 2013).

METHODOLOGY

The study was conducted during the *Kharif* 2012 at Students' Farm of College of Agriculture, CCS Haryana Agricultural University; Kaul campus (Kaithal) with 14 treatments and three replication (Table 1). Rice variety *'PUSA 1121'* was seeded on 19th June 2012 in rows 22.5 cm apart using seed drill. Weed density (no./m^2) were recorded species wise in each plot using quadrate of 50 x 50 cm (0.25 m^2) from the area selected randomly for observations.

RESULTS

Weed flora of the experimental field was mainly dominated by *Cyperus difformis*, *Cyperus rotundus*, *Leptochloa chinensis*, *Echinochloa glabrescens*, *Eclipta alba* and *Ammania* spp. All the treatments recorded significant reduction in the density of weeds compared to weedy check. Sequential application of pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha and metsulfuron-methyl + chlorimuron-ethyl 4 g/ha gave minimum density of *Echinochloa glabrescens*, *Cyperus* spp. and *Ammania* spp. among all herbicidal treatments (Table 1). However, the minimum density of *Leptochloa chinensis* was reported with herbicidal combination of pendimethalin 1000 g/ha as pre emergence *fb* fenoxaprop 67 g/ha. This may be due to more effectiveness of fenoxaprop 67 g/ha to control *Leptochloa chinensis*. All the treatments produced significantly higher number of effective tillers than weedy check (Table 1). Weed free treatment recorded highest number of effective tillers (210) and grain yield (4.12 t/ha) being at par with sequential application of pendimethalin 1000 g/ha *fb* bispyribac sodium 25 g/ha and metsulfuron methyl + chlorimuron ethyl 4 g/ha.

Table 1. Effect of different weed control treatments on weed density at 45 DAS, effective tillers and grain yield in direct seeded rice

Treatment	Dose g/ha	Time DAS	Weed density (no./m^2) *Echinochloa glabrescens*	*Leptochloa chinensis*	*Cyperus* spp.	*Ammania baccifera*	Effective tillers/m^2	Grain yield (t/ha)
Pendimethalin *fb* bispyribac-Na	1000 *fb* 25	3 *fb* 25	3.3(9.9)	5.6(30.8)	5.6(30.5)	3.2(9.3)	184.5	3.57
Pendimethalin *fb* bispyribac-Na + ethoxysulfuron	1000 *fb* 25 +18.75	3 *fb* 25	3.2(9.2)	5.1(25.5)	2.3(5.1)	2.5(5.3)	206.7	3.83
Pendimethalin *fb* bispyribac-Na + metsulfuron-methyl + chlorimuron-ethyl	1000 *fb* 25 +4	3 *fb* 25	2.9(7.2)	5.5(29.6)	2.2(4.4)	1.8(2.7)	209.3	3.97
Pendimethalin *fb* fenoxaprop	1000 *fb* 67	3 *fb* 25	4.2(17.2)	2.3(4.1)	5.3(28.2)	3.2(9.3)	180.0	3.57
Pendimethalin *fb* fenoxaprop + ethxysulfuron	1000 *fb* 67 + 18.75	3 *fb* 25	4.1(16.4)	2.4(4.7)	2.4(6.0)	2.3(5.3)	193.3	3.71
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl + chlorimuron-ethyl	1000 *fb* 67 + 4	3 *fb* 25	3.9(14.8)	2.4(4.5)	2.4(5.5)	1.8(2.7)	198.7	3.77
Oxadiargyl *fb* bispyribac-Na	100 *fb* 25	3 *fb* 25	3.7(13.1)	5.6(30.3)	5.6(30.7)	3.6(12.0)	174.7	2.93
Oxadiargyl *fb* bispyribac-Na + ethoxysulfuron	100 *fb* 25 + 18.75	3 *fb* 25	3.7(12.8)	5.7(31.5)	2.6(7.2)	3.0(8.0)	182.3	3.25
Oxadiargyl *fb* bispyribac-Na + metsulfuron-methyl + chlorimuron-ethyl	100 *fb* 25 + 4	3 *fb* 25	3.5(11.2)	6.0(35.7)	2.5(6.1)	2.7(6.7)	188.3	3.47
Oxadiargyl *fb* fenoxaprop	100 *fb* 67	3 *fb* 25	4.7(21.2)	2.4(4.5)	6.7(43.7)	3.8(13.3)	165.3	2.77
Oxadiargyl *fb* fenoxaprop + ethoxysulfuron	100 *fb* 67 + 18.75	3 *fb*25	4.5(20.1)	2.6(5.7)	2.6(7.3)	3.0(8.0)	166.7	2.87
Oxadiargyl *fb* fenoxaprop + metsulfuron-methyl + chlorimuron-ethyl	100 *fb* 67 + 4	3 *fb* 25	4.4(18.4)	2.6(5.6)	2.5(6.7)	2.7(6.7)	168.0	2.94
Weed free			1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	210.7	4.12
Weedy check			7.0(48.4)	7.5(56.0)	8.6(72.6)	4.2(17.3)	97.3	1.52
LSD (P=0.05)			0.7	0.6	1.0	0.8	20.0	0.43

*Original values are in parenthesis and before statistical analysis were subjected to square root transformation ($\sqrt{x+1}$)

CONCLUSION

Sequential application of pendimethalin 1000 g/ha *fb* post emergence application of bispyribac sodium 25 g/ha and metsulfuron methyl + chlorimuron ethyl 4 g/ha produced lowest weed density at 45 DAS among all treatments. This treatment also recorded highest number of effective tillers and grain yield as compared to all other treatments.

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Effect of different formulation of herbicides on weed flora and yield of soybean

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Soybean is an important *Kharif* oil seed crop having multiple uses. Weeds are the major biotic factor responsible for poor yield in soybean. Simultaneous emergence and rapid growth of large number of weed species causes severe crop-weed competitions and reduction in crop yields (30-80%) depending upon the type of weed flora and weed density (Kuruchania 2000). Studies indicated that crop losses due to weed competition throughout the world as a whole, are greater than those resulting from combined effect of insect pests and diseases. In the *kharif* season, continuous rains do not permit timely manual/mechanical weed control operations. However, the choice of most appropriate herbicide, proper time of application and proper dose is an important consideration for lucrative returns.

MATERIALS

The present investigation was conducted at Agricultural Research Farm, IAS, BHU, Varanasi during *Kharif*, 2016. The soil of the experimental field was low in organic carbon, available nitrogen, sulphur whereas P and K were medium. The experiment was laid out in randomized block design with three replications and consisted of eleven treatments with different formulations.

Table 1. Effects of different herbicides on noxious weeds and yield of soybean

Treatment	Dose/ha (kg)		*Cynodon dactylon*	Parthenium hysterophorus	*Cyperus rotundus*	Seed yield (kg/ha)	Straw yield (kg/ha)
	a.i.	Formulation	20 DAS	20 DAS	20 DAS		
Metribuzin 70 WP (sample from imported technical)	1.05-2.0	1.5	2.68 (6.67)	1.87(3.00)	1.58 (2.00)	102.78	833.33
Metribuzin 70 WP (sample from imported technical)		3	1.22(1)	1.35(1.33)	0.91(0.33)	1555.56	3166.67
Metribuzin 70 WP (sample from imported technical)	4	6	1.96(3.33)	1.47(1.67)	0.92(0.33)	1361.11	3388.89
SULM 70 WG (triazinone herbicide)	1.05-1.4	1.5	2.61(6.33)	1.87(3.00)	1.35(1.33)	383.33	1000
SULM 70 WG (triazinone herbicide)		2	2.48(5.67)	1.87(3.00)	1.35(1.33)	441.67	1444.44
SULM 70 WG (triazinone herbicide)	1.4-2.0	2.5	2.27(4.67)	1.68(2.33)	1.35(1.33)	916.67	2111.11
SULM 70 WG (triazinone herbicide)		3	2.12(4)	1.58(2.00)	0.93(0.33)	1194.44	2388.89
SULM 70 WG (triazinone herbicide)	4	6	2.13(4.01)	1.59(2.03)	1.22(1.00)	583.33	2388.89
Metribuzin 70 WP (market sample)	1.05-2.0	1.5	2.35(5)	1.87(3.00)	1.35(1.33)	688.89	4388.89
Metribuzin 70 WP (market sample)		3	2.27(4.67)	1.58(2.00)	1.22(1.00)	805.56	2333.33
Untreated control	-	-	4.26(17.67)	2.42(5.33)	3.24(10.00)	88.89	333.33
LSD (P=0.05)	-	-	2.6				
SE(m)	-	-	0.88	0.48	0.55	118	260
SE(d)	-	-	1.25	0.68	0.77	167	367

RESULTS

The effect of different herbicides on weed density were significant. Among the different herbicide formulations the minimum weeds density of *Cynodon dactylon*, *Parthenium hysterophorus*, and *Cyperus rotundus* was recorded with Metribuzin 70 WP (Sample from imported technical) 3 kg/ha while the maximum total weed density was in weedy check at 20 DAS. The seed and straw yield was recorded highest with the treatment metribuzin 70 WP (Sample from imported technical) 3 kg/ha which was significantly superior then rest of treatments. Similar results were also recorded by Habimana (2013). Metribuzin 70 WP application was better than other treatments and this might be due to broadness of metribuzin 70 WP against broad and grassy leaves and sedges weeds.

CONCLUSION

Pre-emergence application of metribuzin 70 WP (Sample from imported technical) 3 kg/ha resulted in higher grain yield besides giving broad spectrum of weed control.

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Efficacy of herbicide mixtures and sequential application against herbicide resistant *Phalaris minor* Retz. in wheat

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Wheat is the pre-dominant spring crop in North India and an important crop from the point of food security. Its productivity and production substantially diminished by weeds owing to competition for various inputs with the crop plants. *Phalaris minor* has been emerged as most deleterious grassy weeds in the Indo Gangetic region especially in large areas of Haryana and adjoining states. Herbicide application is a preferred method for its control due to lesser feasibility of mechanical or manual weeding in wheat because of its morphological similarity with wheat, narrow spacing, as well as scarce and costly labour. For its control isoproturon was used in 1970, but because of its continuous use for about 8-10 years resulted into resistant populations of *P. minor* having enhanced herbicide degradation mechanism (Singh 2006, 2007). Alternate herbicides of different site of action *i.e.* PS II inhibitors, ACCase inhibitors and ALS inhibitors were recommended, but again their continuous application for years brought multiple herbicide resistance in *P. minor* apart from shift in weed flora in wheat. In Punjab and Haryana different populations of *P. minor* infesting the wheat fields have evolved multiple herbicide resistance to four group of herbicides *i.e*. phenylurea (isoproturon), aryloxyphenoxy propioanate (clodinafop, fenoxaprop), sulfonylurea (sulfosulfuron, meso+iodosulfuron) and phenylpyrazolin (pinoxaden) (Singh 2015a). At present, all the resistant *P. minor* populations can't be controlled effectively using single recommended herbicide (Singh 2015b). Herbicide mixtures and sequential application may be one of the effective measures for multiple herbicide resistance management by increasing the spectrum of weed control and reducing selection pressure.

METHODOLOGY

To assess the efficacy of herbicide mixtures and sequential application against herbicide resistant *Phalaris* in real field situation trials were conducted under CCSHAU, Hisar at resistant affected farmer's fields on large plots in Jind and Kaithal District of Haryana, India. Treatments included different herbicides alone or as mixtures and sequential applications at particular doses and combinations (Fig. 1). Each location was considered as one replication in a randomized complete block design. Herbicides were applied with a flat-fan nozzle using spray volume of 500 l/ha. Data on visual percent weed control was recorded at 70 DAS.

RESULTS

Among different treatments, pre-emergence application of pendimethalin followed by pendimethalin + metribuzin (TM) / fenoxaprop+ metribuzin (Accord Plus)/ pinoxaden (Axial) provided higher percent control of the resistant *P. minor* population as compared to post emergence application of sulfosulfuron *fb* pinoxaden/Accord plus/Atlantis/ metribuzin.The pre emergence applications of pendimethalin + pyroxasulfone (TM) was found most effective to control resistant *P. minor* population as compared to pre emergence application of pendimethalin / pyroxasulfone / pendimethalin+metribuzin. Concurrently crop injuries were also observed with the application of mesosulfuron +iodosulfuron (Atlantis) and metribuzin.

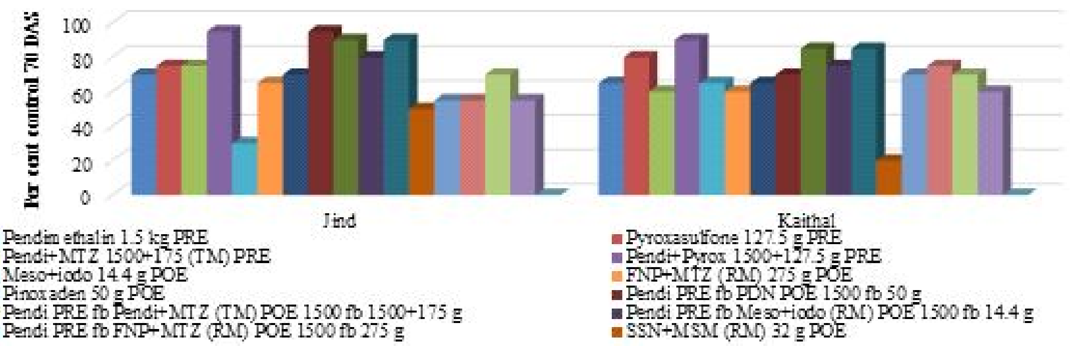

Fig. 1. Per cent control of resistant *Phalaris minor* at two locations under farmers' fields using different PRE/POE herbicides

CONCLUSION

It is concluded that for pre-emergence application of pendimethalin + pyroxasulfone (TM) 1500+127.5 g/ha and post-emergence application of pinoxaden 50 g/ha POE after pendimethalin 1500 g/ha PRE provided higher weed control in wheat crop.

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Evaluating the effect of weed management practices and fertility levels on weed dynamics and productivity of soybean

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Soybean [*Glycine max* (L.) Merr.] is one of the major *Kharif* season field crop in south-eastern Rajasthan and has been recognized as the efficient producer of the two major quality characters *i.e.* oil (20%) and protein (40%), which are not only the major components in the diet of vegetarians but also a boon to the economy of the developing countries (Chandrakar *et al.* 2012). Major concerns to lower productivity are heavy infestation by weeds and inadequate supply of nutrients. The present investigation was undertaken to evaluate the effect of weed management practices and fertility levels on weed dynamics and productivity of soybean.

METHODOLOGY

A field experiment was conducted at Agricultural Research Station, Ummedganj, Kota (Rajasthan) during *Kharif* 2013 and 2014 to evaluate the impact of weed management practices and fertility levels on weed dynamics and productivity of soybean. The topography of field was uniform with gentle slope. The experiment was laid out in split plot design comprising of seven weed management practices in main plot and four fertility levels in sub plots with three replications. Sowing of soybean *cv. 'RKS-45'* was done in July 2013 and 2014. The RDF for soybean in the zone is 40 kg N, 40 kg P_2O_5, 40 kg K_2O and 30 kg S/ha. Pre or post-emergence application of herbicides was done as per treatment. Data on weeds were recorded at 25, 50, 75 DAS and at harvest in each plot from randomly selected two spots. Weed data were subjected to square root transformation before statistical analysis.

RESULTS

At the experiment site, the most prominent monocot were *Echinochloa colona, Echinochloa crus-galli, Cynodon dactylon, Cyperus rotundus* whereas among dicot *Celosia argentea, Digera arvensis, Acalypha indica and Trianthema portulacastrum* were dominant species. It can be inferred from results (Table 1) Pooled data showed that two hand weedings at 20 and 40 DAS, ready mix of imazamox + imazethapyr 75 g/ha at 15 DAS, imazethapyr 100 g/ha at 15 DAS and pendimethalin 1.0 kg/ha as PE + 1 HW (30 DAS) exhibited 85.3, 75.9, 69.9 and 73.2%; 82.4, 77.7, 76.0 and 57.7%; and 83.6, 77.0, 73.6 and 63.9% reduction in dry matter of monocot, dicot and total weeds, respectively as compared to weedy check. Similarly, weed control efficiency at harvest was the highest with two hand weeding closely followed by ready mix of imazamox + imazethapyr 75 g/ha, imazethapyr alone, pendimethalin +1 HW, quizalofop-ethyl and clodinafop-propargyl with a mean value of 83.71, 77.14, 73.76, 64.24, 34.40 and 32.08%, respectively.

Different fertility levels were also significantly affected the weed dry matter of all categories during both the years. Pooled data revealed that in comparison to 100 % NPK without sulphur, increase in dry matter of monocot, dicot and total weeds were recorded to the tune of 14.0, 16.3 and 19.4; 7.5, 8.5 and 10.3 and 9.3, 10.7 and 12.8% due to 100% NPK along with sulphur, 125% NPK without and with sulphur, respectively.

Table 1. Effect of weed management practices and fertility levels on weed dry weight at harvest, weed control efficiency at harvest and yields of soybean (pooled data of two years)

Treatment	Weed dry weight (kg/ha) at harvest			Weed control efficiency (%) at harvest			Seed yield (t/ha)	Haulm yield (t/ha)
	Monocot	Dicot	Total	Monocot	Dicot	Total		
Weed management practices								
Weedy check	938.18	1453.13	2391.31	-	-	-	0.89	1.37
HW (20 and 40 DAS)	137.71	252.29	390.00	85.24	82.66	83.71	2.20	3.34
Pendimethalin 1.0 kg/ha+ HW (30 DAS)	251.16	605.61	856.77	73.21	58.35	64.23	1.90	2.89
Imazethapyr 100 g/ha(15 DAS)	282.29	343.91	626.20	69.60	76.19	73.76	1.94	2.96
Imazamox + imazethapyr 75 g/ha (15 DAS)	226.55	319.54	546.09	75.53	77.95	77.14	2.01	3.06
Clodinafop-propargyl 60 g/ha (15 DAS)	264.40	1360.01	1624.41	71.81	6.41	32.08	1.53	2.34
Quizalofop-ethyl 50 g/ha (15 DAS)	240.25	1329.35	1569.60	74.68	8.41	34.40	1.65	2.52
LSD (P= 0.05)	42.97	56.15	68.75				0.10	0.15
Fertility levels								
100% NPK without S	297.43	759.29	1056.71	-	-	-	1.59	2.45
100% NPK with S	339.09	815.97	1155.06	-	-	-	1.74	2.64
125% NPK without S	345.81	824.04	1169.85	-	-	-	1.79	2.72
125% NPK with S	355.14	837.18	1192.32	-	-	-	1.82	2.76
LSD (P= 0.05)	29.79	34.63	42.09				0.06	0.09

Increase in seed yield by two hand weeding, ready mix of imazamox + imazethapyr 75 g/ha, imazethapyr 100 g/ha at 15 DAS, pendimethalin 1.0 kg/ha PE + 1 HW (30 DAS), quizalofop-ethyl 50 g/ha and clodinafop-propargyl 60 g/ha was observed over weedy check. Among the fertility levels, application of 100 and 125% NPK along with sulphur were significantly influenced yield of soybean over 100 % NPK without sulphur.

CONCLUSION

Based on the two years experimentation, it could be concluded that among the herbicidal treatments, post emergence application of ready mix of imazamox + imazethapyr 75 g/ha at 15 DAS provided effective weed management and produced highest seed yield of soybean. Supplementation sulphur with 00% NPK further improved the yield.

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Effect of weed management on weed dynamics and productivity of sorghum

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Sorghum [*Sorghum bicolor* (L.) Moench] is also known as the king of millets, holds promise for food, feed, fodder and ration for humanity, cattle and poultry. Like other rainy season crops, sorghum also severely infested with several types of weeds i.e. *Cynodon dactylon, Echinochloa colona, Setaria gluca, Dactyloctenium aegyptum, Cyprus rotundus, Amaranthus sp., Digera arvensis, Trianthema portulacastrum, Tridax procumbens, Commelina benghalensis, Celosia argentea* etc. Farmers either do not pay attention to weeds or undertake one or two manual or mechanical weeding. Frequent rainfall in *Kharif* season further makes the manual/mechanical weeding operations even more difficult. Under such situation, application of herbicides at the time of sowing may be more effective way for weed management.

METHODOLOGY

A field experiment was conducted at the Instructional Farm, Rajasthan College of Agriculture, Udaipur during *Kharif* 2011. The experiment comprised of 12 treatment combinations *i.e.*T_1: Atrazine 0.50 kgha^{-1} as pre-emergence followed by 1HW/ interculture at 30 DAS, T_2: Atrazine 0.25 kg/ha as pre-emergence followed by 2HW/interculture at 30 and 45DAS, T_3: Pendimethalin 0.50 kg/ha as pre-emergence followed by 1HW/ interculture at 30 DAS, T_4: Oxyfluorefen 0.15 kg/ha as pre-emergence followed by 1HW/ interculture at 30 DAS, T_5: Atrazine 0.25 kg/ha + pendimethalin 0.25 kg/ha as pre- emergence, T_6: Atrazine 0.25 kg/ha + pendimethalin 0.50 kg/ha as pre-emergence, T_7: Atrazine 0.25 kg/ha + oxyfluorefen 0.15 kg/ha as pre-emergence, T_8: Atrazine 0.25 kg/ha + oxyfluorefen 0.15 kg/ha as pre-emergence *fb* 2,4- D 0.50 kg/ha as post-emergence, T_9: Atrazine 0.25 kg/ha + pendimethalin 0.50 kg/ha as pre-emergence *fb* 2,4- D 0.50 kg/ha as post-emergence, T_{10}: Atrazine 0.25 kg/ha *fb* 2,4- D 0.50 kg/ha as post-emergence, T_{11}: Atrazine 0.25 kg/ha as pre-emergence *fb* pendimethalin 0.50 kg/ha as post-emergence at 30 DAS, and T_{12}: Weedy check. Variety *'CSV 23'* was sown at 12 kg/ha seed rate by adopting full package. These treatments were replicated thrice in randomized block design.

RESULTS

The density of monocot weeds *i.e. Cyanodon dactylon, Echinochloa spp., Cyperus rotundus* and other monocot weeds reduced significantly with application of atrazine 0.25 kg + oxyfluorfen 0.15 kg/ha *fb* 2,4-D 0.50 kg/ha, oxyfluorfen *fb* one hand weeding at 30 DAS. In all, treatment T_8 recorded significantly minimum monocot weeds population and T_9 recorded significantly minimum dicot weeds population. (Table 1). All the weed management treatment significantly reduce the individual monocot, dicot and total weed dry matter than weedy check at harvest. Treatment T_2 and T_8 recorded significantly lower dry matter of monocot, dicot and total weeds at harvest.

Table 1. Effect of integrated weed management on weed count, weed dry matter and yield of sorghum

Treatment	Weed count (no./m^2)						Weed dry matter (g/m^2)at harvest			Yield (t/ha)		
	At 30 DAS			At harvest								
	monocot	Dicot	Total	monocot	Dicot	Total	Monocot	Dicot	Total	Grain	Fodder	Biological
T_1	34.00	41.00	75.00	60.67	70.33	131.00	149.00	172.74	321.74	37.89	118.03	155.92
	(5.87)	(6.44)	(8.69)	(7.82)	(8.42)	(11.47)						
T_2	41.33	48.00	89.33	9.33	11.67	21.00	21.97	28.71	50.68	43.45	132.24	175.69
	(6.47)	(6.96)	(9.48)	(3.12)	(3.49)	(4.63)						
T_3	40.67	46.67	87.33	51.67	52.67	104.33	126.89	129.35	256.24	35.34	115.88	151.23
	(6.42)	(6.87)	(9.37)	(7.22)	(7.29)	(10.24)						
T_4	35.67	40.33	76.00	49.00	51.67	100.67	120.34	126.89	247.24	35.37	116.48	151.85
	(6.01)	(6.39)	(8.75)	(7.03)	(7.22)	(10.06)						
T_5	36.33	42.33	78.67	52.33	58.00	110.33	128.53	142.45	270.98	30.90	126.54	157.44
	(6.07)	(6.54)	(8.90)	(7.27)	(7.65)	(10.53)						
T_6	37.00	39.33	76.33	49.00	52.00	101.00	120.34	127.71	248.06	30.72	127.65	158.37
	(6.12)	(6.31)	(8.77)	(7.03)	(7.25)	(10.07)						
T_7	30.33	37.67	68.00	42.00	54.33	96.33	103.15	133.44	236.59	37.67	130.54	168.20
	(5.55)	(6.18)	(8.28)	(6.52)	(7.40)	(9.84)						
T_8	30.78	38.3	69.11	43.33	44.33	87.67	106.43	108.88	215.31	40.54	133.42	173.96
	(5.59)	(6.23)	(8.34)	(6.62)	(6.70)	(9.39)						
T_9	33.33	38.00	71.33	48.67	44.67	93.33	119.53	109.70	229.23	43.30	128.54	171.84
	(5.82)	(6.20)	(8.48)	(7.01)	(6.72)	(9.69)						
T_{10}	36.00	39.00	75.00	49.67	43.00	92.67	121.98	105.61	227.59	40.78	125.65	166.41
	(6.04)	(6.28)	(8.69)	(7.08)	(6.59)	(9.65)						
T_{11}	41.00	42.33	83.33	43.33	52.33	95.67	106.43	128.53	234.96	32.90	124.76	157.66
	(6.44)	(6.54)	(9.16)	(6.62)	(7.27)	(9.80)						
T_{12}	70.00	99.00	169.00	98.67	138.67	237.33	243.00	341.85	584.85	18.94	97.24	116.18
	(8.39)	(9.97)	(13.02)	(9.96)	(11.80)	(15.42)						
LSD(P=0.05)	0.292	0.243	0.203	0.363	0.277	0.311	11.45	9.86	15.20	5.16	13.25	14.63

Data in Table 1 reveals that treatment T_2 recorded maximum grain and biological yields (43.45 and 175.69 q/ha) and T_8 recorded maximum stover (133.42 q/ha) which was found closely at par with T_9 and T_{10}. Application of herbicides integrated with 1 HW reduced weed density and dry matter most efficiently compared to weedy check might be due to fact that pre-emergence herbicide controls early flushes of weeds, while hand weeding destroyed late flushes of weeds. Hence, crop could remain weed free for comparatively longer duration (Choudhary 2013).

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Integrated weed management in berseem

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Berseem (*Trifolium alexandrinum* L.) is one of the most important *Rabi* legume fodder crop grown under irrigated conditions occupying about 2 million hectares crops in north, north-west and central parts of India. In Punjab, the area under this crop is more than 65% of the total area under fodder crops and also known as milk multiplier. Due to its excellent and quick re-growing ability and long durational nutritious green fodder availability (November to April), the crop is grown under irrigated conditions. Because of its slow growth in the initial stages, crop suffers heavily due to weed infestation. Weed competition reduces the green forage yield up to 30-40% besides deteriorating quality of green forage. Therefore, there is need to create an environment that is detrimental to weeds and favorable to the crops. Hence, weed control need to be restored during initial period of crop growth. To assess the bio-efficacy of different weed control practices the present investigation was undertaken to evaluate the bio-efficacy of herbicide alone or in combination with use of two different herbicides in sequence for managing the weeds in berseem.

METHODOLOGY

An experiment was conducted at Forage Research Farm, Punjab Agricultural University, Ludhiana during *rabi* season 2013-14 and 2014-15. The experiment consisting of 10 treatments (elaborated in Table1) was laid out in randomized block design and replicated thrice. The pre-emergence herbicides were sprayed 3 days after sowing prior to emergence of weed as well as crop and post emergence herbicide was applied immediately after harvest of 1^{st} and 2^{nd} cut for fodder as per the treatment. The weed count and weed dry weight values were subjected to square root transformation and weed control efficiency (WCE) was calculated as per the standard formula suggested by Gautam *et al.* (1975). Data on fodder yield, seed yield and economics were recorded.

RESULTS

The data on weed density and weed dry matter revealed that maximum weed density and weed dry matter was recorded in case of weedy check after first and second cut (Table 1). Among the weed control treatments minimum weed density (39.8 and 18.7/m^2 after 1^{st} and 2^{nd} cut, respectively) and weed dry matter (0.19 and 0.15 t/ha after 1^{st} and 2^{nd} cut, respectively) was observed where imazethapyr was applied 0.1 kg/ha immediately after 1^{st} and 2^{nd} cut and it was significantly lower as compared to all the other treatments. The weed control efficiency was also highest in this treatment.

Application of imazethapyr 0.1 kg/ha immediately after 1^{st} and 2^{nd} cut resulted in significantly higher green fodder yield (94.36 t/ha), seed yield (0.69 t/ha) and crude protein yield (2.18 t/ha) over all the other weed control treatments (Table 1). The green fodder yield of berseem in other herbicidal treatments was even lower than weedy check because of phytotoxic effect of these herbicides. The economic analysis of the data revealed that application of imazethapyr 0.1 kg/ha immediately after 1^{st} and 2^{nd} cut resulted in significantly higher net returns (Rs. 207955/ha) and benefit cost ratio (4.64) over all the other herbicidal treatments and weedy check. These results were found to be in line with the findings of Pathan and Kamble (2012).

Table 1. Weed dynamics, yield and economics of berseem as influenced by various weed control treatments in berseem

Treatment	*Weed density/m^2		*Weed dry matter (q/ha)		Weed control efficiency (%)		Green fodder yield (t/ha)	Seed yield (kg/ha)	Crude protein yield (t/ha)	Net returns (Rs./ha)	Benefit Cost Ratio
	After 1^{st} cut	After 2^{nd} cut	After 1^{st} cut	After 2^{nd} cut	After 1^{st} cut	After 2^{nd} cut					
Weedy check	16.20 (265)	18.10(331)	4.31(17.6)	4.52(20.1)	-	-	83.42	464	1.91	156606	3.99
Pendimethalin 0.3 kg/ha (PE)	13.46(184)	15.72(251)	3.79(13.5)	3.91(15.1)	23.3	24.9	63.19	550	1.29	139910	3.19
Pendimethalin 0.4 kg/ha (PE)	14.65(220)	14.81(220)	3.70(13.0)	3.72(13.3)	26.1	33.8	57.05	466	1.26	116499	2.69
Pendimethalin 0.5 kg/ha (PE)	13.93(196)	14.82(223)	3.70(13.1)	3.65(12.6)	25.6	37.3	49.06	367	1.27	87767	2.06
Oxyflourfen 0.100 kg/ha (PE)	7.60(57)	12.97(168)	3.14(9.5)	3.01(8.9)	46.0	55.7	20.63	219	0.51	22317	0.60
Imazethapyr 0.100 kg/ha (IAH of 1^{st} and 2^{nd} cut)	6.25(39)	4.37(18)	1.86(2.5)	1.53(1.4)	85.8	93.0	94.36	692	2.18	207955	4.64
Oxyflourfen 0.100 kg/ha (PE) + imazethapyr 0.1 kg/ha (IAH of 1^{st} cut)	7.93(62)	11.26(130)	3.21(9.8)	3.10(9.2)	44.3	54.2	32.26	223	0.70	39042	1.03
Pendimethalin 0.3 kg/ha (PE) + imazethapyr 0.1 kg/ha (IAH of 1^{st} cut)	12.73(165)	11.04(134)	3.65(12.6)	2.75(6.8)	28.4	66.2	61.34	512	1.32	129809	2.88
Pendimethalin 0.4 kg/ha (PE) + imazethapyr 0.1 kg/ha (IAH of 1^{st} cut)	11.61(142)	12.03(150)	3.76(13.4)	3.15(9.2)	23.9	54.2	50.61	449	1.24	103746	2.34
Pendimethalin 0.5 kg/ha (PE) + imazethapyr 0.1 kg/ha (IAH of 1^{st} cut)	9.70(96)	11.48(139)	3.28(10.0)	2.74(6.8)	43.2	66.2	45.46	385	0.92	85146	1.96
LSD (P=0.05)	1.93	1.79	0.85	0.49	-	-	4.96	080	0.12	16904	0.38
CV	7.25	8.10	9.28	9.13	-	-	0.76	119	0.79	10.28	9.76

IAH: Immediately after harvest; PE: Pre-emergence spray; *Data after square root transformation and figures in parenthesis are original means

CONCLUSION

From the results of the study it can be concluded that application of imazethapyr 0.1 kg/ha immediately after 1^{st} and 2^{nd} cut of berseem effectively controls weeds and was effective in getting higher green fodder yield of superior quality, higher seed yield and was also economically profitable.

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Growth and yield response of *Kharif* groundnut to pre and post emergence herbicides

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The main hurdle in growing *Kharif* groundnut is severe infestation of weeds which caused to reduce crop yield up to 40%. Manual weeding is laborious, tedious and costly job which is also unable to protect crop at later stages of crop growth. Chemical weed control with combination of pre and post emergence herbicides will be an emerging solution to provide better plant protection from weeds with practical convenience and economic feasibility.

METHODOLOGY

An agronomic investigation was conducted for five consecutive years from 2006 to 2010 in *kharif* season at Oilseed Research Station located at Jalgaon and established under Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was laid out in randomized block design with 7 treatments (Table 1) replicated thrice on medium black soil with soil pH: 8.2, EC: 0.336, organic carbon: 0.48% and 223, 13.3, 369 kg/ha of available N, P and K, respectively.

RESULTS

Weed management in kharif groundnut either with pre emergence application of pendimethalin 1.0 kg/ha + 1 hand weeding or Pre emergence application of pendimethalin 1.0 kg/ha + post-emergence application of imazethapyr 750 ml/ha at 20 days after sowing recorded significantly higher plant height, number of branches per plant, dry pod and haulm yield over rest of the all other treatments and both these treatments were on par with each other. Highest B:C ratio was recorded in combination of pre and post emergence application of pendimethalin and imazethapyr. Similar results were reported earlier by Kalhapure *et al.* (2013) in *Kharif* groundnut

Table 1. Effect of different weed control treatments on various growth and yield parameters in *Kharif* groundnut (pooled from year 2006 to 2010)

Treatment	Plant stand (cm)	No. of branches/ plant	Dry pod yield (kg/ha)	Haulm yield (kg/ha)	B:C ratio
Unweeded control	52.7	4.1	819	4266	1.42
Weed free check	46.9	7.1	2250	5675	2.48
Pre emergence application of pendimethalin 1.0 kg/ha + 1 hand weeding	52.1	6.5	1963	5281	2.35
Post emergence application of quizalofop ethyl 750 ml/ha at 20 days after sowing	51.0	4.7	1252	4787	1.85
Post emergence application of imazethapyr 750 ml/ha at 20 days after sowing	47.4	5.2	1807	5346	2.68
Pre emergence application of pendimethalin 1.0 kg/ha + post-emergence application of quizalofop-ethyl 750 ml/ha at 20 days after sowing	48.6	4.9	1489	5112	1.85
Pre-emergence application of pendimethalin 1.0kg/ha + Post emergence application of imazethapyr 750 ml/ha at 20 days after sowing	51.9	6.5	1968	5497	2.54
LSD (0.05)	6.5	2.1	397	411	--

CONCLUSION

Pre emergence application of pendimethalin 1.0 kg/ha combined with post emergence application of imazethapyr 750 ml/ha at 20 days after sowing is economically more beneficial method of weed control in *Kharif* groundnut for higher yield.

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Effect of pre and post emergence herbicides on weed control in *Kharif* groundnut

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Severe weed infestation in successive flushes during the entire crop growth period is main yield reducing factor in *Kharif* groundnut. Manual weeding is laborious, tedious and costly job which is also unable to protect crop at later stages of growth. Chemical weed control with combination of pre and post emergence herbicides will be an emerging solution to provide better plant protection from weeds with practical convenience and economic feasibility.

METHODOLOGY

The field experiment was conducted for five consecutive years from 2006 to 2010 in *Kharif* season at Oilseed Research Station, Jalgaon. The experiment was laid out in randomized block design with 7 treatments replicated thrice on medium black. Treatments consist of different combinations of hand weeding and pre and post emergence application of herbicides as per the Table 1.

RESULTS

Pre emergence application of pendimethalin 1.0 kg/ha + 1 hand weeding and pre emergence application of pendimethalin 1.0 kg/ha + Post emergence application of imazethapyr 750 ml/ha at 20 days after sowing recorded significantly lower weed count, weed dry matter and weed index over rest of the treatments and both these treatments were on par with each other. Significantly higher weed control efficiency and dry pod yield were recorded in combination of pre and post emergence application of pendimethalin and imazethapyr. Similar results were reported earlier by Kalhapure *et al.* (2013) in *Kharif* groundnut

Table 1. Effect of different weed control treatments on various weed parameters and yield in *kharif* groundnut (pooled from year 2006 to 2010)

Treatment	Weed count/m2	Weed dry matter (g/m2)	Weed control efficiency (%)	Weed index	Dry pod yield (kg/ha)
Unweeded control	95.5	523.4	--	65.5	819
Weed free check	19.3	69.1	91.8	--	2250
Pre-emergence application of pendimethalin 1.0kg/ha + 1 hand weeding	42.7	154.0	62.0	11.3	1963
Post-emergence application of quizalofop ethyl 750 ml/ha at 20 days after sowing	72.1	313.5	33.2	39.2	1252
Post-emergence application of imazethapyr 750 ml/ha at 20 days after sowing	53.4	180.9	57.8	17.3	1807
Pre-emergence application of pendimethalin 1.0kg/ha + post emergence application of quizalofop ethyl 750 ml/ha at 20 days after sowing	55.7	203.5	50.7	33.9	1489
Pre-emergence application of pendimethalin 1.0kg/ha + Post emergence application of imazethapyr 750 ml/ha at 20 days after sowing	40.5	174.2	63.3	15.2	1968
LSD (0.05)	30.7	94.1	24.6	18.1	397

CONCLUSION

Pre emergence application of pendimethalin 1.0 kg/ha combined with post emergence application of imazethapyr 750 ml/ha at 20 days after sowing is more practically efficient method to control weeds in *Kharif* groundnut along with higher yield.

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Assessment of prevalent weed flora and weed management practices of cropped area in different *tehsils* of Jaipur district of Rajasthan during *Kharif* season

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It has been observed that there is considerable variation in the floristic composition of weeds, not only from different regions but also from field-to-field in the same eco-region. This highlights the role of crop management practices in general, and weed management practices in particular. Weeds are not static but respond positively to management practices. A minor weed may emerge as a major one after some years under a set regime. The impact of herbicides on weed flora shift is also very conspicuous. Herbicides exhibit varied effect on weeds depending upon their morphological, physiological and biochemical characteristics. There is urgent need to intensify the research on biology and ecology of weeds for developing sound integrated management practices. To achieve this, a project on weed survey in different *tehsils* of Jaipur district was selected by Department of Science and Technology, Rajasthan, under the "Student Project Programme 2014-15", to monitor the weed dynamics of Jaipur district for developing ecological based data.

METHODOLOGY

Initially, a grid map of Jaipur district was prepared to conduct an effective survey of prevalent weed flora of *Kharif* season. All the 16 *tehsils* of Jaipur district were surveyed during *Kharif* in 2015, which includes total of 80 villages of these 16 *tehsils*. Fields of three farmers from each village was chosen for the study. At each point of survey, for taking weed observation through quadrate method, quadrate of 0.5 m (i.e. 0.25 sq. m. area) was used. This quadrate was dropped randomly at five different places in cropped area. Total number of all types of weed species occurring in each quadrate was recorded. The weed species uprooted during the observation were dried at room temperature initially and finally were dried in the oven and dry weight was recorded for each species of weeds surveyed. Accordingly, density of weed per sq. m.; dominance, frequency %, relative density, relative dominance, relative frequency and Importance Value Index (IVI) were calculated. Farmers were enquired about the weed management practices followed by them through questionnaire.

RESULTS

The main crops in different *tehsils* of Jaipur district during *kharif* season were pearl millet, sorghum, groundnut, green gram and cluster bean. A total number of 21 weed species were identified in the cropped area of *Kharif* season. *Cynodon dactylon* registered with highest IVI among the 21 weed species in all the *tehsils* of Jaipur district. Second most dominant weed species observed in Jaipur, Amber, Chaksu, Sanganer, Shahpura, Kishangarh renwal and Dudu *tehsils* was *Cyperus rotundus*, in Bassi, Mojmabad and Jamwa Ramgarh was *Digra arvensis*, in Phagi and Phulera was *Commelina benghalensis*, in Viratnagar and Kotkhawda was *Echinochloa colona*, in Kotputli was *Amaranthus virdis* while in Chomu it was *Celosia arvensia.* Next most dominant weed species recorded in Amber, Bassi, Chaksu, Phagi and Phulera *tehsils* was *Euphorbia hirta*, in Chomu, Mojmabad, Jamwa Ramgarh, Kotputli, Viratnagar and Kotkhawada was *Cyperus rotundus*, in Jaipur, Sanganer, Shahpura and Kishangarh renwal was *Commelina benghalensis* and in Dudu *tehsil* was *Digra arvensis*.

Hand weeding was the most common practice adopted by the farmers of Jaipur district for weed management in all the *kharif* crops. Beside hand weeding, farmers also sprayed atrazine in pearl millet and sorghum while pendimethalin and imazathypr were sprayed in groundnut, green gram and cluster bean.

CONCLUSION

In order of Importance Value Index, the most commonly occurring weeds in the cropped area of Jaipur district during *Kharif* season of 2015 were *Cynodon dactylon, Cyperus rotundus, Commelina benghalensis* and *Euphorbia hirta*. Hand weeding was the most common weed management practice adopted by the farmers of Jaipur district.

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Profitability of Mustard as influenced by weed control and sulphur fertilization in semi-arid region of Rajasthan

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Indian mustard is predominantly cultivated in the states of Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, Gujarat, Punjab and Bihar. Rajasthan state contributed major part of 2.78 m ha with 3.62 mt production and 1301 kg/ha productivity. Thus, it has major share in area (46%) and production (49%) of mustard in our country (Anonymous, 2013-14). Heavy weed growth is a major recognized bottleneck in realizing the full yield potential of mustard. Weeds appear to be the most serious menace in crop production due to their extensive losses. Due to severe weed competition, the yield reduction in Indian mustard may go as high as 70 percent. For successful control of weeds during this stage, one HW at 25 to 30 DAS is enough, but in view of scanty availability of labour and ever increasing wages, the manual weed control has become cumbersome, labour intensive, time consuming and costly. Therefore, it has become essential to search out effective pre-plant incorporation (PPI) and/ or pre-emergence (PE) herbicide which can take care of early flush of weeds.

METHODOLOGY

A field experiment was conducted under loamy sand soil during *Rabi* 2014-15 and 2015-16 at Agronomy farm, S.K.N. College of Agriculture, Jobner. The treatments comprising seven weed control measures [weedy check, HW once at 25 DAS, HW twice at 25 and 45 DAS, pendimethalin at 0.75 kg/ ha, isoproturon at 1.0 kg/ha, oxyflourfen at 0.125 kg/ha and trifluralin at 0.75 kg/ha] and four levels of S [0, 20, 40 and 60 kg/ ha] assigned respectively to main and sub plots were replicated thrice in split plot design. Mustard variety 'Lakshmi' was used as a test crop. All the herbicide except trifluralin (PPI) were applied as pre-emergence. Sulphur was applied through gypsum as treatment.

RESULTS

Pooled results showed that two HW done at 25 and 45 DAS produced the maximum seed yield of 2.49 t/ha that was significantly higher over rest of treatments. Application of pendimethalin at 0.75 kg/ha was found to be the next better and most effective herbicidal treatment. All the weed control treatments provided significantly higher net returns and B: C ratio in comparison to weedy check which is obviously due to higher seed yield obtained under different weed control treatments. Two HW treatment fetched the maximum net return of ' 58371/ha with B: C ratio of 3.04 thus increasing it by ' 32986/ha over weedy check. Pendimethalin at 0.75 kg/ha (PE) was the next better treatment which recorded ' 5078/ha with a B: C ratio of 3.06. However, it was found at par with one HW at 25 DAS (' 48602/ha) with B: C ratio of 2.89. Trifluralin at 0.75 kg/ha and isoproturon at 1.0 kg/ha recoded 68.4 and 58.4 per cent more net returns over weedy check with B: C ratio of 2.78 and 2.66. The higher net returns and B: C ratio recorded under these superior treatments can be explained easily with the corresponding higher seed yield. The maximum B: C ratio (3.06) under pendimethalin seems to be due to comparatively lower cost of treatment application. Due to unrestricted weed growth in weedy check treatment recoded the lowest seed yield that was eventually reflected in the lowest net returns (' 25385/ha) and B: C ratio (2.11). Results further shows that application of 40 kg S/ha, being at par with 60 kg S/ha, fetched the net returns of ' 48,963/ha that were 9.0 and 90.7 per cent more than obtained under 20 kg S/ha and control, respectively. Application of 60 kg S/ha also provided the additional net returns of ' 5852 and 25110/ha, respectively over 20 kg/ha and control and thus was found at par with 40 kg S/ha.

CONCLUSION

Based on the results of two years experimentation, it is concluded that two hand weedings at 25 and 45 DAS proved the most effective weed control measure in mustard representing the maximum seed yield (24.93) and net return (' 58371/ha). Producing the seed yield of 2.16t/ha and net return (' 5078/ha) pre emergence application of pendimethalin at 0.75 kg/ha was found as the best herbicidal treatment and next better option for weed control under labour scarce conditions. Bringing about significantly higher seed yield (21.09 q/ha) and net return (' 48,963/ha) application of 40 kg S/ha was found as the most remunerative level in mustard and can be recommended under loamy sand soils in semi-arid regions of Rajasthan.

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Correlation co-efficient influenced by weed management in gram (GG 2) under South Gujarat condition

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Gram (*Cicer arietinum* L.) commonly known as Bengal gram and locally *Chana* is an important and unique food legume because the variety of food products like sweets, condiments and vegetables are prepared from it world-wide. Gram is a good source of protein (18-22 per cent), carbohydrate (52-70 per cent), fat (4-10 per cent), minerals (calcium, phosphorus, iron) and vitamins. It is an excellent animal feed. Its stover has good forage value. India is a premier chickpea growing country in the world, accounting 76 per cent of total area and 67 per cent production of the world. In India, it occupies about 7.58 m ha area with an average production of 6.91 m t and productivity of 780 kg/ha (Anon., 2009).

Weed not only compete for nutrient, moisture, light and space, but also increase the cost of labour make harvesting and threshing operation difficult. Taller and fast growing crop are known to be more competitive which can smother weeds from the early stage of their growth. Contrary to this, slow growing and draft plant type crop like gram often suffer severe weed competition as weeds invade and smother the crop very rapidly causing yield losses up to 50 per cent or more. Chickpea often suffers from severe weed competition especially during early growth phase owing to its slow growth in the initial stage and short statured nature of plant. The magnitude of crop yield losses depends on the number of weed flora, period of crop weed competition and its intensity (Balyan *et al*., 1987).

METHODOLOGY

A field experiment was conducted during *Rabi* season of 2010-11 at the College Farm, Navsari Agricultural University, Navsari. Total twelve weed management treatments were assigned in randomized block design with three replications. The gram 'GG 2' were sown at 30 x 10 cm spacing. The gram was sown on 16 October 2010 and finally harvested on 31 January 2011. The soil of experimental field was clay in texture, low in available nitrogen (219.52 kg/ha), medium in available phosphorus (30.91 kg/ha) and fairly rich in available potash (387.60 kg/ha). The soil was found with normal in respect of pH (7.8) and electric conductivity (0.36 ds/m). Recommended dose of fertilizers (20 and 40 kg N and P/ha) were applied at time of sowing based. Weed population and total weed dry matter were recorded at stage with the help of quadrate and then converted in per square metre and the data on weed population and total weed dry matter were subjected to square root transformation before statistical analysis (Panse and Sukhatme 1967).

RESULTS

Correlation co-efficient

The values of correlation co-efficient 'r' are presented in It was observed that the entire yield attributes and growth parameters showed significant and positive correlation with grain yield of gram, but the correlation between dry weight of weeds and grain yield was significant and negative. From the correlation matrix, it was observed that the correlation between grain yield and number of branches per plant was the highest (r= 0.9833) followed by plant height (= 0.9725), pods per plant (r= 0.9468), dry matter accumulation by plant (r= 0.9242), grain yield per plant (r= 0.8586), number of grains per pod (r= 0.8497) and test weight (r= 0.8418). This means that 98.33 per cent variation in gram yield was explained by variation in number of branches per plant. Similarly, 97.25, 94.68, 92.42, 85.86, 84.97 and 84.18 per cent variations in grain yield were attributed on account of plant height, pods per plant, dry matter accumulation, grain yield per plant, number of grains per pod and test weight, respectively. Negative correlation between grain of gram yield and dry weight of weeds (r= -0.9700) indicated adverse effect of weeds on grain yield.

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Evaluation of herbicides for weed control in transplanted winter rice and residual effect on succeeding *Rabi* crops in West Bengal delta

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Rice (*Oryza sativa* L.), an anchor for the global rural population, is life for more than half of humanity and the principal source of food for nearly half of the world's seven billion people. Rice by directly supplying 21% calorie in world food (39% in Asian food), is producing 697.22 mt by cultivating in an area of 153.43 m ha with an average productivity of 4.40 t/ha. The major constraints in productivity are the competition through weeds that caused 45-55% reduction of grain yield (Ghosh *et al*. 2013). Chemical weed management is low cost alternative but still needs more eco-sustainable and farmers' acceptance. In view of above, the present experiment was undertaken to study the bioefficacy of some eco-sustainable herbicides on transplanted rice and residual effect on succeeding *Rabi* crops.

METHODOLOGY

Field experiment was carried out during 2013-14 at on farm, Kalyani, West Bengal in randomized block design with 7 treatments replicated thrice in a sandy loam soil. The pre-treated germinated seeds of variety IET-4786 were sown during last week of July in both the years in 6 x 10 m plots with a spacing of 20 cm (R-R) x 15 cm (P-P). The recommended fertilizer N:P:K: 60:30:30 kg/ha were used along with 2000 kg FYM/ha. Irrigation was applied depending on rainfall giving priority on the critical rice physiological stages. For insect and disease management ecosafe pesticides were used as and when required. Tested PE and POE herbicides with different doses were sprayed at 1 and 14 DAT, respectively. The residual effects of the tested herbicides were also evaluated on three succeeding *Rabi* crops linseed, lentil and coriander grown with conservation tillage methodology following recommended package of practices.

RESULTS

The dominant weed flora in the experimental plots was *Echinochloa spp.* (*colona, formosensis & crusgalli*) *Leersia hexandra, Cyperus difformis, Fimbristylis dichotoma, Alternanthera philoxeroides, Ammania baccifera* and *Eclipta alba*. The higher dose of testing Basagran 48% SL (1200 g/ha) recorded better dicot weed control efficiency in comparison to its lower dose (720 g/ha). Standard check herbicide oxadiargyl 80% WG and pretilachlor 50% EC also showed better result in controlling all categories of weed while ethoxysulfuron 15% WDG was effective against minimizing the population and biomass of monocots. The maximum grain yield was recorded against basagran 48% SL 1200 g/ha (3.85 t/ha in 2013and 3.94 t/ha in 2014) while the minimum was from the weedy check (2.43 t/ha in 2013 and 2.77 t/ha in 2014). The biological yield also showed similar variations among the treatments as found in grain yields of transplanted rice. The standards oxadiargyl 80% WG, ethoxysulfuron 15% WDG and pretilachlor 50% EC also gave better productivity in comparison to weedy check. The data on population density recorded at 30 DAS and grain yield of the three succeeding crops linseed (oilseed crop), lentil (pulse crop) and coriander (vegetables) did not show any significant variation among the different treatments used in the previous transplanted rice crop.

Table 1. Grain yield of transplanted rice and WCE at different DAA of herbicides during 2013-14

Treatment	Dose (g/ha)	Grain Yield (t/ha)		WCE %					
				20 DAA		40 DAA		60 DAA	
		2013	2014	2013	2014	2013	2014	2013	2014
Basagran 48% SL w/v	720	2.92	3.48	65.44	50.12	63.43	49.58	62.00	46.93
Basagran 48% SL w/v	960	3.36	3.63	68.92	56.74	67.96	51.78	65.30	49.42
Basagran 48% SL w/v	1200	3.85	3.94	74.59	70.88	73.01	66.13	71.03	58.94
Ethoxysulfuron 15% WDG	15	3.34	3.51	71.72	65.97	69.74	54.27	68.12	49.00
Oxadiargyl 80% WP	80	3.52	3.28	73.91	64.39	71.07	60.02	69.00	58.37
Pretilachlor 50% EC	500	3.48	3.63	72.54	63.73	70.59	55.23	68.21	52.73
Weedy check	-	2.43	2.77	-	-	-	-	-	-
LSD (P=0.05)	-	0.428	0.566	-	-	-	-	-	-

CONCLUSION

The higher dose of basagran 48% SL 1200 g/ha recorded better weed control efficiency as well as higher productivity of transplanted rice in comparison to its lower two doses (960 and 720 g /ha). Neither in transplanted rice plant or in the succeeding crops, phytotoxicity was observed against any of the doses of the testing and the standard herbicides.

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Evaluation of post emergence herbicides for the control of resistant little seed canary grass in wheat at farmers' fields of Haryana

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Phalaris minor is the most dominant weed of wheat in the rice-wheat cropping system (RWCS) in the north-western Indo-Gangetic Plains of India. During the eighties isoproturon provided very effective control of this weed, but its continuous use resulted in the evolution of resistance in *P. minor* biotypes in north-western India. Alternate herbicides *viz.* clodinafop, sulfosulfuron and fenoxaprop were recommended to control isoproturon resistant population of *P. minor* during 1997 provided effective control of this weed up to 2007 (Chhokar and Sharma 2008), but over the years, loss of efficacy to these herbicides has made the task of managing herbicide resistant *P. minor* biotypes more daunting (Dhawan *et al.* 2009). Presently, its control has become even more difficult after it evolved multiple herbicide resistance to recommended herbicides. so present experiment was planned to evaluate the bio-efficacy of available herbicides, their mixtures and sequential use for management of the resistant *P. minor.*

METHODOLOGY

To evaluate the bio-efficacy of available post emergence herbicides, their mixtures and sequential application for the control of the resistant little seed canary grass (*Phalaris minor*) and other weeds in wheat, farmers' participatory field trials were conducted at village Kheri Raiwali in Kaithal district of Haryana during winter seasons of 2011-12 and 2012-13 The experiment with plot size of 160 m^2 replicated thrice included treatments of pinoxaden 50 and 60 g/ha, clodinafop 60 and 120 g/ha, fenoxaprop 120 g/ha, sulfosulfuron 25 g/ha, mesosulfuron + iodosulfuron (RM) 14.4 g/ha, fenoxaprop+ metribuzin (RM) 100 + 175 g/ha, clodinafop+ metribuzin (RM) 60 + 210 g/ha, sulfosulfuron+metsulfuron (RM) 32 and 40 g/ha, and sulfosulfuron + metsulfuron (RM) 32 g/ha before irrigation (25 DAS) *fb* sulfosulfuron+metsulfuron (RM) 32 g/ha after irrigation (40 DAS).

RESULTS

Application of clodinafop 60 g/ha, fenoxaprop 120 g/ha and sulfosulfuron 25 g/ha at 35 days after sowing (DAS) did not provide satisfactory control of *P. minor*; however, mesosulfuron+iodosulfuron 14.4 g/ha provided better control (85-90%). Pinoxaden 50 g/ha resulted in 80% control of *P. minor* during first year but it provided only 55% control during second year. Ready-mix combination of metribuzin with fenoxaprop and clodinafop significantly improved the control of *P. minor* and broadleaf weeds as compared to alone application of fenoxaprop and clodinafop. Maximum weed control efficiency (WCE) and highest grain yield (5.2 t/ha) was recorded with the application of sulfosulfuron+metsulfuron 32 g/ha during 2011-12, which was statistically at par with mesosulfuron+iodosulfuron and clodinafop+metribuzin, whereas during the second year, sulfosulfuron+metsulfuron 40 g/ha resulted in highest grain yield. Sequential application of sulfosulfuron+metsulfuron 32 g/ha at 25 DAS *fb* sulfosulfuron+metsulfuron 32 g/ha registered 97% WCE.

CONCLUSIONS

The study indicates that there is an urgent need of a new post emergence herbicide with different mechanism of action (MOA), which must be integrated with non-chemical weed control strategies and used in rotation with other herbicide MOAs for management of resistant *P. minor* and prevention of herbicide resistance.

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Response of different herbicides on nutrient depletion in sugarcane under weedy situations

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Sugarcane occupies an area about 5.06 million hectares with a production of 334.54 Million tonnes of canes. In India, 26.34 million tonnes of sugar produced with a recovery of 10.25%. Sugarcane productivity in India is low (66.08 t/ha) compared with other sugarcane growing countries Egypt (121.14 t/ha) and Colombia (100.42 t/ha). Uttar Pradesh ranks first both area (2.21 mha) and production (130.51 mt) of sugarcane contributing 43.68 and 39.01 per cent, respectively at the national level. Various factors such as major acreage under small and marginal holdings, non-availability of quality inputs, attack of diseases and insect-pest and occurrence of various inevitable stresses during the crop growth period restrict the crop yield particularly in the sub-tropical region of the country. Negligent attitude of farmers towards weed control is the most important among losses due to various factors in sugarcane (Srivastava, 2001).

METHODOLOGY

The present investigation was carried out during two consecutive spring seasons of 2014-15 and 2015-16 at the Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.). The experiment was laid the experiment was laid out in a randomized block design with eight treatments with replicated thrice. The treatment of herbicide application which were alone application of Atrazine 2 kg/ha., metribuzin 2 kg/ha. and sulm (triazinone) 1 kg/ha as well as sequential application of atrazine 2 kg/ha. *fb* halosulfuron-methyl 150g/ha, metribuzin 2 kg/ha. *fb* Halosulfuron-methyl 150 g/ha and sulm (triazinone) 1 kg/ha. *fb* Halosulfuron Methyl @ 150g/ha. The soil of the experimental field was low in organic carbon, available nitrogen, available sulphur whereas available P and K were medium.

RESULTS

Nutrient depletion by weeds is the resultant of NPK content in weeds and weed dry weight (biomass). Higher the nutrient content in weeds and weed dry matter more is the nutrient depletion by weeds. Nutrient depletion by weeds was found to be significantly influenced by weed control treatments. Three hoeings at 30, 60 and 90 days after planting in spring planted sugarcane recorded significantly lower nutrients depletion by weeds than other weed control treatments. Among herbicidal treated plots, minimum depletion of nutrients in the treatment of atrazine 2 kg/ha. *fb* halosulfuron-methyl 150 g/ha. The probable reason might be that weed population and their biomass were significantly lower under three hoeings at 30, 60 and 90 DAP and consequently its nutrient depletion by weeds was reduced. Weed infestation was recorded maximum under weedy plot thus leading to highest nutrient depletion by weeds in this plot. Similar results were also found by Tomar *et al.* (2002).

Table1. Nutrient (NPK) depletion by weeds at 90 DAP as influenced by weed control treatments in sugarcane

Treatment	N depletion (kg/ha)		P depletion (kg/ha)		K depletion (kg/ha)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Weedy	5.64(31.31)	5.29(27.53)	3.84(14.21)	3.21(9.80)	6.85(46.44)	6.51(41.88)
Conventional practice (three hoeings) (30, 60 & 90 DAP)	3.68(13.04)	3.10(9.09)	2.56(6.05)	1.92(3.19)	4.78(22.35)	4.09(16.22)
Sulm (triazinone) 1 kg/ha (4 DAP)	4.82(22.74)	4.44(19.25)	3.26(10.13)	2.79(7.27)	6.19(37.87)	5.72(32.22)
Metribuzin 2 kg/ha (4 DAP)	4.69(21.51)	4.27(17.72)	3.22(9.87)	2.73(6.94)	6.09(36.64)	5.56(30.41)
Atrazine 2 kg/ha (4 DAP)	4.56(20.29)	4.12(16.45)	3.17(9.55)	2.67(6.61)	5.99(35.42)	5.43(28.98)
Sulm (triazinone) 1 kg/ha *fb* halosulfuron-methyl 150 g/ha (4 *fb* 45 DAP)	4.30(18.02)	3.93(14.94)	2.94(8.15)	2.45(5.50)	5.64(31.31)	5.10(25.51)
Metribuzin 2 kg/ha *fb* halosulfuron-methyl 150 g/ha (4 *fb* 45 DAP)	4.24(17.46)	3.79(13.90)	2.90(7.92)	2.36(5.09)	5.51(29.86)	4.81(22.64)
Atrazine 2 kg/ha. *fb* halosulfuron-methyl 150 g/ha (4 *fb* 45 DAP)	4.09(16.21)	3.61(12.53)	2.85(7.64)	2.26(4.60)	5.34(28.02)	4.69(21.50)
LSD (P=0.05)	*	*	*	*	*	*
CV	5.04	5.02	5.02	5.08	5.04	5.04

CONCLUSION

From the results of the present field experiment on response of NPK uptake by weeds in sugarcane to different weed control practices conducted during two consecutive years from 2014 to 2016, it can be concluded that atrazine 2 kg/ha. *fb* Halosulfuron Methyl 150 g/ha is recorded minimum NPK depletion by the different weed flora present in the sugarcane field.

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Effect of chemical weed management on quality and yield of sweet corn

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Heavy weed infestation is one of the major constraints that limit productivity of sweet corn. Wider spacing and slow growing nature of the crop during first 3-4 weeks provide enough opportunity for weeds to invade and offer severe competition resulting in 30-100 % yield reduction (Walia *et al.* 2007). In order to achieve desired yield of sweet corn, it is imperative to minimize weed competition particularly during the critical period of crop growth. The sequential use of pre-emergence and post-emergence herbicides would be a good alternative for this purpose. Hence, present investigation was undertaken to observe the effect of herbicides and their mode of application on weed control in sweet corn fields.

METHODOLOGY

A field experiment was conducted during *Kharif* season of 2014 at Agronomy Farm, Agricultural College, Dhule. The experiment consisted of ten treatments laid out in randomized block design with three replications. The treatments included, weedy check, weed free check, hand weeding (20 and 40 DAS), atrazine (1.50 kg/ha (PE), pendimethalin (1.50 kg/ha (PE), atrazine + pendimethalin (0.75 + 0.75 kg/ha (PE), atrazine + 2,4-D (0.75 + 0.75 kg/ha (PE), pendimethalin *fb* atrazine (0.75 kg/ha (PE) *fb* 0.75 kg/ha), atrazine *fb* 2,4-D (0.75 kg/ha (PE) *fb* 0.75 kg/ha (PoE) and atrazine *fb* metasulfuron-methyl (0.75 kg/ ha (PE) *fb* 0.004 kg/ha (PoE). Sweet corn variety '*Sugar-75*' was sown during 2nd week of July with a spacing of 60 cm x 20 cm and cultivated as per the recommended practices.

RESULTS

Quality studies

The results revealed that difference in protein content of grain of sweet corn due to various weed management treatments were not significant. Reducing, non-reducing and total sugar content in grain of sweet corn was observed numerically more under weed free practice (T_2) (3.73, 8.68 and 12.92%, respectively) than those in registered in rest of treatments, while it was recorded the lowest in weedy check (T1) treatment. Among the herbicides treatments, application of atrazine *fb* metsulfuron-methyl (0.75 kg/ha (PE) *fb* 0.004 kg/ ha (PoE) (T_{10}) which found better than other herbicidal treatments in respect of reducing, non-reducing and total sugar content (3.71, 8.62 and 12.49 %, respectively) in grain of sweet corn. The sequential spraying of pre and post emergence herbicides recorded higher values of reducing, non-reducing and total sugar content in grain of sweet corn as compared to application of pre-emergence herbicide only. This result corroborates the finding of Kannur (2008) and Kumar *et al.* (2012).

Green cob and fodder yield

The green cob and fodder yield of sweet corn was significantly higher (207.33 and 41.27 t/ha, respectively) in treatment of weed free check (T_2). The next best treatment was spraying of atrazine *fb* metasulfuron-methyl (0.75 kg/ha (PE) *fb* 0.004 kg/ha (PoE) (T_{10}) which yielded 184.17 and 39.75 t/ha green cob and fodder yield, respectively, as compared to the application of pre-emergence herbicide treatments. However, it was at par with the application of atrazine *fb* 2,4-D (0.75 kg/ ha (PE) *fb* 0.75 kg/ha (PoE) (T_9), pendimethalin *fb* atrazine (0.75 kg/ha (PE) *fb* 0.75 kg/ha (PoE) (T_8) and hand weeding (T_3) (Table 2). Among the herbicide treatments tried in the experiment, application of pre-emergence herbicide *i.e.* atrazine 0.75 kg/ha followed by post-emergence herbicide *i.e.* metasulfuron-methyl 0.004 kg/ha at 15 DAS treatment was found significantly better than application of pre-emergence herbicide in respect of green cob and fodder yield of sweet corn, which may probably be due to better weed management resulting in improvement in all growth and yield parameters. The results are in agreement with the finding of Kannur (2008) and Kumar *et al.* (2012).

Table 1. Protein, reducing, non-reducing and total sugar content of sweet corn as influenced by different treatments

Treatment	Protein content (%)	Reducing sugar (%)	Non- reducing Sugar (%)	Total sugar (%)
Weedy check	13.77	2.69	8.15	11.07
Weed free check	14.76	3.73	8.68	12.92
Hand weeding	14.72	3.55	8.56	12.27
Atrazine (1.50 kg/ha (PE)	14.55	2.96	8.34	11.77
Pendimethalin (1.50 kg/ha (PE)	14.11	2.77	8.21	11.32
Atrazine + Pendimethalin (0.75 +0.75 kg/ha (PE)	14.22	3.24	8.44	11.91
Atrazine + 2,4-D (0.75+ 0.75 kg/ha (PE)	14.35	3.37	8.47	11.96
Pendimethalin *fb* Atrazine (0.75 kg/ha (PE) *fb* 0.75 kg/ha (PoE)	14.44	3.42	8.50	12.00
Atrazine *fb* 2,4-D (0.75 kg/ha (PE) *fb* 0.75 kg/ha (PoE)	14.55	3.47	8.55	12.20
Atrazine *fb* Metsulfuron-methyl (0.75 kg/ha (PE) *fb* 0.004 kg/ha (PoE)	14.69	3.71	8.62	12.49
LSD (P=0.05)	NS	0.32	0.25	0.55

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Effect of continuous and rotational use of herbicides on weed shiftsin rice - wheat system with particular reference to rice

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Weed shifts occur when weed management practices do not control an entire weed community or population. The management practice could be herbicide use or any other practice such as tillage, manure application, or harvest schedule that brings about a change in weed species composition. Rice-wheat is the predominant cropping system in India occupying around 10.5 million ha area. Weeds are serious constraints in rice-wheat cropping system. Of the total losses caused by pests, weeds have a major share (30%). Declining trend in the productivity of rice have been reported in long term experiments (Duxbury *et al.* 2000) which may be due to changes in weed flora (Singh *et al.* 2012). Therefore, the present study was undertaken to evaluate the effect of continuous use of herbicides in rice on shifts in weed flora over a period of fourteen years.

METHODOLOGY

A long-term experiment was conducted on rice-wheat cropping system was initiated during *rabi* 2000 at Palampur. The soil of the test site was silty clay loam in texture, acidic in reaction, low in available N, P and K with CEC of 11.5 mol (P±). Nine treatments viz. farmers' practice (T_1), continue use of herbicides (butachlor + 2,4-D) with 100% N through inorganic or 25% N substitution through fresh *Lantana* leaves in rice followed by continue (isoproturon + 2,4-D; T_2 and T_4) and rotational (clodinafop/isoproturon; T_3 and T_5) use of herbicides in wheat and rotational use of herbicides (butachlor/pretilachlor (cyhalofop-butyl) in later years) + 2, 4-D) with 100% N through inorganic or 25% N substitution through fresh *Lantana* leaves in rice followed by continue (isoproturon + 2, 4-D; T_6 and T_8) and rotational (clodinafop/ isoproturon; T_7 and T_9) use of herbicides in wheat were tested in rice – wheat cropping system from *Rabi* 2000 to 2015-16.

RESULTS

In *kharif*, *Echinochloa crusgalli*, *Panicum dichotomiflorum* and *Cyperus iria* were the main weeds initially. The population of these weeds decreased over the years. Lately *Digitaria*, *Eschaemum*, *Aeschynomene*, *Commelina*, *Paspalum*, *Ammannia*, *Eriocolon* and *Monochoria* appeared in the experimental field. The population of *Monochoria* and *Ammannia* was in the decreasing trend while that of *Ericolon* showed increasing trend. The pentad-wise analysis of weed in rice has been presented in Table 1. *Echinochloa colona* (40.3/m^2) was the most dense weed during the initial years followed by *Cyperus* sp (17.6 individuals/m^2). These were followed by *Panicum* sp (4.9 plants/m^2), *Digitaria* sp (4.3/m^2) and *Scirpus* sp (3.1/m^2). During the middle years, *Ageratum* had highest density followed by *Echinochloa* and *Ammannia baccifera*. In the later years, *Echinochloa* followed by *Eriocolon, Cyperus* sp and *Ammannia* had higher density. Overall, during a period of 14 years, *Echinochloa* had higher density followed by *Cyperus* sp, *Ageratum* sp, *Ammannia* and *Eriocolon*. On an average, weed density (73.7/m^2) was maximum in the first pentad and decreased with time with 28/m^2 in the 2nd pentad and 20.5/m^2 in the third. On an average, in rice the weed density was to the tune of 38.6 individuals/m^2.

Based on phytosociological analysis, *Echinochloa* was the most important weed in Butachlor 1.5 kg/ha *fb* 2,4 DEE 1.0 kg/ha (100% fert.), Butachlor 1.5 kg/ha *fb* 2,4 DEE 1.0 kg/ha (100%fert.), Butachlor 1.50 kg/ha *fb* 2, 4-DEE 1.0 kg/ha (75% N Fert. + 25% N through *Lantana*, Butachlor *fb* 2,4-DEE (75% N Fert.+ 25% N through *Lantana* and Pretilachlor 0.75 kg/ha / Butachlor 1.5 kg/ha*(75% N Fert. + 25% N Lantana. *Ageratum* was most important weed in Pretilachlor 0.75 kg/ha/Butachlor 1.5 kg/ha*(100% Fert.). Irrespective of the treatment, *Cyperus* ranked 3rd or 4th. *Panicum* ranked 4th in Pretilachlor 0.75 kg/ha /Butachlor 1.5 kg/ha* (75% N Fert. + 25% N Lantana and 5th in Pretilachlor 0.75 kg/ha/Butachlor 1.5 kg/ha*(100%Fert.). *Ammannia* had 3rd, 4th or 5th ranking in some of the treatments. *Eriocolon* had 5th ranking in Farmers' practice.

Table 1. Density (No/m^2) of weeds during *kharif*- average of the fourteen years starting from 2000 to 2015-16

Weed Species	First Pentad	Second Pentad	Third Pentad	Overall
Echinochloa	40.3	5.9	6.1	15.8
Panicum	4.9	0.6	0.0	1.6
Cyperus	17.6	1.7	4.5	7.3
Digitaria	4.3	0.0	0.0	1.2
Ageratum	1.6	9.3	0.0	3.8
Scirpus	3.1	1.2	0.1	1.4
Potamozeton	0.4	0.0	0.0	0.1
Ishaemum	1.1	1.4	0.0	0.8
Aeschynomene	0.4	1.5	0.1	0.7
Commelina	0.0	0.2	0.0	0.1
Paspalum	0.0	0.3	0.0	0.1
Ammania	0.0	5.5	3.6	3.3
Erioclon	0.0	0.4	5.3	2.1
Monochoria	0.0	0.0	0.8	0.3

CONCLUSION

The findings of the investigation inferred the dynamic nature of the weeds. It was revealed that their populations are largely influenced by cropping systems and management strategies adopted.

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Optimization of planting and weed management methods for direct seeded rice

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In Bihar, rice is cultivated in around 3.34 million ha with a production of 7.2 million tonnes productivity of 2.16 t/ha. Among various depressing factors, abiotic stress i.e. water and nutrient stress and biotic stress i.e. weed infestations in the field are the most crucial factors due to which rice production is considerably low. Weed infestation during early period of crop growth caused yield reduction to the tune of 33-74% or sometimes more depending on the type of the weeds and their infestation. Uncontrolled weeds cause up to 80% reduction in grain yield and even complete failure of rice crop (Gopinath and Kundu 2008). Direct seeding with pre-germinated rice seed in unpuddled condition could be an effective option to curtail several options of transplanted rice cultivation, reduce engagement of manual labour and irrigation. DSR has a potential to replace the transplanted rice if weeds are controlled effectively. The yield loss due to poor weed management may vary from 10% to complete failure (Rao and Nagmani 2007).

METHODOLOGY

A field experiment was conducted during *Kharif* season of 2016 at research farm of Dr. Rajendra Prasad Central Agricultural University, Pusa. The soil of the experimental plot was sandy loam with pH 8.38 and organic carbon 0.42%.The fertility status was moderate with low in available nitrogen (213.24 kg/ha), phosphorus (18.9 kg/ha) and potassium (73.02 kg/ha). Recommended dose (120-60-40 N-P-K kg/ha) was applied along with N in three equal splits. The experiment was laid down under split plot design with three planting methods (main plots) and seven weed control measures (sub-plots) with three replications. Planting methods include puddling, zero-tillage and dry seeding of direct seeded rice. Treatments of sub-plots include pendimethalin 1.0 kg/ha as pre-emergence (PE), pretilachlor 1.5 kg/ha (PE), pendimethalin 1.0 kg/ha (PE) + one hand weeding at 30 days after sowing (DAS), pretilachlor 1.5 kg/ha (PE) + one hand weeding at 30-40 DAS, dhaincha (*Sesbania aculeata*) + 2,4-D 1.0 kg/ha at 25 DAS, two hand weeding at 20 and 40 DAS and weedy check. Observation on weed density and weed biomass were recorded and weed control efficiency was worked out.

RESULTS

Amongst different planting methods, puddling reduced the population of all the weed species as well as total population compared with the zero tillage and dry seeding method. Dry seeding after monsoon resulted in higher population of all the weeds (Table 1). Two hand weeding at 20 and 40 DAS recorded least weed population as compared to pendimethalin 1.0 kg/ha (PE). Yield attributes such as plant height, number of tillers and panicle length were significantly increased in puddling with maximum rice yield and weed control measures where two hand weeding at 20 and 40 DAS were 3.56 t/ha and 3.8 t/ha, respectively. Weed density and weed biomass were recorded highest in dry seeding method of planting and weedy check plots and weed control efficiency was recorded highest in case of two hand weeding at 20 and 40 DAS.

Table 1. Effect of weed management and planting methods on growth and yield of direct seeded rice

Treatment	Weed count (no./m^2)	Weed dry matter weight (g/m^2)	WCE (%)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
Main plots									
Puddling	20.87	31.76	-	3.58	4.86	42.33	61237	35388	1.37
Zero-tillage	25.11	38.80	-	3.39	4.59	42.42	58022	31572	1.19
Dry seeding	34.11	52.37	-	2.86	3.91	42.36	49218	22867	0.86
LSD (P=0.05)	1.218	2.76	-	0.15	0.21	NS	1628	1628	0.06
Sub-plots									
Pendimethalin 1.0 kg/ha (PE)	28.43	44.13	44.20	3.21	4.34	42.44	54906	30283	1.23
Pretilachlor 1.5 kg/ha (PE)	27.63	42.77	45.93	3.26	4.45	42.29	55837	31381	1.29
Pendimethalin (PE) 1.0 kg/ha + one hand weeding at 30 DAS	20.53	31.77	59.83	3.58	4.83	42.54	61214	32592	1.14
Pretilachlor 1.5 kg/ha (PE) + one hand weeding at 30 DAS	19.23	29.60	62.57	3.62	4.92	42.35	61970	33513	1.18
Dhaincha (*Sesbania aculeata*) + 2,4-D 1 kg/ha at 25 DAS	23.47	36.00	54.48	3.43	4.64	42.49	58664	34419	1.42
Two hand weeding at 20 and 40 DAS	14.97	23.47	70.33	3.82	5.17	42.45	65356	34799	1.14
Weedy check	52.63	79.10	0	2.02	2.83	42.03	35165	12609	0.56
LSD (P=0.05)	1.953	2.32	-	0.11	0.19	NS	1820	1820	0.07

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Effect of row spacing and weed management practices in pearl millet under guava based agri-horti system

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Pearl millet (*Pennisetum glacum* L.) is important drought resistance crop under guava based agri-horti system in *Vindhyan* region of India. In view of increasing weed problem and crisis of labour, an effective weed management option is needed for improving productivity under this system. Hence, the present investigation was carried to evolve appropriate weed management option for *Vindhyan* region in pearl millet under guava based agri-horti system.

METHODOLOGY

An experiment was conducted to evaluate row spacing and weed management practices in pearl millet (*Pennisetum glaucum* L.) under guava (9 year old with spacing of 7 x 7 m) based agri-horti system during *Kharif* season of 2015-16 at Agricultural Research Farm, Rajiv Gandhi South Campus, Banaras Hindu University, Barkachha, Mirzapur, Uttar Pradesh, India. Three row spacing (30 cm, 37.5 cm and 45 cm) were kept in main plot where as six weed management practices, *viz.* (weedy check, tow hand weeding at 20 and 40 DAS, atrazine 0.75/kg- PE, pendimethaline at 1/kg PE, atrazine 0.75/kg + pendimethalin 0.75/kg PE, atrazine 0.75/kg + pendimethalin 0.75/kg PE + hand weeding at 30 DAS) were adjusted in sub plot and experiment was laid out in split plot design with three replications.

RESULTS

Row spacing and weed management practices significantly influenced the total weed density at 40 DAS. Significantly lowest density of total weeds (6.81) and maximum weed control efficiency (33.66) was recorded at 30 cm row spacing as compared to 37.5 cm and 45 cm row spacing. Significantly lowest weed index was recorded at 45 cm as compared to 37.5 cm and 30 cm row spacing. The data pertaining to grain and straw yield of pearl millet have been showed that highest grain yield (1.17 t/ha) has been recorded at 45 cm row spacing. Similarly, maximum net return and B: C ratio was recorded at 45 cm row spacing.

Among weed management practices, significantly lowest density of total weeds (5.89) and highest weed control efficiency (46.73) was recorded in hand weeding twice at 20 and 40 DAS (W_2) followed by atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (PE) + HW at 30 DAS, atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (PE) , pendimethalin 1.0 kg/ ha (PE) and atrazine 0.75 kg/ha- (PE) . maximum weed index was observed in weedy check and minimum weed index was noticed in atrazine 0.75/kg + pendimethalin 0.75 kg + hand weeding at 30 DAS followed by atrazine 0.75/kg + pendimethalin 0.75/kg, pendimethaline at 1/kg and atrazine 0.75/kg PE, similar finding were recorded by Dhage *et al.* (2008). Highest grain and straw yield was recorded by hand weeding twice. Among the herbicidal treatment atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (PE) + HW at 30 DAS recorded significantly highest grain yield and straw yield over the rest of the treatments, *i.e.* atrazine 0.75/kg + pendimethalin 0.75/kg, pendimethaline at 1/kg and atrazine 0.75/kg PE. Highest net return and B:C ratio was recorded with treatment atrazine 0.75/kg + pendimethalin 0.75 kg + hand weeding at 30 DAS whereas lowest with weedy check. These findings are in confirmation with the results of Munde *et al.*, 2012.

Table 1. Weed density, weed control efficiency, weed index, grain yield, straw yield, net returns and benefit cost ratio as influenced by row spacing and weed management practices in pearl millet under guava based agri-horti system

Treatment	Total Weed density (no./m^2)	Weed control efficiency (%)	Weed index (%)	Grain yield (t/ha)	Straw yield (kg/ ha)	Net return (10^3 `/ha)	Benefit: Cost ratio
	At 40 days after sowing						
Row Spacing							
S1-30 cm	6.81* (53.17)	27.87	23.54	0.90	4.18	22.52	1.02
S2- 37.5	8.03 (69.72)	29.69	18.39	1.02	4.36	24.51	1.12
S3- 45	9.26 (90.0)	33.66	15.93	1.18	4.63	27.19	1.24
LSD (P=0.05)	0.40			0.08	1.10	1.09	
Weed Management practices							
Weedy check	11.33 (128.67)	0.00	50.63	0.63	4.23	20.52	1.02
Tow hand weeding at 20 and 40 DAS	4.15 (18.56)	55.67	0.00	1.27	4.52	27.17	1.18
Atrazine 0.75/kg PE	9.84 (97.22)	17.82	28.56	0.91	4.32	23.69	1.11
Pendimethaline at 1/kg	9.06 (82.44)	24.28	17.53	1.05	4.35	24.91	1.12
W5-Atrazine 0.75/kg + pendimethalin 0.75/kg	7.91 (62.78)	37.96	14.56	1.09	4.43	25.35	1.13
Atrazine 0.75/kg + pendimethalin 0.75 kg + hand weeding at 30 DAS	5.89 (36.11)	46.73	4.64	1.22	4.48	26.79	1.16
LSD (P=0.05)	0.24			0.03	0.03	0.52	

*Data transformed to square root transformation. Values in parenthesis are original

CONCLUSION

In view of the above experimentation, it may be concluded that 45 cm row spacing and application of atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (PE) + HW at 30 DAS can be used for minimizing weed growth, maximizing crop growth, yield and net return in pearl millet under guava based agri-horti system in vindhyan region.

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Weed management practices to control the problematic weeds in green gram

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Green gram (*Vigna radiata* L.) is extensively cultivated pulse crop of arid and semi-arid region of India. It is nutritionally important for our daily diet and contains about 25% protein, 1.3% fat, 3.5% mineral, 4.1% fibre and 56.7% carbohydrate. Weed management is an important key factor for enhancing the productivity of green gram. Moreover, besides low yield of crop, weeds increase production cost, harbour insect-pest and diseases, decreases quality of farm produce, reduce land value leading to reduction in crop production; but amongst the various factors, weed stand first in ranking (Subramainian *et al*. 1993).

METHODOLOGY

The field experiment was conducted during *Kharif* 2016 at Research Farm College of Agriculture, Gwalior (M.P.) The soil was sandy clay loam in texture, low in available nitrogen (195 kg/ha), medium in phosphorus (13 kg/ha) and potash (204 kg/ha) with pH 7.7 and EC 0.41 dS/m. The 10 treatments replicated thrice in a completely RBD with quizalofop-p-ethyl 50, 75 and 100 g/h as post-emergence (PoE), fenoxaprop-p-ethyl 100 g/ha as PoE, pendimethalin 1000 g/ha as pre-emergence (PE), pendimethalin + imazethapyr (RM) 750 and 1000 g/ha as PE, imazethapyr + imazamox (RM) 80 g/ha as PoE, two hand weeding at 20 and 40 DAS and weedy check. Pre-emergence herbicides were applied within 48 hours of sowing and post-emergence herbicides were applied at 20 DAS.

RESULTS

The major weed flora of experimental site during *Kharif* 2016 were observed included grasses such as *Echinochloa crusgalli, Setaria glauca, and Eragrostis spp.* and broad-leaf weeds such as *Commelina benghalensis*, *Digera arvensis*, *Celosia argentia*, and *Phyllanthus niruri*. The only sedge *Cyperus rotundus* was most dominating among all the weeds. Population and dry weight of weeds were significantly affected by weed management practices. Population of all weeds were significantly reduced by two hand weeding at 20 and 40 DAS followed by imazethapyr + imazamox (RM) 80 g/ha as PoE and pendimethalin + imazethapyr (RM) 1000 g/ha as PE as compared to weedy check except *Setaria glauca* and *Eragrostis spp*. Lowest total weed population was recorded in 2 HW followed by imazethapyr + imazamox (RM) 80 g/ha as PoE, pendimethalin + imazethapyr (RM) 1000 g/ha as PE and pendimethalin + imazethapyr (RM) 750 g/ha PE. The highest weed control efficiency (86.94%) was recorded with two hand weeding at 20 and 40 DAS followed by imazethapyr + imazamox 80 g/ha (71.47%) and pendimethalin + imazethapyr 1000 g/ha (52.24%), respectively. At harvest stage, number of branches and number of pods/plant were significantly higher in imazethapyr + imazamox 80 g/ha followed by 2 HW and pendimethalin + imazathapyr 750 g/ha over weedy check. Maximum seed yield 972 kg/ha was recorded under imazethapyr + imazamox 80 g/ha followed by two hand weeding at 20 and 40 DAS (898 kg/ha), pendimethalin + imazathapyr 750 g/ha and 1000 g/ha. Similar trend was recorded in straw yield. As per economic point of view the application of imazethapyr + imazamox (RM) 80 g/ha as PoE was proved economically best treatment with highest net return Rs. 42490/ha followed by two hand weeding (Rs 35310/ha) and pendimethalin + imazethapyr 750 g/ha PE (Rs.33842/ha). However highest B:C Ratio of 3.18 was found in imazethapyr + imazamox (RM) 80 g/ha as PoE followed by pendimethalin + imazethapyr 750 g/ha PE (B:C Ratio of 2.80).

Table 1. Effect of different weed management practices on weeds, grain yield, straw yield and economics of green gram crop

Treatment	Effect on weeds			Effect on yield of green gram and economics			
	Weed density (g/m^2)	Weed dry weight (g)	WCE (%)	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (Rs/ha)	B:C Ratio
Quizalofop-p-ethyl 50 g/ha as PoE	2.17(148.33)*	70.33	27.49	569	1176	19770	1.85
Quizalofop-p-ethyl 75 g/ha as PoE	2.09(130.00)	67.33	30.59	676	1222	20570	2.09
Quizalofop-p-ethyl 100 g/ha as PoE	1.99(102.00)	47.33	51.21	537	1163	21370	1.62
Fenoxaprop-p-ethyl 100 g/ha as PoE	1.90(90.00)	59.33	38.84	639	1278	19670	2.08
Pendimethalin 1000 g/ha as PE	1.97(102.67)	59.33	38.84	704	1289	18930	2.37
Pendimethalin + imazethapyr (RM) 750 g/h as PE	1.84(91.33)	47.33	51.21	824	1590	18778	2.80
Pendimethalin + imazethapyr (RM) 1000 g/ha as PE	1.76(61.00)	46.33	52.24	754	1435	18980	2.53
Imazethapyr + imazamox (RM) 80 g/ha as PoE	1.61(41.00)	27.67	71.47	972	1843	19516	3.18
2 HW at 20 and 40 DAS	1.49(31.33)	12.67	86.94	898	1747	22064	2.60
Weedy check	2.28(188.67)	97.00	-	417	741	18170	1.46
LSD (P=0.05)	0.37	21.53	-	119	389	-	-

Weed data subjected to $\sqrt{x+0.5}$ transformation, *Values in parantheses are original

CONCLUSION

On the basis of above result, it is concluded that imazethapyr + imazamox (RM) 80 g/ha as PoE gave maximum seed yield (972 kg/ha) *fb* two hand weeding at 20 and 40 DAS (898 kg/ha) and pendimethalin + imazethapyr 750 g/ha as PE (824 kg/ha). However, highest B:C ratio was recorded in imazethapyr + imazamox 80 g/ha as PoE (3.18) followed by application of pendimethalin + imazethapyr 750 g/ha as PoE (2.80) and 2 hand weeding (2.60).

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Efficacy of pendimethalin in transplanted rice weed management

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National food grain production touched 264.77 million tones (mt) with paddy contributing 106.54 mt grown in 43.95 million ha and having a productivity of 2.42 t/ha (Agricultural Statistics at a Glance 2014). Weed infestation in transplanted rice reduces crop yield to an extent of 45-55 % (Bera *et. al.* 2012). Chemical weed management is a better option over conventional manual control as they check weed growth from early stage of crop growth, requires less time and more economic but cost, availability at rural areas and eco-safety of new herbicides need to be investigated. The present experiment was undertaken to study the efficacy of different formulations of pendimethalin 38.7% CS on weed management and yield in transplanted rice with effect on residual *Brassica campestris var yellow sarson* (Rapeseed).

METHODOLOGY

The field experiment was carried out during *Kharif* 2014 and 2015 at farmer's field, Kalyani, Nadia, West Bengal to evaluate the effect of three different doses of test herbicide pendimethalin 38.7% CS (1250, 1500 and 1750 ml/ha), pretilachlor 50% EC 750 g/ha, butachlor 50 EC 1250 g/ha and bensulfuron + pretilachlor 6.6% GR 660 g/ha on weed control in transplanted rice and its' residual effect on rapeseed. The experiment was laid out in RBD with 7 treatments replicated thrice in a sandy loam soil. The 24 days old seedlings of pre-treated germinated seeds cv. IET-4786 were transplanted in early July in both the years with a spacing 20 cm (Row to Row) x 10 cm (Plant to Plant). The tested herbicides were sprayed as early pre-emergence (3 DAT) with the spray volume of 500 lit. water/ha. The residual effects were studied in *rabi* crop rapeseed cv. B-9 (Binoy). Both the paddy and rapeseed crop were grown with recommended balanced nutrition NPK + Neemcake along with judicious water use only in crop critical physiological stages and for insect and disease management eco-safe pesticides were used.

RESULTS

The dominant weed flora in the experimental field was *Echinochloa spp. (colona & formosensis), Leersia hexandra, Cyperus difformis, Fimbristylis dichotoma* and *Cyperus iria* among monocots and *Ammania baccifera, Alternanthera philoxeroides, Eclipta alba, Marsilea quadrifolia, Ludwigia octovalvis* and *Stellaria media* among the dicot broadleaf weed flora. Pendimethalin 38.7% CS 1750 ml/ha (677.25 g/ha) recorded significantly better weed control efficiency (88.34%) and significantly higher grain yield (5.28 t/ha) over the other treatments. The highest dose of pendimethalin 38.7% CS recorded 66.93% while pendimethalin all three doses showed 51.9% higher grain yields over weedy check. The corresponding figures for pretilachlor 50% EC, butachlor 50% EC and bensulfuron + pretilachlor 6.6% GR were 49.53, 48.73 and 55.54% (Table1). The testing herbicides pendimethalin 38.7% CS and other standard herbicides used in this experiment at pre-emergence did not show any phytotoxic effect in the transplanted rice or in succeeding rapeseed crop.

Table 1. Effect of different herbicides on WCE and grain yield of transplanted rice during 2014 and 2015

Treatment	Dose (g/ha)	Formulation (ml/ha)	WCE (%) 2014	WCE (%) 2015	Grain yield (t/ha) 2014	Grain yield (t/ha) 2015
Pendimethalin 38.7% CS	483.75	1250	78.50	74.76	4.60	4.00
Pendimethalin 38.7% CS	580.5	1500	82.72	83.33	4.88	4.76
Pendimethalin 38.7% CS	677.25	1750	87.76	88.92	5.26	5.29
Pretilachlor 50% EC	750	1500	77.85	82.18	4.90	4.55
Butachlor 50% EC	1250	2500	83.40	80.64	4.96	4.44
Bensulfuron + pretilachlor 6.6% GR	660	10000	79.97	82.66	5.11	4.72
Control		-	-	-	2.82	3.50
LSD(P=0.05)					0.13	0.37

CONCLUSION

Pendimethalin 38.7% CS applied 1750 ml/ha may be an effective substitute of the presently used herbicides for higher productivity of transplanted rice by reducing the weed losses and also did not phytotoxic to either the transplanted rice plants or residual crop rapeseed or even not detrimental for sustainable soil health.

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Evaluation of herbicide combinations to control the complex weed flora in wheat

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Wheat (*TriticumaestivumL.*) is an important staple food crop for billions people of the world and among cereals, it occupies maximum area (219.04 m/ha) globally (FAO 2014). For food security, its assured production and supply are necessary. The estimated yield loss worldwide caused by weeds varied between 7.7 to 23.9% depending on the region. Wheat is infested with diverse weed flora, as it is grown in diverse agro-climatic conditions, under different cropping sequence, tillage and irrigation regimes. For controlling weeds in wheat, growers mostly rely on herbicides due to cost and time effectiveness. For control of diverse weed flora in wheat combination of herbicides are required. In recent year, many herbicides have been found effective against associated weeds of wheat. Therefore, the present investigation was undertaken on the research farm of Department of Agronomy, College of Agriculture, Gwalior during Rabi season of 2014-15 to test the efficacy of different doses of *Pendimelhalin, Sulphosulfuron, Metribuzin, Clodinofop, Metsulfuron, Pinoxadenand* and their combinations. Observations on weed density and dry matter of weeds were recorded from 1.0 m^2 quadrate in each plot to determine species wise weed density and dry weight of weeds at 60 DAS. The major weed flora were comprised of grassy weeds *Phalaris miner, Cyperus rotundus* and broad leaves weeds *Chenopodium album, Spergula arvensis, Convolvulus arvensis* and *Rumex dentatus*.

METHODOLOGY

The field experiment was conducted during rabi 2014-15 at the Research Farm College of Agriculture, Gwalior. The soil of the experimental field was low in organic carbon and nitrogen and medium in available phosphorus and potassium having pH 7.8 with sandy clay loam in texture. Wheat variety MP 4010 was sown in rows 20 cm apart on 3rd December 2014 and harvested on 28th march 2015, using 120, 60, 40 NPK kg/ha. Full dose of P and K and half dose of N were applied at sowing time, whereas rest of the N was given in 2 equal splits doses as top dressing at crown root initiation and late jointing tillering stage of crop. Irrigation was applied at all the critical stages of crop growth during the experimentation. The 12 treatments consisting of pendimethalin (0.75 kg/ha) PE, sulfosulfuron (0.025 kg/ha PoE), metribuzin (0.21 kg/ha PoE), clodinafop (0.06 kg/ha PoE), pendimethalin + metribuzin (1.0 + 0.175 kg/ha PE), pendimethalinfbsulfosulfuron (1.0 + 0.018 kg/ ha PE &PoE), sulfosulfuron + metsulfuron (Total) 0.03 + 0.002 kg/ha at 5 WAS, pinoxaden + metsulfuron (Premix) 0.06 + 0.004 kg/ha at 5 WAS, mesosulfuron + iodosulfuron (Atlantis) 0.012 + 0.0024 kg/ha at 5 WAS, clodinafop + metsulfuron (Vesta) 0.06 + 0.004 kg/ha at 5 WAS, 2 HW at 30 & 60 DAS (weed free) and unweeded control were arranged in randomized block design with three replications. Herbicides were applied at proper timings with the help of knapsack sprayer with flat fan nozzle at spray volume of 600 liters water/ha. Observations on weed density and dry matter of weeds were recorded from 1.0 m^2 quadrate in each plot to determine species wise weed density and dry weight of weeds at 60 DAS.

RESULTS

On the basis of one year data, it is concluded that two hand weeding at 30 and 60 DAS (weed free) weed management practice gave maximum grain yield (5.03 t/ha) followed by herbicide combinations (RM*) pinoxaden + metsulfuron, sulfosulfuron + metsulfuron, mesosulfuron + iodosulfuron* and *clodinofop + metsulfuron* as PoE application. Whereas Highest B:C ratio of (3.69) was obtained in treatment *pinoxaden + metsulfuron* (premix) followed by *sulfosulfuron + metsulfuron* (3.67) and *metsulfuron + iodosulfuron* (3.53). No visual phytotoxic effect was observed on crop due to application of herbicide combinations except in *sulfosulfuron + metsulfuron* (0.03 + 0.002 kg/ha) initially on plant growth which was recovered within 10 -15 days after application. Whereas Highest B: C ratio of (3.69) was obtained in treatment pinoxaden + metsulfuron (premix) followed by sulfosulfuron + metsulfuron (3.67) and metsulfuron + iodosulfuron (3.53).

Weed management in direct seeded rice

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Weeds are the major cause of yield reduction in direct seeded rice. Hand weeding is the traditional weed control measure and still being the most popular in rice. However, due to high labour cost, non-availability of labour and huge time requirement for manual weeding, farmers are inevitable to go for other alternative measures like chemical weed control. The recent trend of herbicide use is to find out an effective weed control measure by using low dose high efficiency herbicides which will not only reduce the total volume of herbicide use but also the application become easier and economical. Studies on bio-efficacy and phytotoxicity of low dose high potency herbicide molecules in direct seeded rice are scanty. The present experiment was therefore undertaken to study the bio-efficacy and phytotoxicity of pre-emergent followed by post emergent herbicides for control of major weeds in direct seeded rice.

METHODOLOGY

An experiment was conducted during *Kharif* season of 2014 and 2015 at Agricultural Research Station, Dhadesugur, UAS, Raichur, the experiment was laid out in a randomized block design with ten treatments and replicated thrice. Pre-emergent herbicides were applied within three days after sowing and post emergent herbicides were applied at 20-25 days after sowing (DAS) as per the treatment. The rice variety used was Gangavathi sona of 135 days duration. The crop was sown during 1st week of July in both the years.

RESULTS

In the experimental plots, the dominant weeds were *Echinochloa sp., Panicum repens, Cynodon doctylon, Leptochloa chinensis, Bracharia* sp., *Ludwigia parviflora, Commelena* sp. All the herbicides showed effective control of all categories of dominant weeds resulting in less weed numbers per square meter, weed dry matter (g) and higher weed control efficiency (%) at 30 days after sowing compared to untreated check (Table 1**.** Significantly better weed control was observed with the application of pyrazosulfuron-ethyl 10% WP 20 g/ha as pre-emergent herbicide followed by the application of bispyribac sodium 10% SC 250 ml/ha as post-emergent herbicide and which was on par with the application of pendimethalin 30 EC 1 kg/ha as pre-emergent herbicide followed by one hand weeding at 30 DAS and weed free check. Similar result was reported by Angiras and Kumar (2005). There was no phyto-toxic effect was observed in direct seeded rice when applied pre-and post-emergent herbicides.

Table 1. Effect of weed control treatments on weed counts (no./m^2) in direct seeded rice at 30 days after sowing

Treatment	Weed population (Count/m^2)										
	Grasses (no./m^2)			Broad leaf weeds (no./m^2)			Sedges (no./m^2)			Total Weed dry weight (g/m^2)	Weed Control Efficiency (%)
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	Pooled	Pooled
Pendimethalin *fb* bispyribac-sodium	1.98 (2.92)	1.99 (2.95)	1.98 (2.94)	1.12 (0.26)	1.13 (0.28)	1.13 (0.27)	1.82 (2.32)	1.83(2.35)	1.83(2.34)	2.56(5.5)	87.2
Pendimethalin *fb* 2,4-D sodium salt	2.05 (3.21)	2.14 (3.56)	2.09 (3.39)	1.49 (1.21)	1.50 (1.26)	1.49 (1.24)	1.91 (2.65)	1.92(2.69)	1.92(2.67)	2.88(7.3)	83.2
Pendimethalin *fb* azimsulfuron	2.02 (3.10)	2.08 (3.31)	2.05 (3.21)	2.20 (3.84)	2.23 (3.98)	2.22 (3.91)	2.40 (4.78)	2.43(4.92)	2.42(4.85)	3.60(12.0)	72.5
Pendimethalin *fb* metsulfuron methyl	2.07 (3.28)	2.08 (3.31)	2.07 (3.30)	2.22 (3.92)	2.26 (4.12)	2.24 (4.02)	2.42 (4.85)	2.43(4.89)	2.42(4.87)	3.63(12.2)	72.0
Pyrazosulfuron ethyl *fb* metsulfuron-methyl	2.06 (3.25)	2.14 (3.56)	2.10 (3.41)	2.21 (3.89)	2.22 (3.92)	2.21 (3.91)	2.42 (4.86)	2.43(4.92)	2.43(4.89)	3.63(12.2)	71.9
Oxodiagil *fb* penoxsulam	2.07 (3.29)	2.08 (3.32)	2.07 (3.31)	2.20 (3.86)	2.21 (3.89)	2.21 (3.88)	2.49 (5.21)	2.50(5.24)	2.49(5.23)	3.66(12.4)	71.4
Pyrazosulfuron ethyl *fb* bispyribac-sodium	1.97 (2.89)	1.98 (2.91)	1.97 (2.90)	1.11 (0.24)	1.12 (0.25)	1.12 (0.25)	1.50 (1.26)	1.51(1.29)	1.51(1.28)	2.33(4.42)	89.8
Pendimethalin *fb* HW at 30 DAP	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00(0.00)	1.00(0.00)	1.00(0.0)	100
Weed free check	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00(0.00)	1.00(0.00)	1.00(0.0)	100
Weedy check	4.40 (18.4)	4.49 (19.2)	4.45 (18.8)	4.05 (15.4)	4.15 (16.2)	4.10 (15.8)	3.08 (8.48)	3.20(9.25)	3.14(8.87)	6.67(43.5)	
LSD= (P=0.05)	0.38	0.32	0.69	0.52	0.24	0.52	0.63	0.54	0.58	3.21	6.72

Note : Figures in the parenthesis are square root transformed values *fb*: followed by

Further, application of pyrazosulfuron-ethyl 10% WP 20 g/ha as pre-emergent herbicide followed by the application of bispyribac sodium 10% SC 250 ml/ha as post-emergent herbicide recorded significantly lower weed dry weight (4.42 g/m^2 at 30 DAS) and which was on par with the application of pendimethalin 30% EC 1 kg/ha as pre-emergent herbicide followed by one hand weeding at 30 DAS and weed free check. The overall result showed that pyrazosulfuron ethyl 10% WP 20 g/ha as pre-emergent herbicide followed by the application of bispyribac sodium 10% SC 250 ml/ha as post emergent herbicide was comparatively more effective against broad-leaved, grassy and sedge weeds in direct seeded rice.

Similarly, weed control efficiency (100 %) was higher in weed free check at 30 DAS compared to other treatments. Application of pyrazosulfuron-ethyl 10% WP 20 g/ha as pre-emergent herbicide followed by the application of bispyribac sodium 10% SC 250 ml/ha as post emergent herbicide recorded significantly higher weed control efficiency (89.8 %) and which was on par with the application of pendimethalin 30% EC 1 kg/ha as pre-emergent herbicide followed by one hand weeding at 30 DAS (100 %).

CONCLUSION

Results are concluded that application of pyrazosulfuron ethyl 10% WP 20 g /ha as pre-emergent herbicide followed by the application of bispyribac sodium 10% SC 250 ml/ha as post emergent herbicide or application of pendimethalin 30 % EC 1 kg /ha as pre-emergent herbicide followed by one hand weeding at 30 Days after sowing was effectively controlled the broad leaved, grasses and sedges in direct seeded rice.

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Seed bank dynamics and emergence pattern of weeds as influenced by different tillage systems in maize

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Maize (Zea mays L.), an important crop for food and nutritional security in India, is grown in diverse ecologies and seasons on an area of 8.67 million hectare. Globally, it provides approximately 30% of the food calories to more than 4.5 billion peoples in 94 developing countries, and the demand of maize is expected to double worldwide by 2050. The sustainable agricultural practices, which herald a paradigm shift in tillage and land preparation options, aid farmers in cost-saving and yield enhancement by resource-saving practices. Weeds are one of the major biotic constraints in maize, causing grain yield losses up to 30 to 50% by unmanaged weeds. After dispersal, seeds remain on the soil surface or buried through different tillage practices thus forming a weed seed bank in soil, which leads the infestation of weeds in the soil/crop ecosystem (Lal *et al*., 2016). Soil weed seed bank is a general term which is used for viable weed seeds existing in the soil. Changes in tillage intensity can lead to shifts in weed species and densities with increased incidence of perennial and some annual monocot weeds (Blackshaw *et al*., 2001). The success of a crop production depends on good understanding of the dynamics of weed seed bank in the soil. Factors affecting germination and emergence of weed seeds are complex under natural conditions and poorly understood, especially for zero tillage systems in India. Tillage systems, residue retention and cover crop are some of the important factors that affect weed seed germination and emergence in zero tillage. Therefore, the present study was carried out to study the seed bank dynamics and emergence pattern of weeds in zero and conventional tillage systems in maize.

METHODOLOGY

A field experiment was initiated in 2012 at research farm of ICAR-Directorate of Weed Research, Jabalpur, M.P., India (23°14'8.51" N and 79°58'4.88" E). The soil of the experimental site was classified as typic chromusterts with sandy loam texture, 0.48% organic C, 238 kg/ha available N, 16.4 kg/ha available P and 340 kg/ha available K. The study compared four tillage systems, conventional tillage (CT), conventional tillage with residue incorporation (CT+R), zero tillage with residue retention (ZT+R) and zero tillage without residue (ZT) in a thrice replicated randomized block design. Data presented here of maize crop for the same treatments were collected in the *Rabi* season of 2015-16. Weed emergence was recorded in all plots from three quadrates of 50×50 cm at 30, 60 and 90 days after sowing (DAS), and expressed as seedling emergence m^{-2}. A naturally occurring seed bank was recorded by taking three soil cores (10 cm in diameter) of three different depths (0-2, 2-5 and 5-10 cm) per plot before sowing.

RESULTS

Data on weed emergence pattern was taken at 30, 60 and 90 days. Major weeds were *Rumex dentatus*, *Medicago polymorpha*, *Chenopodium album*, *Avena fatua* and *Sonchus oleraceus*. Other weeds were *Dinebra retroflexa*, *Phalaris minor*, *Echinochloa colona*. It was observed that weed emergence was more in conventional tillage than ZT at 30 DAS but at 60 DAS more in ZT than CT. At 90 DAS weed emergence more in ZT than CT. *Echinochloa colona* was mainly observed at 90 DAS.

In CT and ZT+R, broad leaved weed seeds were higher in upper soil layer (0-2 cm) and lowest in the ZT system. But narrow leaf weeds were higher in ZT+R and lowest in CT+R system. At 2-5 cm layer, broad leaved weeds were highest in ZT+R and lowest in the CT+R system. But narrow leaf weeds were highest in CT+R and lowest in the CT system. At 5-10 cm layer broad leaved weed seeds were higher in ZT and almost similar in other system. But narrow leaf weeds were higher in CT+R and lowest in ZT+R system (Fig 1). The vertical seed distribution, as affected by tillage systems, has implications in weed management. Weeds present on or close to the soil surface usually loses their viability more rapidly through germination and mortality than when buried in the soil.

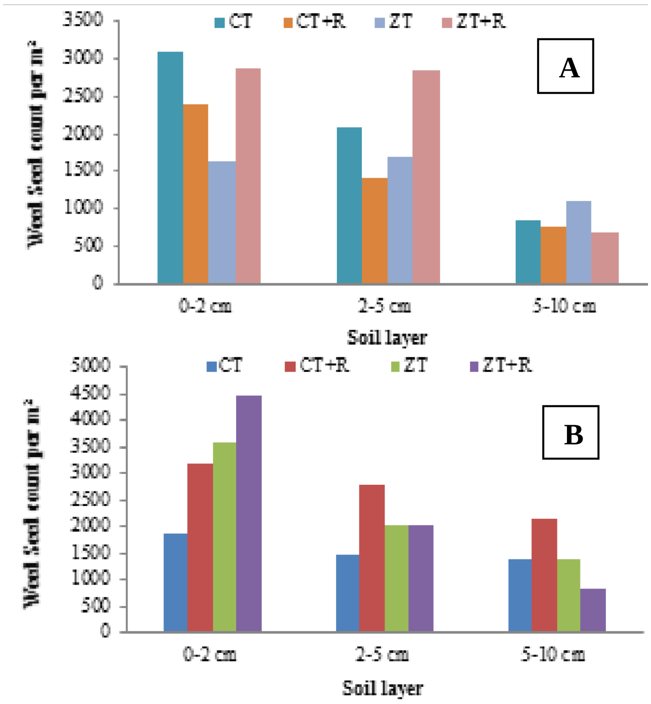

Fig 1. Vertical seed distribution of broad leaved (A) and narrow leaved weeds (B) in different tillage system

CONCLUSION

The results suggest that, zero tillage systems could favour the emergence of many weed species which could become major problem in ZT systems. Management of weed seed bank through stale seedbed technique and control of weeds before seed setting may need to be exposing to control weeds in such situations. On the other hand, CT systems may encourage the weed seed bank in lower layer which may persist by inducing dormancy in weed seeds.

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Influence of herbicide combinations on weed control and productivity of wheat

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Wheat is the second most important cereal in India after rice contributing substantially to the national food security by providing more than 50 per cent of the calories to the people who mainly depend on it. The production of wheat grain in the year 2013-14 was estimated to be 95.91 mt from acreage of 31.19 m ha with productivity of 3075 kg/ha. During this period, Rajasthan accounted for about 9.01 per cent of the national area and 9.3 per cent of production with average productivity of 3175 kg ha^{-1} (Agricultural statistics at a glance 2014). Weed is one of the major biotic constraints in wheat production as they compete with crop for nutrients, moisture, light and space. Weed control cost is a major segment of input cost in crop production and herbicides provide a better opportunity to control weeds in close row crops like wheat where manual or mechanical weeding is not possible. Under such situations, herbicides are far cheaper and more readily available recourse than labour for hand weeding. Wheat is infested with grassy as well as broad-leaved weeds, control of which requires a variety of herbicides. To control mixed population of weeds and also to avoid herbicides resistance by continuous use of single herbicide, compatible mixtures can be employed to widen the spectrum of weed control (Das and Yaduraju 2012; Pal *et al.* 2016).

METHODOLOGY

A field experiment was conducted during *Rabi* season of 2015-16 at Maharana Pratap University of Agriculture and Technology, Udaipur to study the efficacy of herbicide combination for weed control of wheat. The soil of experimental field was clay loam low in available nitrogen, medium in organic carbon and phosphorus and high in available potassium. Thirteen treatment combinations were arranged in randomised block design and replicated thrice. Wheat variety 'Raj-4037' was sown with recommended package of practices. Data on weed growth, yield performance and economics were recorded.

RESULTS

Application of different herbicidal combinations significantly influenced on weed density and weed dry matter production, wide ranging reductions (57.8 to 96.3 per cent) in total weed density at harvest were observed by exercising various options of weed control in wheat crop. Among the different herbicide combinations lowest weed population at harvest (2.78 /m^2) was observed by sulfosulfuron + metsulfuron followed by mesosulfuron + iodosulfuron (3.32/ m^2) clodinafop + metsulfuron (3.91/m^2). However, sulfosulfuron + metsulfuron were more effective and gave 87.98% WCE of total weeds that is at par to two rest of treatments in order of merit mesosulfuron + iodosulfuron and clodinofop + metsulfuron gave 85.95 and 84.22% WCE of total weeds.

The higher grain yield (6.02 t/ha) were obtain with weed controlling through sulfosulfuron + metsulfuron followed by mesosulfuron + iodosulfuron (5.80 t/ha) and clodinofop + metsulfuron (5.60 t/ha). The net returns (85566 Rs/ha) was found maximum with application of sulfosulfuron + metsulfuron (Table 1).

Table 1. Weed density, yield (t/ha) and net returns as influenced by different treatments in wheat.

Treatment	Weed density (no./m^2)	Weed control efficiency (%)	Grain yield (t/ ha)	Net returns (` /ha)
Pendimethalin* 750 g ha (PE)	6.51** (42.00)	50.34	4.71	60646
Sulfosulfuron 25 g/ha at 35 DAS	5.01 (24.66)	68.96	4.84	63720
Metribuzin 210 g/ha (PE)	6.09 (36.67)	51.59	4.50	57033
Clodinafop 60 g/ha^- at 35 DAS	5.72 (32.33)	63.22	4.74	61549
Pendimethalin *fb* sulfosulfuron 1000 g (PE) + 18 g/ha at 35 DAS	4.62 (21.00)	71.80	5.28	72166
Pendimethalin + metribuzin (Tank mix)1000 g +175 g/ha (PE)	5.66 (31.67)	67.57	5.33	72645
Sulfosulfuron + metsulfuron (Premix) 30 g + 2 g/ha at 35DAS	2.78 (7.33)	87.98	6.02	85566
Pinoxaden + metsulfuron (Tank mix) 60 g + 4 g/ha at 35 DAS	4.41(19.00)	82.47	5.40	74247
Mesosulfuron + iodosulfuron (Premix) 12 g + 2.4 g/ha at 35 DAS	3.32 (10.67)	85.95	5.80	81265
Clodinafop + metsulfuron (Premix) 60 g + 4 g/ha at 35 DAS	3.91 (15.00)	84.22	5.60	76938
One Hand Weeding at 30 DAS	9.13 (83.00)	39.81	4.07	49014
Two Hand Weeding at 30 and 45 DAS	8.61 (73.67)	49.67	4.30	53691
Weedy check	14.04 (196.67)		3.59	39443
LSD (P=0.05)	0.44	-	0.34	-

*Pendimethalin (Stomp Xtra 38.7% CS); DAS: Days after sowing; PE: pre-emergence; **$\sqrt{x+0.5}$ Transformed values and Data in parenthesis are original values.

CONCLUSION

It was concluded that the pre-mix application of sulfosulfuron + metsulfuron at (30 g + 2 g/ ha) or mesosulfuron + iodosulfuron (12 g + 2.4 g/ ha) or clodinofop + metsulfuron (60 g + 4 g/ ha) as post-emergence at 35 DAS should be used for the control of complex weed flora in wheat crop as these resulted in significant reduction in weed density and dry matter along with significantly higher grain yield and net return.

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Weed growth and yield of summer green gram as influenced by land configuration, variety and nutrient management

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Among the pulses, green gram (*Vigna radiate* L.) is the third most important and extensively cultivated crop in India and cultivated in all the three seasons. Its importance in terms of nutritive value, palatability, digestibility and non flatulent nature is well established. It contains about 3.5% mineral, 4.1% fibre and 56.7% carbohydrate. Among those the crop-weed competition irrespective of the season has become a major concern of the pulse growers. Thus weed management has emerged as an important key factor towards enhancing the productivity of green gram. The loss of green gram yield due to weeds ranges from 65.4 to 79.0% as reported by Dungarwal *et al*. (2003).

METHODOLOGY

A field experiment was carried out during summer, 2016 in Agronomy Main Research Farm, Department of Agronomy, O.U.A.T. Bhubaneswar. The experiment was carried out in a split plot design with three replications and twenty four treatment combinations comprising of four main plots (two varieties V_1- Nayagarh local, V_2- PDM-139 and two land configurations, M_1- flat bed, M_2- raised bed) and six sub plots (F_1-Farmer's practice-125 kg DAP/ha + need based plant protection, F_2-F_1 + seed inoculation with *Rhizobium* + PSB soil application, F_3-F_2 + lime, F_4-F_2 + NPK as RDF *i.e.* 20-40-20 kg N-P_2O_5-K_2O/ha and no flat application of DAP, F_5-F_2 + Soil test based NPK application, F_6-F_2 + STCR based NPK application)**.** The soil of the experimental field was sandy clay loam in texture and showed low soil available nitrogen (225.5kg/ha) high phosphorous (45.6 kg/ha) and medium potassium (129.0 kg/ha), respectively. The soil was found to be slightly acidic with a pH 5.5 and electrical conductivity 0.079 dS/m. The organic carbon content was found to be 0.75%.

RESULTS

Predominant weed species observed in the experimental plot included *Digitaria sanguinalis*, *Eleusine indica Alternanthera sessilis and Heliotropium indicum*,. Broad leaved weeds were predominant (77.51%), followed by grassy weeds (22.48%). *Alternanthera sessilis* among the broad leaved weeds and *Digitaria sanguinalis* among the grassy weeds were predominant. The distribution of species did not show any appreciable difference due to the treatments. In the flat bed method with the local variety broad leaved weeds were dominant (74.32%) followed by grassy weeds (25.68%). In the raised bed method also, broad leaved weeds were more (72.86%) than the grassy weeds (27.145).

Data revealed that weed density per unit area (per m^2) differed significantly due to land configuration and nutrient management practices. Weed density was significantly the lowest (2.65 per m2) when the crop was seeded under raised bed method with PDM-139 and increased significantly by 18.9% and 15.8% when seeded on flat bed with Nayagarh Local. Similarly the weed density was significantly the lowest (2.53) when the crop was raised under nutrient management practice of F_6 (F_2 + STCR based NPK application) when compared with other nutrient management practices. The two factor interaction was also found to be significant. Significantly the lowest weed density of 2.07/m^2 was observed when variety PDM-139 was seeded under raised bed method with F_4 (F_2 + NPK as RDF i.e. 20-40-20 kg N-P_2O_5-K_2O/ha and no flat application of DAP) nutrient management practice.

The data on grain yield indicated significantly the highest (556 kg/ha) under T_3 (V_2M_1) and 455 kg/ha when crop was fertilised with F_6 (F_2 + STCR based NPK application) nutrient management practice. The land configuration and variety combination of PDM-139 and flat bed V_2M_1 also registered comparatively low weed density being at par with V_1M_2 and V_2M_2.

Table 1. Effect of land configuration and nutrient management on weed density (per m²) and grain yield of summer green gram

Treatment	Weed density (per m^2)	Yield (kg/ha)
T1 (local and flat bed)	9.1 (3.15)*	379
T2 (local and raised bed)	6.50 (2.70)	340
T3 (HYV and flat bed)	9.82 (3.08)	556
T4 (HYV with raised bed)	8.12 (2.65)	424
LSD(P=0.05)	0.30	80
F1	10.48 (3.04)	342
F2	8.93 (2.76)	411
F3	6.09 (3.07)	434
F4	7.73 (2.83)	452
F5	8.74 (2.81)	454
F6	8.92 (2.53)	455
LSD(P=0.05)	0.30	76

*Figures in parenthesis indicate transformed data

Table 2. Interaction effect of land configuration and nutrient management on weed density (number/m²) of summer green gram

	F1	F2	F3	F4	F5	F6	TOTAL	MEAN
V1M1	10.92 (3.03)	8.68 (2.73)	10.25 (3.03)	11.40 (3.45)	6.95 (3.38)	8.68 (3.28)	56.88 (18.9)	9.48 (3.15)
V1M2	6.79 (2.35)	8.02 (2.65)	5.80 (2.92)	6.89 (2.72)	6.52 (2.70)	5.02 (2.51)	39.04 (16.2)	6.50 (2.70)
V2M1	23.41 (3.66)	9.61 (3.59)	3.95 (3.15)	3.78 (3.06)	9.11 (2.78)	9.11 (2.21)	58.97 (18.42)	9.82 (3.07)
V2M2	0.82 (3.10)	9.42 (3.10)	4.38 (3.18)	8.86 (2.07)	12.38 (2.36)	12.89 (2.11)	48.75 (15.9)	8.12 (2.65)
TOTAL	41.94 (12.12)	35.73 (12.04)	24.38 (12.28)	30.93 (11.28)	34.96 (11.20)	35.70 (10.08)		
MEAN	10.48 (3.03)	8.93 (3.01)	6.09 (3.07)	7.73 (2.82)	8.74 (2.80)	8.92 (2.52)		
LSD (P=0.05)	VM=0.30	F=0.30	VM within F= 0.60	F within VM= 0.60				

*VM f= Effect of VM at same or different levels of F. F VM= Effect of F at same or different levels of VM

CONCLUSION

Sowing summer green gram in flat bed method with PDM-139 recorded the highest grain yield.

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Nutrient losses and yield reduction due to weeds in clusterbean in western Rajasthan

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Clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] commonly known as guar, is an important drought hardy leguminous crop. Clusterbean is mostly cultivated in arid and semiarid regions of tropical India during *Kharif* season. Being a rainy season crop, it suffers badly due to severe competition by mixed weed flora. Yield reduction due to weed infestation is to the tune of 53.7% has been observed (Saxena *et al.* 2004). Therefore, weed control needs to be restored to exploit the yield potential of this crop.

METHODOLOGY

An experiment was conducted during *Kharif* 2013 to find out suitable herbicides for weed management in clusterbean at Instructional Farm of Agriculture Research Station, S.K. Rajasthan Agricultural University, Bikaner. The experiment comprises of 16 treatment combinations (Table 1) replicated thrice in randomized block design. Herbicides pendimethalin as pre-emergence, imazethapyr and imazethapyr + imazamox as post-emergence were applied as per treatment.

RESULTS

The experimental field of clusterbean was heavily infested with mixed flora of broad leaved and grassy weeds mainly consisted of *Amaranthus spinosus* L., *Euphorbia hirta* L., *Aristida depressa* L., *Portulaca oleracea* L., *Digera arvensis* Forsk., *Gisekia poiedious*, *Cenchrus biflorus* L., *Tribulus terrestris* L., *Aerva tomentosa* Forsk., *Corchorus tridense* L., *Eleusine verticillata* L., *Eragrostis tennela* and *Trianthema portulacastrum* L. Weed management practices adopted during the experimentation resulted in significant increase in growth and yield. All weed control treatments recorded significant increase in N, P and K uptake by the crop compared over weedy check (Table.1). The highest nutrient uptake was obtained with weed-free treatment, which was statistically at par with all other treatments except weedy check. Uptake of N, P and K by weeds followed the trend of weed biomass. It was found that all weed control treatments significantly reduced N, P and K uptake by weeds at harvest. The lowest total uptake by weeds was recorded with weed-free, which was at par with rest of the weed control treatments except imazethapyr 40, 50, 60 g/ha. Reduced nutrient uptake by weeds under the influence of different weed control measures was also reported by Gaikwad and Pawar (2003) and Chhodavadia *et al.* (2013).

Table 1. Effect of weed control measures on yield and nutrient uptake by weeds and clusterbean (kg/ha)

Treatment	Clusterbean			Weeds			Yield (kg/ha)	
	N	P	K	N	P	K	Grain yield	Straw yield
Pendimethalin 0.75 kg/ha (pre-emergence)	84.2	16.9	65.5	7.71	1.04	5.19	1439.9	3973.2
Pendimethalin 0.75 kg/ha PE + hand weeding (HW) 30 DAS	85.8	17.6	66.5	9.56	1.28	6.52	1445.0	4070.3
Imazethapyr 40 g/ha 25 DAS	71.4	14.7	54.8	34.03	4.48	23.43	1319.8	3604.8
Imazethapyr 50 g/ha 25 DAS	73.1	15.2	56.3	32.51	4.28	22.40	1328.5	3761.5
Imazethapyr 60 g/ha 25 DAS	73.1	15.2	56.2	32.29	4.25	22.17	1333.0	3735.4
Imazethapyr 40 g/ha 25 DAS + HW 40 DAS	76.7	15.9	58.9	5.41	0.74	3.90	1368.2	3794.8
Imazethapyr 50 g/ha 25 DAS + HW 40 DAS	77.4	15.9	59.3	4.39	0.61	3.24	1379.1	3747.7
Imazethapyr 60 g/ha 25 DAS + HW 40 DAS	78.1	16.1	59.9	3.61	0.51	2.73	1387.2	3808.3
Imazethapyr + imazamox 40 g/ha 25 DAS	78.4	16.2	60.2	13.47	1.80	9.95	1352.0	3788.6
Imazethapyr + imazamox 60 g/ha 25 DAS	78.2	16.1	60.0	13.55	1.81	10.02	1355.3	3701.7
Imazethapyr + imazamox 80 g/ha 25 DAS	78.8	16.3	60.5	14.31	1.91	10.62	1358.1	3766.8
Imazethapyr + imazamox 40 g/ha 25 DAS + HW 40 DAS	81.7	16.8	62.8	11.94	1.60	9.13	1402.2	3810.4
Imazethapyr + imazamox 60 g/ha 25 DAS + HW 40 DAS	83.4	17.2	64.0	10.81	1.46	8.39	1408.3	3926.1
Imazethapyr + imazamox 80 g/ha 25 DAS + HW 40 DAS	83.6	17.2	64.1	9.78	1.32	7.74	1416.1	3907.5
Weedy check	41.3	8.6	31.8	180.9	23.74	133.4	767.0	2183.0
Weed free	88.2	17.9	70.8	0.00	0.00	0.00	1485.1	4140.3
LSD (P=0.05)	7.2	1.8	5.6	7.00	0.92	6.07	279.97	646.67

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Seedling number per hill and chemical weed management effects on rice in Kashmir

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Kashmir valley comprises 4.1 lakh ha of total irrigated area and 1.5 lakh ha is unirrigated. Maximum irrigated area is covered with rice, which is staple food of general mass and is cultivated over an area of 158,000 ha with a productivity of 3.55 t/ha (Anonymous, 2015). Rice cultivation in Kashmir is proving to be less remunerative enterprise. Due to low temperature in Kashmir, rice is subjected to intense competition from weeds at its critical stages. But with the concept of SRI or less number of seedling/hill, it has become imperative to find out more effective herbicide molecules. Hence this experiment was designed to evaluate most effective herbicide on rice weed flora and its phototoxic effect on rice if any as influenced by number of seedlings.

METHODOLOGY

A field experiment was conducted during *Kharif*, 2016 at the Agronomy Research Farm, Faculty of Agriculture, SKUAST–K, Wadura Sopore to evaluate new herbicide molecules in transplanted rice as influenced by seedling number, apart from knowing the phyto-toxicity effect, if any. Rice Cv. Jhelum was transplanted at a common spacing of 30 cm x 15 cm and fertilizer level of 100 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha. These treatment combinations were replicated thrice in a split plot design. The data on species wise weed count, dry weight of weeds (g/m^2) was also collected.

RESULTS

The major weed observed in weedy check plots were *Potamogeton distinctus Ammannia baccifera Rotalla indica, Polygonum hydropiper* among broadleaf weeds; *Echinochloa crusgalli* among grasses and *Cyperus difformis, Cyperus iria, Fimbristylis miliace* among sedges. At 60 days after transplanting (DAT), herbicide treatments were significantly superior to unweeded control with regards to weed density and dry weight irrespective of type of weed flora. Further, irrespective of weed flora, the single seedling transplanted plots have more infestation of weeds and are followed with 5 seedling transplanted plots. Except in case of sedges, it was found at par. Among the chemical weed management practices, the maximum control of weeds was observed in plots treated with bispyribac-sodium + azimusulfuron (25 +17.5 g/ha at 15 DAT). The combination of herbicides were more effective in controlling the weed flora as compared to single salt application, indicating the necessity of combination of herbicides to manage complex weed flora in transplanted rice (Table 1).The three seedling transplanted resulted higher panicles/m^2 and grain and straw yields and was significantly superior over 02, 04 and 05 number of seedlings/hill. However 03 and 04 number of seedling per hill were at par in grain yield (Table 1). Among the weed management practices, all herbicide treatments along with weed free were significantly higher panicles/m^2 and grain and straw yields over weedy check. Amongst all the chemical management practices, the application of bispyribac- sodium + azimusulfuron (25 +17.5 g/ha at 15 DAT) was significantly superior in terms of yield and yield attributes (Table 1). These results are in conformity with the findings of Singh *et al.* (2013).

Table 1. Effect of Seedling number and weed management practices on weed parameters and grain yield

Treatment	Weeds' density (no./m^2)				Weed dry weight (g/m^2)				Weed Control Efficiency (%)	Grain Yield (t/ha)
	Sedges	Grasses	Broad-leaf	Total	Sedges	Grasses	Broad-leaf	Total		
Number of Seedlings										
02	20.9 (4.38^{a})	23.2 (4.62^{a})	37.4 (5.92^{a})	82.3 (8.69^{a})	8.61 (2.65^{a})	11.03 (3.02^{a})	25.53 (4.58^{a})	45.15 (5.99^{a})	55.28	2.50
03	12.93 (3.50^{c})	13.9 (3.61^{d})	22.4 (4.60^{d})	49.43 (6.75^{d})	5.17 (2.12^{d})	6.62 (2.40^{d})	15.32 (3.58^{d})	27.09 (4.67^{d})	73.17	4.18
04	17.24 (4.02 ^{b})	16.3 (3.89^{c})	26.1 (4.97^{c})	57.66 (7.29^{c})	6.03 (2.26^{c})	7.72 (2.57^{c})	17.87 (3.86^{c})	31.60 (5.03^{c})	68.70	3.76
05	20.47 (4.37^{a})	20.9 (4.39^{b})	33.6 (5.62^{b})	74.14 (6.75^{d})	7.75 (2.53^{b})	9.93 (2.88^{b})	22.98 (4.35^{b})	40.63 (5.69^{b})	59.76	2.92b
LSD (P=0.05)	0.118	0.131		0.402	0.61	0.0987	0.1029	0.159		0.45
Weed Management Practices										
Weedy Check	37.3 (6.12^{a})	37.5 (6.13^{a})	54.0 (7.34^{a})	127.7 (11.26 ^{a})	22.32 (4.75^{a})	26.72 (5.19^{a})	52.00 (7.20^{a})	100.96 (10.02^{a})	59.75	1.45
Penoxsulam 22.5 g/ha (pre-emergence)	19.7 (4.48^{c})	21.5 (4.67^{c})	36.1 (6.02^{c})	76.8 (8.74^{c})	7.20 (2.76^{c})	8.40 (2.96^{c})	25.04 (5.02^{c})	40.64 (6.38^{c})	93.74	3.06c
Bispyribac- sodium + azimusulfuron (25 + 17.5 g/ha at 15 DAT)	7.03 (2.73^{e})	7.2 (2.76^{e})	11.6 (3.47^{e})	26.4 (5.16^{e})	1.20 (1.29^{e})	1.76 (1.49^{e})	3.44 (1.97^{e})	6.32 (2.60^{e})	53.17	4.02
Pyrazosulfuron-ethyl + pretilachlor (30g + 0.75 kg/ ha 3 DAT)	20.6 (4.57^{b})	26.3 (5.15^{b})	40.6 (6.38^{b})	86.6 (9.28^{b})	7.68 (2.84^{b})	10.80 (3.34^{b})	28.80 (5.38^{b})	47.28 (6.87^{b})	81.77	2.89
Pretilachlor + bensulfuron methyl" (Eraze*Post 500 g/ha)	18.1(4.29^{d})	14.8 (3.9^{d})	27.0 (5.22^{d})	59.2 (7.78^{d})	2.48 (1.71^{d})	4.64 (2.25^{d})	11.28 (3.41^{d})	18.40 (4.32^{d})	96.91	3.91
Weed free	4.43 (2.21f)	4.3 (2.18f)	10.1 (3.23f)	18.6 (4.35f)	0.48 (0.98f)	0.64 (1.06f)	2.0 (1.57f)	3.12 (1.89f)	59.75	4.71
LCD (P=0.05)	0.031	0.0329	0.0351	0.0813	0.022	0.0329	0.0507	0.0747		0.14

Data in the parentheses are transformed values

CONCLUSION

It was concluded that among seedling number, 03 number seedling/hill were significantly superior in registration of yield and yield attributes. Similarly among weed management practices, bispyribac-sodium + azimusulfuron (25 +17.5 g/ha at 15 DAT) were better in controlling weeds and getting higher paddy grain yields in temperate Kashmir valley conditions.

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Influence of weed management practices on yield and energetics of aerobic rice cultivars

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In the 21st century along with population pressure, the scarcity of agricultural land, water and shortage of labour maintained pressure for a shift towards direct seeding methods in rice cultivation. Aerobic rice systems, wherein the crop is established through direct seeding in non-puddled, non-flooded fields, are among the most promising approaches for saving water. Weeds pose a serious threat to the direct seeded aerobic rice by competing for nutrients, light, space and moisture throughout the growing season which can cause yield loss upto 92% (Singh *et al.* 2008). It is necessary to develop suitable weed management practice to increase productivity and energy efficiency. Therefore, the present study was undertaken to identify weed management practices that improve crop competitiveness against weeds by reducing weed biomass and increase grain yield and energy efficiency.

METHODOLOGY

Field experiment was conducted at ICAR-Indian Institute of Rice Research farm, Rajendranagar, Hyderabad, during *Kharif* 2015. The experiment comprised of two cultivars namely, DRRH 2 (hybrid), DRR Dhan 44 (high yielding variety) and six weed control treatments, *viz.* benzyl ester + cyhalofop-butyl 180 (30+150) g/ha, cyhalofop-butyl 150 g/ha, bispyribac-Na 25 g/ha, cyhalofop-butyl 80 g/ha, hand weeding at 30 and 45 days after sowing (DAS), weed free along with weedy check. The trial was conducted in split plot design with cultivars in main-plots and weed control treatments in sub-plots. The treatments were replicated four times. All herbicide were applied at 20 DAS. The crop was supplied with the recommended dose of fertilizer 120 N, 60 P_2O_5, 40 K_2O and 20 Sulfur kg/ha. Data on yield and energy consumption were recorded and conversion of inventory into energy as is suggested by Nassiri and Singh (2009) were used.

RESULTS

The grain yield was significantly influenced by varieties and weed management practices (Table 1). The maximum grain yield was recorded in weed free plots followed by (*fb*) two hand weeding plots in both varieties. In case of chemical weed management, maximum yield was recorded in the plots receiving benzyl ester + cyhalofop-butyl 180 (30+150) g/ha followed by bispyribac-Na 25 g/ha in both the varieties. The energy inputs were expressed in absolute terms (MJ/ha) for all inputs, *viz.* seed, fertilizer, irrigation, herbicides and insecticides. However, total input energy in aerobic rice varied from 19905 MJ/ha to 20659 MJ/ha among the different weed management treatments. The variation in total input energy was due to different weed management practices adopted. The maximum energy use was in weed free *fb* two hand weeding *fb* benzyl ester + cyhalofop-butyl 180(30+150) g/ha. Among the cultivar - weed management treatments, the maximum output energy, output-input ratio and energy use efficiency was obtained in benzyl ester + cyhalofop butyl 180 (30+150) g/ha, *fb* bispyribac-Na 25 g/ha in both varieties. The unweeded check produced the least amount of output energy, output-input ratio and energy use efficiency.

Table 1. Yield and Energetics of different weed management practices in aerobic rice cultivars

Weed management practices cultivars	Benzyl ester + cyhalofop butyl 180(30+150) g/ha	Cyhalofop-butyl 150 g/ha	Bispyribac-Na 25 g/ha	Cyhalofop-butyl 80 g/ha,	Hand weeding (30 and 45 DAS)	Weed free	Weedy check
DRRH 2							
Yield (t/ha)*	3.89	3.11	3.56	2.78	4.27	5.04	1.66
Input energy (MJ/ha)	19927	19923	19908	19915	20408	20659	19905
Output energy (MJ/ha)	138565	110787	129414	98966	152179	179417	59193
Output-input ratio	6.95	5.56	6.50	4.97	7.46	8.68	2.97
Energy use efficiency	4.73	3.78	4.22	3.38	5.07	5.91	2.02
DRR Dhan 44							
Yield (t/ha)	4.06	3.54	3.86	3.31	4.31	5.42	1.89
Input energy (MJ/ha)	19927	19923	19908	19915	20408	20659	19905
Output energy (MJ/ha)	144518	126242	137587	117981	153437	193053	67344
Output-input ratio	7.25	6.34	6.91	5.92	7.52	9.34	3.38
Energy use efficiency	4.94	4.31	4.70	4.03	5.12	6.36	2.30

*Statistical analysis value of grain yield- Main plot (LSD 0.31), Sub plot (LSD 0.98) and Interaction (LSD 1.41)

CONCLUSION

The high yielding variety DRR Dhan 44 with weed management by post-emergence application of benzyl ester + cyhalofop-butyl 180 (30+150) g/ha at 20 DAS has recorded high grain yield, low energy input, high energy ratio and energy use efficiency under aerobic rice cultivation in deccan plateau region of Telangana state.

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Weed manager: A mobile app for weed management

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India is an agriculture based developing country. Agriculture is the primary occupation of 65-70% Indian population who depends on agriculture for their living. In this competitive world, farmers need to produce more and more. To achieve higher agricultural production, farmers should be well equipped with latest technology and current information on day-to-day agricultural affairs. The data regarding farming are available from many sources such as print media, audio and visual aids, newspaper, TV, internet, mobile etc., but the formats and structures of data are dissimilar. Information dissemination to the knowledge intensive agriculture sector is upgraded by mobile-enabled information services and rapid growth of mobile telephony. It bridges the gap between the availability of agricultural input and delivery of agricultural outputs. Mobile communications technology has quickly become the world's most common way of transmitting voice, data, images and services in the developing world. Mobile phones have many key advantages: affordability, wide ownership, voice communications, and instant and convenient service delivery. The cost of acquisition of a typical mobile phone is lower than that of a PC. It is also easy to learn how to use a mobile phone, even for computer-illiterate people. This fact makes a mobile device the most appropriate medium to introduce technology to users who are not computer savvy. The objective of the present study was to develop a software or App for mobile phones to cover weed management related information among stakeholders.

Weed manager - A mobile app for weed management

A mobile app named as Weed manager was developed by the ICAR-Directorate of Weed Research, Jabalpur. It is a user-friendly mobile app for farmers and agricultural industry professionals. This app allows users to scout crop name and identify common dominated weeds with control recommendations.

The basic requirement to operate this app is have an Android device with net connectivity, and the software of Weed manager to be downloaded from the directorate website (www.dwr.org.in). After completion of download, run the setup file for the installation **Weed manager** in a device. After complete installation a Weed manager icon () will appear on mobile screen.

It is totally menu-driven app, crops are grouped by season. User can select crop by selecting the season either rainy or winter or summer (i.e. *Kharif*, *Rabi* and Jayad). After selecting season, user can select the crop for weed management in a particular crop. A screen will appear with

Icon of Weed manager mobile application

dominated weeds with recommendations for a particular crop. Main features of the ICAR-DWR developed mobile app is as follows.

- The App is easily accessible and simple in use
- It is designed for the end user
- From installed App, user can select its crop by selecting the season (i.e. *Kharif*, *Rabi* and Jayad)
- It provides multiple, high quality photos of dominated weeds along with recommendations for weed management in selected crop.

Nutrient depletion and yield as influenced by weed control in groundnut with varying levels of sulphur

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Groundnut is one of the top oilseed crop grown in India popularly known as peanut, monkeynut and locally called as '*moongphali*'. It was grown on 5.1 lakh hectares in the Rajasthan with a total production of 10.4 lakh tones and average productivity of 2029 kg/ha (Anonymous, 2015-16). It is a short stature and initial slow growing crop in comparison to the weeds, so the weeds smother the crop at early stage. Groundnut is an oilseed crop so optimization of sulphur fertilization and weed management involving use of selective herbicide can be a good answer to increase the groundnut production.

METHODOLOGY

A field experiment was conducted under loamy sand soil during *Khairf*, 2013 at agronomy farm, S.K.N. College of Agriculture, Jobner. The treatments comprising six weed control treatments and four levels of S assigned to main and sub-plots in spilt plot design, respectively were replicated thrice. Groundnut variety RG-382 was used as a test crop. Sulphur was applied through gypsum as per treatments at the time of sowing and mixed properly into the soil.

RESULTS

Weed control treatments resulted significantly lower depletion of N, P and K by weeds in comparison to weedy check. Keeping the field weed free throughout the growing season resulted no depletion of nutrients under this treatment. Under the various treatments pre-emergence application of pendimethalin at 0.75 kg/ha resulted in the significantly lowest depletion of N, P and K by weeds may be due to corresponding reduction in dry matter production by weeds due to effective control and suppression of weed growth by crop (Dhaka, 2003). However, it was found at par with one hand weeding (HW) at 25 DAS.

Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were found the next superior treatments which reduced the N, P and K depletion as compared to weedy check. Weed free check produced significantly higher pod yield, haulm yield and kernel yield of groundnut and remained at par with the application of pendimethalin at 0.75 kg/ha over rest of treatments (Table 1). The increase in pod yield of groundnut with these treatments was also largely due to high partitioning co-efficient towards sink in the weed free environment. But weed control in weed free treatment significantly increase the shelling percentage and remained at par with one hand weeding at 25 DAS, pendimethalin at 0.75 kg/ha and imazethapyr at 100 g/ha over weedy check and fluazifop-p-butyl at 0.20 kg/ha. These results are close in conformity with the finding of Chaitanya *et al.* (2013). With the increasing levels of S fertilization in groundnut also caused significantly higher N,P and K depletion by weeds upto its highest level of 60 kg/ha over 40 and 20 kg S/ha and control. The increasing levels of sulphur upto 60 kg/ha produced significantly higher pod yield, haulm yield, karnel yield and shelling percentage over rest of the treatments (Table 1). Supply of sulphur in adequate amount helps in the development of floral primordial i.e. reproductive parts, which results in the development of pods and kernels in plants. Similar finding have also been reported earliar by Patel *et al.* (2009) in groundnut.

Table 1. Effect of weed control and sulphur levels on yield, shelling percentage and N, P and K depletion

Treatment	Pod yield (kg/ha)	Haulm Yield (kg/ha)	Kernel yield (kg/ha)	Shelling%	N (kg/ha)	P (kg/ha)	K (kg/ha)
Weed control							
Weedy check	977	1788	635	64.23	45.44	7.06	39.26
Weed free	1971	3671	1453	72.80	0.00	0.00	0.00
One HW at 25 DAS	1750	3259	1254	70.78	10.20	1.55	8.95
Pendimethalin at 0.75 kg/ha	1854	3456	1339	71.36	8.63	1.29	7.58
Fluazifop-p-butyl at 0.20 kg/ha	1343	2590	912	67.08	15.94	2.34	14.28
Imazethapyr at 100 g/ha	1555	2864	1088	69.10	12.82	1.94	11.43
LSD (P = 0.05)	151.47	230	119	4.77	1.82	0.35	1.40
Sulphur levels (kg/ha)							
0	908	1855	592	64.61	15.00	2.29	13.15
20	1558	2789	1067	67.89	18.56	2.83	16.47
40	1835	3429	1314	70.99	19.89	3.04	17.50
60	1999	3679	1480	73.40	20.98	3.18	18.09
LSd (P = 0.05)	69.81	144	71	2.27	0.74	0.13	0.73

CONCLUSION

It may be concluded that weed free check and sulphur at 60 kg/ha significantly increased in respect of pod and haulms yield and nutrient depletion by weeds that was followed by pendimethalin at 0.75 kg/ha.

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Growth and yield of maize as influenced by different doses of tembotrione under mill-hill conditions of Himachal Pradesh

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Maize is important food crop of Himachal Pradesh after wheat and is cultivated on area of 300 thousand ha with a total production of 752.7 thousand tonnes (Anonymous 2015a). Maize is very sensitive to weed infestation that usually causes severe yield reduction especially in dryland conditions. A wider row spacing and sowing of the crop with the onset of monsoon provides a favourable environment for weed growth. A higher level of infestation coupled with many weed species poses a major problem in *Kharif* maize. Atrazine, recommended as a pre-emergence herbicide, is not effective against some of the weeds like *Cyperus rotundus*. The extent of nutrient loss due to weeds varies from 30-40% of the applied nutrients (Mundra *et al.* 2002). Hence, there is need for some alternate post-emergence herbicide which can provide broad spectrum weed control in *kharif* maize without affecting the crop growth and yield. Keeping in view the above facts, the present investigation was carried out for the evaluation of post-emergence herbicide tembotrione with or without surfactants against mixed weed flora in maize at the research farm of CSKHPKV, Palampur.

METHODOLOGY

A field experiment was carried out during *Kharif* season of 2014 at research farm of CSKHPKV, Palampur to test the bioefficacy of tembotrione on growth and yield of maize. Fifteen treatments consisting of tembotrione at varying doses along with conventional herbicides (atrazine and 2-4, D) were arranged in randomized block design with three replications. Maize variety 'Girija composite' was sown in lines at row-to-row distance of 60 cm and plant to plant 20 cm in the experimental field with recommended package of practices. Fertilizers were applied uniformly through urea, single super phosphate and muriate of potash 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha, respectively. Data on plant growth and yield performance were recorded.

RESULTS

A perusal of the data in table 1 indicated that plant height and number of leaves/plant were significantly influenced with application of different weed control practices. Results showed that weed free treatment produced significantly taller plants and higher number of leaves/plant. The maximum plant height in treatment T14 (weed free) was found statically at par to T12 ($H_{130}S_1W_2$) T11 ($H_{130}S_1W_1$) T10 ($H_{130}S_0W_2$) T9 ($H_{130}S_0W_1$) while five these treatments were found significantly superior to rest of the treatments. The result in respect of grain and stover yield of maize is summarized in table 1. Both grain and stover yield of maize were significantly affected by different weed control practices. Grain yield of maize varied from 1.99 in T15 (weedy check) to 4.61 t/ha in T14 (weed free). The highest grain yield in the treatment of T14 (weed free) was recorded statically at par to T12 ($H_{130}S_1W_2$) while, both these treatment were found significantly superior to rest of the treatments. The effect of different weed control practices was significant on the maize stover yield. It ranged from 3.76 to 8.82 t/ha stover yields in T15 and T14 treatments, respectively. The maximum stover yield in the treatment of T14 (weed free) was observed statically at par to T12 ($H_{130}S_1W_2$) treatments. The treatment effect on stover yield of maize was similar as that in case grain yield of maize.

Table 1. Effect of different weed control treatments on growth and yield of maize

Treatment	Plant height (cm)	Number of leaves/plant	Grain yield (t/ha)	Stover yield (t/ha)
$H_{110}S_0W_1$	210.57	7.33	3.18	6.01
$H_{110}S_0W_2$	212.91	7.53	3.22	6.09
$H_{110}S_1W_1$	215.66	7.83	3.28	6.20
$H_{110}S_1W_2$	218.98	8.00	3.33	6.31
$H_{120}S_0W_1$	225.31	8.27	3.55	6.69
$H_{120}S_0W_2$	230.05	8.53	3.61	6.86
$H_{120}S_1W_1$	233.67	8.67	3.69	7.01
$H_{120}S_1W_2$	235.71	8.80	3.77	7.21
$H_{130}S_0W_1$	238.53	9.00	3.90	7.50
$H_{130}S_0W_2$	240.55	9.07	3.95	7.81
$H_{130}S_1W_1$	243.27	9.30	4.14	7.99
$H_{130}S_1W_2$	245.02	9.53	4.36	8.25
Atrazine (1.5 kg/ha)	232.04	8.47	3.70	7.14
Weed free (Atrazine *fb* 2-4,D *fb* hand-weeding if required)	251.35	9.93	4.61	8.82
Weedy Check	193.78	6.73	1.99	3.76
LSD (P=0.05)	6.00	1.06	0.48	0.66

H: Dose of tembotrione (g/ha), **S_0:** No surfactant, **S_1:** With surfactant (1000 ml/ha); **W_1:** 2 weeks after sowing, **W_2:** 3 weeks after sowing

CONCLUSION

It can be concluded that the $H_{130}S_1W_2$ can achieve similar results for yield as achieved by weed free treatment.

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Effect of fertilizer levels and herbicides on wild oat management in wheat

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Wheat (*Triticum aestivum* L.) is a primary source of nutrition and staple food by majority of world's population. India is the second largest producer of wheat in 31.19 m ha area with a production and productivity of 95.85 mt and 3.07 t/ha, respectively. There is greater scope to increase wheat productivity by bridging the gap between potential and achieved yield. Wheat productivity is a result of many factors, but weed management is one of the major and less cared causes of low yield. Wild oat (*Avena ludoviciana*) and wild canary grass (*Phalaris minor)* are two dominant weeds making wheat cultivation less remunerative due to significant yield losses. Wild oat is more competitive than little seed canary grass as it emerges early and competes more vigorously with wheat. Moreover, it responds more favorably with fertilizers and irrigation hence, not only weed biology, but also the knowledge about the herbicides and nutrients synergy is vital to promote the growth in getting higher yield of wheat.

Though wild oat is a serious problem worldwide (Singh *et al*. 1995); its greater prevalence in cotton/millet-wheat rotations in the north India has made it a tough weed to control. Isoproturon efficacy has been found to reduce significantly if used after 6 leaf stage. Clodinafop, fenoxaprop and sulfosulfuron were recommended for the control of grassy weeds in the late nineties, followed by pre-mix of mesosulfuron + iodosulfuron and fenoxaprop + metribuzin in the last decade; however despite of these its efficient control posed a significant challenge as some herbicides had either lower efficacy or caused crop injury necessitating a new and effective herbicide or a change of agronomic practice for wild oat management.

METHODOLOGY

Field and pot studies were carried out for two consecutive years during 2015-16 and 2016-17 at CCS HAU to evaluate the response of increased application of nutrients and efficacy of herbicides. The experiment was laid out in split plot and CRD in field and pots, respectively with 24 treatment combinations replicated thrice. Fertilizers levels taken in the main plot treatments (100, 110, 120% N with 100% P_2O_5 and K_2O) and the sub plots have different pre-emergence (pendimethalin 1.5 kg and pendimethalin + metribuzin 1.5 kg/ha) and post-emergence (clodinafop 60 g, sulfosulfuron 25 g, pinoxaden 50 g and metribuzin 175 g/ha) herbicides with weed free and weedy check. 'WH 1105' variety was drill sown at spacing of 20 x 10 cm. Similar treatment were repeated under pot studies using wild oat only. The herbicides were applied with a knapsack sprayer fitted with flat fan nozzle delivering 300 L water/ha. Pre-emergence herbicides were applied immediately after sowing and post-emergence were sprayed at 35 DAS. Observations were recorded on crop injury, per cent weed control, weed dry weight, growth characters of wheat and its yield. Data were statstically analyzed using SPSS.

RESULTS

Crop injury due to pre-mix application of pendimethalin + metribuzin was more in RDF compared to 10 and 20% higher N. Pendimethalin alone was not effective against wild oat both in the field and pot studies. Similarly, Singh *et al.* (2005) reported that lower efficacy of sulfosulfuron and metribuzin compared to clodinafop. Increased N application over RDF resulted in lower efficacy of herbicides both in field and pot studies; though later on it was similar with clodinafop and pinoxaden due to greater mortality in pots. With just 20% increase of nitrogen dose from RDF efficacy of weed control was reduced by 30 to 50% and yield loss > 30%, whereas 10 to 20% yield loss with 10% higher N over RDF was observed with poor efficacy in all the herbicides over RDF. Higher dosage of fertilizers increased weed count per unit area as well as weed dry weight, hence crop yields of the wheat was significantly reduced. These results indicated that increased fertilizer application was of more advantage to wild oat compared to wheat and will require higher dose of herbicides for its effective control.

CONCLUSTION

With the combination of herbicides and INM approach we can effectively manage weeds; efficacy of herbicide can further be enhanced by using RDF for improved crop growth and suppressed weed growth. Higher herbicide dosage will add cost of cultivation and lesser benefit for improving financial health of farmers.

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Evaluation of Quinchlorac 250 g/l SC for control of grassy weeds in transplanted rice

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Among cereals, rice has been staple food for more than 60 per cent of the world population, providing energy for about 40% of the world population where every third person on earth consumes rice every day in one form or other (Datta and Khushi 2002). There are several reasons for its low productivity but the losses due to weeds are one of the most important. More than one third of the total loss (33%) is caused by weeds alone. In general, weeds problem in transplanted paddy is lower than that of direct seeded paddy because of puddling and stagnation of water in transplanted paddy during early growth stage of crop. Therefore, the present experiment was undertaken to study the evaluation of early post-emergent herbicide for control of major weeds (grasses) in transplanted rice.

METHODOLOGY

An experiment was conducted during *Rabi* 2014-15 and *Kharif* 2015-16 on evaluation of quinchlorac 250 g/l SC on grassy weeds in transplanted paddy at Agricultural Research Station, Dhadesugur. Twenty five days old age seedlings were planted and herbicide was sprayed as per the treatments. On pre-spray, 30 DAT and 60 DAT, number of weeds (m^2) and total dry weight of weeds (g/m^2) were taken in both treated and untreated plots. Species wise, weed population were recorded at before spray, 30 DAT and 60 DAT using quadrates of 1.0 m^2. Further, total dry weight weeds were recorded and used for calculating weed control efficiency (WCE). Weed control efficiency (WCE) was calculated as follows. WCE=Dry weight of weeds under control plot-Dry weight of weeds under treatments/Dry weight of weeds under control plot X 100.

RESULTS

In the experimental plots, the dominant grassy weeds were *Echinochloa* sp, *Panicum repens*, *Cynodon doctylon*, *Leptochloa chinensis and Bracharia* sp. *etc*. The herbicide quinchlorac showed effective control of grassy weeds resulting in higher weed control efficiency (%) at 60 days after planting and grain yield compared to untreated check (Table 1). Experimental results revealed that, significantly higher weed control efficiency of grassy weeds and grain and straw yields were observed under all the doses of quinchlorac 250 g/l SC application treatments compared to untreated control and other herbicide application treatments. Among weed control treatments, application of quinchlorac 250 g/l SC at 312.5 g/ha recorded significantly higher weed control efficiency of grassy weeds at 60 days after transplanting and which was on par with the application of quinchlorac 250 g/l SC at 250 g/ha and quinchlorac 250 g/l SC at 187.5 g/ha compared to other weed control treatments whereas, lower grain and straw yield were recorded in weedy check plot. This is due to the high infestation of weeds.

Table 1. Effect of weed control treatments on weed control efficiency of grasses in transplanted rice

Treatment	Weed control Efficiency (%)			Grain yield (kg/ha)			Straw yield (kg/ha)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
Quinchlorac 250 g/l SC at 125 g/ha	82.4	82.7	82.6	4340	4620	4480	4690	5082	4886
Quinchlorac 250 g/l SC at 187.5 g/ha	86.3	86.4	86.4	5208	5421	5315	5655	5963	5809
Quinchlorac 250 g/l SC at 250 g/ha	88.2	87.7	87.9	5324	5524	5424	5895	6076	5986
Quinchlorac 250 g/l SC at 312.5 g/ha	90.0	90.1	90.1	5440	5623	5531	5924	6185	6055
Cyhalofop butyl 10 % EC at 100 g/ha	76.2	76.9	76.6	4803	4985	4894	5209	5484	5346
Penoxsulam 21.7 % SC at 20 g/ha	78.7	78.9	78.8	5093	5124	5108	5649	5636	5643
Azimsulfuron 50% DF at 28 g/ha	74.3	75.1	74.7	4688	4765	4726	5072	5242	5157
Hand weeding	100	100	100	5903	5988	5945	6407	6587	6497
Weedy check	-	-	-	3472	3456	3464	3759	3802	3780
LSD (P=0.05)	3.10	3.24	3.21	562.3	462.1	526.2	652.1	504.0	505.2

Note: Figures in the parenthesis are square root transformed values (sq. root of x+1), DAT- Days after transplanting, SC- Suspension Concentrates, EC- Emulsifiable Concentrates, DF- Dry Flowable

CONCLUSION

Among the different doses of quinchlorac 250 g/l SC tested as early post emergent herbicide in transplanted paddy, application of quinchlorac 250 g/l SC at range of 187.5 g/ha to 250 g/ha was found to be more effective in control of grassy weeds.

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Efficacy of different herbicides on weed in gram under south Gujarat condition

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Gram (*Cicer arietinum* L.) commonly known as Bengal gram and locally *Chana* is an important and unique food legume because the variety of food products like snake, sweets, Gram is a good source of protein (18-22%), carbohydrate (52-70%), fat (4-10%), minerals (calcium, phosphorus, iron) and vitamins. In India, it occupies about 7.58 million hectare area with an average production of 6.91 million tonnes and productivity of 780 kg/ha (Anonymous 2009).

Weed not only compete for nutrient, moisture, light and space, but also increase the cost of labour make harvesting and threshing operation difficult. Taller and fast growing crop are known to be more competitive which can smother weeds from the early stage of their growth. Contrary to this, slow growing and draft plant type crop like gram often suffer severe weed competition as weeds invade and smother the crop very rapidly causing yield losses up to 50 per cent or more. Chickpea often suffers from severe weed competition especially during early growth phase owing to its slow growth in the initial stage and short statured nature of plant. The magnitude of crop yield losses depends on the number of weed flora, period of crop weed competition and its intensity (Balyan *et al*., 1987).

METHODOLOGY

A field experiment was conducted on gram crop during *rabi* season of 2010-11 at Agronomy Instructional Farm, Navsari (Gujrat). The experiment was laid out in randomized block design with twelve weed management treatments (T_1: Weedy check, T_2: Hand weeding at 20, 40, 60 DAS, T_3: -Pre-emergence application of oxyfluorfen 0.120 kg/ha, T_4: Pre-emergence application of alachlor 1.0 kg/ha, T_5: Post-emergence application of quizalofop-ethyl 0.040 kg/ha at 20 DAS, T_6: Post-emergence application of imazethapyr 0.05 kg/ha at 20 DAS, T_7: Pre-emergence application of oxyfluorfen 0.120 kg/ha + Post-emergence application of quizalofop-ethyl 0.040 kg/ha at 35 DAS, T_8: Pre-emergence application of oxyfluorfen 0.120 kg/ha + post-emergence application of imazethapyr 0.05 kg/ha at 35 DAS, T_9: Pre-emergence application of alachlor 1.0 kg/ha + post-emergence application of quizalofop-ethyl 0.040 kg/ha at 35 DAS, T_{10}: Pre-emergence application of alachlor 1.0 kg/ha + post-emergence application of imazethapyr 0.05 kg/ha at 35 DAS, T_{11}: T_3 + hand weeding and inter-culturing at 40 DAS and T_{12}: T_4 + hand weeding and inter-culturing at 40 DAS) replicated three times. The soil of experimental field was clay in texture, low in available nitrogen (219.52 kg/ha), medium in available phosphorus (30.91 kg/ha) and fairly rich in available potash (387.60 kg/ha).The gram 'GG 2' were sown at 30 x 10 cm spacing.

RESULTS

The result revealed that treatment T_2 recorded significantly lower dry weight (140.80 kg/ha) of weeds at harvest which was closely followed by treatments T_7 (211.20 kg/ha), T_8 (267.52 kg/ha), T_{11} (228.80 kg/ha) and T_{12} (249.92 kg/ha). The highest weed control efficiency (88.30%) at harvest was recorded under treatment T_2 followed by treatments T_7 (82.46%) and T_{11} (80.99%). Weed index which is the indicator of losses in grain yield due to presence of weeds, treatment T_2 was considered as base for calculating weed index, treatments T_7 (7.53) and T_8 (9.30) reported effective as there is less yield reduction and have lower weed index. Significantly highest removal of nutrients (19.95, 4.14 and 21.31 kg/ha N, P and K, respectively) by weeds were recorded under T_1 whereas the lowest nutrient depletion by weeds was recorded under treatment T_2 (1.87, 0.25 and 2.13 kg/ha N, P and K, respectively) followed by treatments T_7 and T_{11}.

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Control of weeds with post-emergence herbicide in pigeon pea

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In our country, pigeonpea is cultivated during *Kharif* season in the month of June-July under assured rainfall condition. During rainy season, slow initial growth and sowing at wider row spacing, severe infestation of weeds is observed in pigeonpea which results in low grain yield. Reduction in seed yield due to weeds in pigeonpea to the tune of 80% has been reported (Talnikar *et al.* 2008). Hence, the present investigation was be under taken to evaluate the efficacy of post-emergence herbicides alone and in combination to control weeds in pigeonpea.

METHODOLOGY

The present investigation was planned and taken up within the scope of the agronomy and the objectives framed out to realize the answers for the problem identified (as discussed in the introduction) during the *Kharif* season of 2015 under edaphic and climatic conditions of Jabalpur. Total ten weed control treatments including propaquizafop 50, 62.5, 100, 125 g/ha, fenoxaprop-p-ethyl 100 g/ha, imazethapyr 100 g/ha, combination of propaquizafop+ imazethapyr (62.5 + 75) and (100+100) g/ha, hand weeding and weedy were laid out in randomized block design with three replications. Herbicides were applied 20 days after sowing using 500 litres of water/ha.

RESULTS

The density of these grassy weeds *Echinochloa colona* and *Dinebra retroflexa* were maximum under weedy check plot where no any weed control measures was adopted. Application of propaquizafop alone at increasing rates (50, 62.5, 100 and 125 g/ha) reduced the weed density. The highest dose of propaquizafop (125 g/ha) curtail the weed density significantly over its lower doses. While the application of fenoxaprop-p-ethyl (100 g/ha) and imazethapyr (100 g/ha) also exhibited significant reduction in density of these weeds over weedy check. Combined application of propaquizafop + imazethapyr (100+100 g/ha) markedly reduced the density over their application at 62.5 + 75 g/ha and alone application of all the herbicides. However, hand weeding twice curtail the density to the maximum extent and was appreciably superior over all the weed control treatments. Significant reduction in the density of broad leaf weeds like *Alternanthera philoxeroides*, *Eclipta alba* and *Phyllanthus niruri* were also occurred. The density of these weeds was maximum under weedy check plots. The application of propaquizafop at lower doses (50 and 62.5 g/ha) and fenoxaprop-p-ethyl (100 g/ha) could not reduce the density of broad-leaved weeds, but slight reduction in density of broad-leaved weeds was observed with increasing doses of propaquizafop (100 and 125 g/ha). Combined application of propaquizafop + imazethapyr at the lower doses (62.5 + 75 g/ha) caused similar reduction in the density of broad-leaved weeds to that of imazethapyr (100 g/ha) and proved significantly superior to weedy check plots. But, efficacy of these herbicides was further enhanced when applied at 100 + 100 g/ha. However, none of the herbicidal treatments surpass the hand weeding twice.

Table 1. Effect of weed control treatments on weed density and yield

Treatment	Grassy weeds at harvest		Broad leaf weeds at harvest			Seed yield (t/ha)
	Echinochloa colona	*Dinebra retroflexa*	*Alternanthera philoxeroides*	*Eclipta alba*	*Phyllanthus niruri*	
Propaquizafop (50 g/ha)	4.60(20.67)	5.05(25.00)	4.26(17.67)	3.85(14.33)	3.48(11.67)	1.54
Propaquizafop (62.5 g/ha)	4.56(20.33)	5.02(24.67)	4.22(17.33)	3.76(13.67)	3.44(11.33)	1.56
Propaquizafop (100 g/ha)	3.98(15.33)	4.60(20.67)	3.48(11.67)	3.39(11.00)	3.13(9.3)	1.72
Propaquizafop (125 g/ha)	3.76(13.67)	4.30(18.00)	3.39(11.00)	3.34(10.67)	3.08(9.00)	1.78
Fenoxaprop-p-ethyl (100 g/ha	4.22(17.33)	4.74(22.00)	4.18(17.00)	3.72(13.33)	3.29(10.33)	1.69
Imazethapyr (100 g/ha)	4.34(18.33)	4.77(22.33)	3.08(9.00)	3.02(8.67)	2.73(7.00)	1.91
Propaquizafop + imazethapyr (62.5 + 75 g/ha)	2.80(7.33)	4.18(17.00)	3.03(8.67)	2.91(8.00)	2.68(6.67)	2.18
Propaquizafop + imazethapyr (100 + 100 g/ha)	2.27(4.67)	3.58(12.33)	2.67(6.67)	2.54(6.00)	2.34(5.00)	2.24
Hand weeding (20 and 40 DAS)	1.46(1.67)	1.46(1.67)	1.34(1.33)	1.05(0.67)	1.22(1.00)	2.37
Weedy check	4.98(24.33)	6.10(36.67)	4.34(18.33)	4.02(15.67)	3.53(12.00)	1.32
LSD (P=0.05)	0.18	0.24	0.27	0.30	0.29	118.37

(Figures in parenthesis are original values)

CONCLUSION

Among the different herbicidal treatments, the combination of propaquizafop + imazethapyr at 100+100 g/ha at 20 DAS followed by their application at 62.5+75 g/ha at 20 DAS was suitable for better control of weed density.

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Effect of different weed management practices on weed population, yield potential of peach cv. July Elberta

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Peach (*Prunus persica* Batsch) is one of the most important stone fruit crops belonging to the family Rosaceae. Peach is the third most important temperate fruit cultivated in India. In India, peach is grown on commercial scale in mid-hills of Himachal Pradesh, Jammu & Kashmir. In Himachal Pradesh, peach is cultivated commercially in an area of 5,182 hectares with a production of 9,527 MT (Anonymous 2011). The production of peach per unit area is very low in India as compared to the developed countries like China, Italy, Spain and USA. The low average yields are primarily due to improper orchard management practices. Weeds compete with the fruit plants for nutrients, space, moisture, light which adversely affect the growth and vigour of plants and thereby directly reducing the productivity of fruit trees. It has been reported that about 37 per cent losses may occur due to inadequate management of weeds in fruits and vegetables (Varshney 2009). Therefore, the use of herbicides in fruit orchards should be done judiciously.

METHODOLOGY

Field experiment was conducted on seven-year-old peach cv. July Elberta in the experimental farm of Fruit Science, Dr. Y S Parmar UHF, Nauni, Solan, Himachal Pradesh. The experiment was conducted in RBD having three replications and the treatment details in table. The pre-emergence herbicide (pendimethalin) were applied to tree basins in the first week of March and post-emergence herbicide (glyphosate) in two applications (first spray – first week of April and second spray – mid July) in 2012 and 2013.

RESULTS

Weed population was noted in T_{13} (29.29) and this treatment had significantly more number of weeds than all the treatments. Whereas, minimum weed population in the treatment T_9 (3.95). The present study was in agreement with the findings of several earlier workers (Kaith and Bhardwaj 2011). The lowest weed population under treatment T_{11} (Grass mulch followed by Glyphosate 0.8 kg/ha) may be attributed to the absence of sunlight coupled with the physical barrier provided by dry grass mulch to the emerging weeds. The data revealed that the maximum cumulative yield per tree was recorded in treatment T_{11} (12.00 kg) and it was significantly different from all other treatments. Minimum yield per tree was recorded in control (9.93 kg).

Table 1. Effect of different weed management practices on weed growth parameters and yield potential

Treatment	Weed population count Days after treatment application Pooled data 2012-2013					Weed control efficiency (%) Days after treatment application Pooled data 2012-2013					Fruit yield kg / tree		
	30	60	90	120	Mean	30	60	90	120	Mean	2012	2013	Pooled
T_1: pendimethalin (1.0 kg/ha),	7.50	9.00	10.50	13.17	10.04	66.54	69.54	68.27	66.49	67.71	10.40	10.63	10.52
T_2: pendimethalin (1.5 kg/ha)	6.83	8.16	9.50	12.33	9.20	69.61	66.87	73.95	68.36	69.70	10.44	10.82	10.63
T_3: pendimethalin (2.0 kg/ha)	6.67	6.33	9.83	11.50	8.58	73.04	74.80	74.02	70.71	73.14	10.54	10.79	10.67
T_4: glyphosate (0.8 kg/ha)	-	5.83	8.00	9.50	7.78	-	76.09	74.84	77.71	76.21	10.68	10.86	10.77
T_5: glyphosate(1.6 kg/ha)	-	4.67	7.50	8.83	7.00	-	79.31	83.81	78.88	80.67	10.88	10.92	10.90
T_6: glyphosate (2.4 kg/ha)	-	3.33	6.67	7.67	5.89	-	82.55	83.07	84.27	83.30	10.99	11.10	11.05
T_7: pendimethalin(1.0 kg/ha) followed by glyphosate (0.8 kg/ha)	4.83	3.66	5.33	7.17	5.25	72.98	83.87	79.40	80.97	79.30	11.10	11.21	11.16
T_8: pendimethalin (1.5 kg/ha) followed by glyphosate (0.8 kg/ha)	4.16	3.50	5.00	6.83	4.87	81.96	83.42	81.65	83.55	82.65	11.20	11.33	11.26
T_9: pendimethalin (2.0 kg/ ha) followed by glyphosate (0.8 kg/ha)	3.33	2.83	4.83	4.83	3.95	86.71	83.49	81.91	85.74	84.46	11.16	11.30	11.23
T_{10}: pendimethalin (2.0 kg/ha) followed by grass mulch	4.00	4.66	3.83	6.17	4.66	80.42	85.34	87.09	83.34	84.05	11.22	11.51	11.36
T_{11}: grass mulch followed by glyphosate (0.8 kg/ha)	2.00	3.50	5.33	5.33	4.04	91.96	85.34	76.61	78.75	83.16	11.56	12.45	12.00
T_{12}: hand weeding at 30 days interval	16.00	20.67	26.83	31.67	23.79	33.99	27.14	11.34	40.33	28.20	9.91	10.02	9.96
T_{13}: control	17.83	24.00	32.83	42.50	29.29	0.00	0.00	0.00	0.00	0.00	9.89	9.98	9.93
Mean	7.32	7.70	10.46	12.88	9.57	65.72	69.06	67.38	69.16	67.83	10.77	10.99	10.88
LSD (P=0.05) Treatment					0.51					0.96	0.25	0.29	0.19
Year					0.28					0.53			0.07
Interaction					1.03					1.92			0.27

CONCLUSION

The results grass mulch followed by two applications of glyphosate 0.8 kg/ha (first week of April and second mid-July) was found to be the best treatment for most of the characters among all the treatments and maximum weed control efficiency and higher yield.

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Efficacy of atrazine on weed growth and yield of maize crop

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Maize (*Zea mays* L.) is the second most important cereal crop in the world in terms of total food production. In India, it is grown over an area of 9.43 m ha with total production of 24.35 m tones. Maize, being a rainy season and widely spaced crop, gets infested with variety of weeds and subjected to heavy weed competition, which often inflicts huge losses ranging from 28 to 100 per cent (Patel *et al*., 2006). Worldwide maize production is hampered up to 40% by competition from weeds which are the most important pest group of this crop (Oerke and Dehne 2004). Maize is very susceptible to competition from weeds especially in the early stages of growth; therefore, efficient control at the pre-and early post-emergence stages is essential. Atrazine acts by inhibiting photosynthesis. Pre-emergence and post-emergence herbicides will be an ideal means for controlling the weeds in view of economics and effectiveness in maize. An investigation was carried out to study the application of pre-emergence and post-emergence herbicides in maize during *Kharif* 2014 and 2015.

METHODOLOGY

Field experiment was conducted during *Kharif* season of 2014 and 2015 at N.E. Borlaug Research Center, G.B.P.U.A & T, Pantnagar. The experiment was laid out in Randomized Block Design with three replications. The maize variety "Gaurav" was sown on 1st August during 2014 and 15th July during 2015. Test herbicide atrazine 50% WP (new source) at dosages of 500 and 1000 g/ha, atrazine 50% WP (existing source) at 500 and 1000 g/ha were applied as pre-emergence at 2nd day after sowing, whereas, standard check, *i.e.* paraquat dichloride 24% SL at 500 g/ha and 2,4-D Sodium salt 80 WP at 1000 g/ha were applied as post-emergence at 2-3 leaf stage of weeds. A quadrate of 0.25 m^2 was placed at four randomly selected places in all the plots of the experimental field and the number of weed flora were count at 45 DAS and expressed in number/m^2.

RESULTS

Statistically analyzed pooled data of both the years showed that among all the weed control treatments, total reduction of weed biomass with 100% weed control efficiency was achieved under weed free situation. Whereas, among the herbicidal treatments, minimum dry matter accumulation and maximum weed control efficiency was obtained with application of atrazine at higher dose (1000 g/ha) either applied as sponser sample or market sample and paraquat dichloride (standard check) at 500 g/ha. Among the different herbicides, maximum yield of maize was achieved with atrazine applied at 1000 g/ha (6.4 t/ha) with minimum weed index (3.0%) and was at par with all other doses either applied as sponsor or market sample.

Table 1. Effect of treatment on weeds dry matter accumulation, weed control efficiency at 45 DAA, weed index and yield of maize

Treatment	Dose g/ha	Weed dry weight (g/m^2)	Weed control efficiency (%)	Weed index (%)	Seed Yield (t/ha)
Atrazine 50 WP (SS)	500	10.9(119.3)	67.1	6.1	6.2
Atrazine 50 WP (SS)	1000	9.4(88.9)	75.4	3.0	6.4
Atrazine 50 WP (MS)	500	11.1(124.1)	65.7	7.6	6.1
Atrazine 50 WP (MS)	1000	9.4(89.4)	75.3	6.1	6.2
Paraquat dichloride 24% SL	500	9.4(87.6)	75.8	13.6	5.7
2,4-D Sodium salt 80 WP	1000	15.6(242.5)	33.0	25.8	4.9
Weed free	-	1.0(0.0)	100.0	-	6.6
Weedy check	-	19.0(362.1)	-	-	3.1
LSD (P=0.05)	-	0.91	-	-	0.33

DAA: Days after herbicide application, SS: Sponsor Sample, MS: Market Sample, Value in parentheses were original and transformed to square root " $(\sqrt{x+1})$ for analysis

CONCLUSION

The effectiveness of the herbicide atrazine (50 WP) against broad-leaved weeds and its high selectivity in maize, make it a plausible candidate for weed control in maize.

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Weed management in Japanese mint

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Japanese mint (*Mentha arvensis* L.) belongs to the family Lamiaceae (Labiate) grown as summer crop in Eastern U.P. It is grown for medicinal and aromatic purposes. In India, the major mint producing states are U.P., Uttrakhand, Punjab, Haryana, Bihar etc. The production and productivity of Japanese mint in India is very low as compared to other countries due to many factors. Grassy weeds is one of the important factors which leads to a huge loss to the mint crop every year and had adversely effected on farmers profitability. Chemically weed management in mentha crop is very effectively and economically due to unavailability of labour in time.

Keeping in view the demand and multifarious uses of mint oil in flavouring and pharmaceutical industries, there is a need to find out suitable method of weed control.

METHODOLOGY

The field experiment was conducted during summer season 2015-16 at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.). The soil of the initial experimental field was silty- loam in texture with saline reaction (pH 8.2). It was low in organic carbon C (0.29%) with low fertility status, i.e. available N (182 kg/ha), available P (18.5 kg/ha) available K (275 kg/ha). The six treatments comprise of viz., propaquixafop (50 g/ha), propaquixafop (62.5 g/ha), propaquixafop (75 g/ha), pendimethalin (100 g/ha), hand weeding twice at 25 and 45 days after sowing (DAS) and unweeded check (control) were laid out in randomize block design with three replication. Mentha variety 'Kosi' was sown in summer season.

RESULTS

Among the herbicide treatment, application of propaquizafop 10% EC at 750 ml/ha recorded the lower weed population and dry weight of weeds followed by propaquizafop 10% EC at 625 ml/ha. Hand weeding thrice recorded the lowest density and dry weight of weeds and the highest weed control efficiency.

The highest weed control efficiency, *i.e.* 89.69% and 19.74% was recorded with propaquizafop 10% EC at 750 ml/ha. The highest weed control efficiency was mainly because of effective control of both monocots and dicots. Hand weeding thrice being at par with propaquizafop 10% EC at 750 ml/ha and 625 ml/ha but gave significantly higher herbage and oil yield over rest of the treatments. Higher herbage yield and oil yield with above treatments could be attributed to effective control of both monocots and dicots which resulted the more availability of nutrients to crop. Weedy check recorded significantly the lower herbage and oil yield *i.e.* 6.03 t/ha and 6.03 l/ha respectively.

Table 1. Effect of treatments on weed density/m^2, weed control efficiency and yield in mint at before and after herbicide application during 2016

Treatment	Dose ml/ha	Weed density per m^2 before application		Weed density per m2 before application		Weed control efficiency (WCE %)		Yield	
		Monocots weeds	Broad leaf weeds	Monocots weeds	Broad leaf weeds			Herbage yield (t/ha)	Oil yield (l/ha)
Propaquizafop 10% EC	500	10.25 (3.28)	17.17 (4.20)	2.89 (1.84)	15.58 (4.01)	74.63	18.03	8.34	83.38
Propaquizafop 10% EC	625	10.33 (3.29)	17.00 (4.18)	1.33 (1.35)	15.00 (3.94)	88.77	19.08	11.51	117.38
Propaquizafop 10% EC	750	10.08 (3.25)	17.00 (4.18)	1.00 (1.22)	15.00 (3.94)	89.69	19.74	11.74	119.69
Pendimethalin 30% EC	1000	10.33 (3.29)	17.42 (4.23)	1.83 (1.53)	15.25 (3.97)	85.06	18.54	8.64	86.42
Hand weeding	-	10.25 (3.28)	17.25 (4.21)	1.00 (1.22)	1.67 (1.47)	90.25	88.12	12.07	123.10
Control	-	10.00 (3.24)	17.00 (4.18)	11.25 (3.43)	17.83 (4.28)	0.00	0.00	6.03	60.33
LSD (P=0.05)		NS	NS	0.15	NS	-	-	0.81	6.50

Data in the parenthesis indicates the square root transformed value

CONCLUSION

Thus, for effective weed control in mint, application of propaquizafop 10% EC 625 ml/ha and 750 ml/ha should be applied.

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Chemical weed control in berseem

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Berseem or egyptian clover (*Trifolium alexandrium* L.) is a well known green forage crop for dairy animals due to its excellent and quick re-growing ability and long durational nutritious green fodder availability. Weed competition substantially reduces the green forage yield and it causes reduction up to 30 to 40 per cent besides deteriorating quality of green forage, if not controlled during critical period of crop-weed competition (Jain 1998). Hence, weeds need to control at initial period with of crop growth with hand weeding is or any effective method. Non availability and cost of labour pose to find the effective chemical weed control method.

METHODOLOGY

The experiment was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri during *Rabi* season of 2012-13, 2013-14 and 2014-15. The experiment was comprised of 10 weed control treatments as in table. The field experiment was laid out in randomized block design with three replications. Pendimethalin and oxyfluorfen were used as the pre-emergence, while imazethapyr as post-emergence herbicide. The pre-emergence herbicides were sprayed three days sowing prior to emergence of weed as well as crop which was irrigated immediate after sowing and post-emergence herbicide was applied immediately after harvest of first and second cut for fodder as per the treatment. The crop was fertilized with the recommended dose of fertilizer, *i.e* 20 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha. The variety '*Wardan*' was sown at 30 cm apart. First two cuts were taken for green forage purpose and after harvesting of second cut for fodder crop was left for seed production.

RESULTS

Among the weed control treatments weed count (27/m^2) was recorded in the application of oxyfluorfen 0.1 kg/ha followed by *(fb)* imazethapyr 0.1 kg/ha immediate after harvest of Ist cut but this treatment was at par with the application of imazethapyr 0.1 kg/ha immediate after harvest of Ist and IInd cut which recorded weed count (33/m^2) .Weed dry weight (68 g/m^2) was recorded significantly lower in the application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha immediate after harvest of Ist cut. However, it was at par with the application of imazethapyr 0.1 kg/ha immediate after harvest of Ist and IInd cut which recorded weed dry weight (78 g/m^2). The total weed control efficiency (70.28 %) was recorded significantly higher at the application of oxyfluorfen 0.1 kg/ha *fb* imazethapyr 0.1 kg/ha immediate after harvest of Ist cut. However, this treatment was at par with the application of imazethapyr 0.1 kg/ha immediate after harvest of Ist and IInd cut (63.80 %). Similar results were reported by Pathan *et al.* (2013).

Table 1. Weed growth and yield of berseem as influenced by different weed control treatments (Pooled mean of three years)

Treatment	Yield (t/ha) Green forage	Seed	Straw	Dry matter	Weed Count (m^2)	Dry weight of weeds (g/m^2)	Weed control efficiency (%)	Gross monetary returns (x10^3 Rs/ha)	Net monetary returns (x10^{3}Rs/ha)
Weedy check (Control)	30.05	0.15	0.74	4.94	12.67(101)	15.61 (206)	0.00	72.66	29.92
Pendimethalin 0.3 kg/ha	25.51	0.12	0.67	4.10	11.00 (77)	14.33 (167)	25.91	60.89	20.29
Pendimethalin 0.4 kg/ha	24.24	0.12	0.58	3.85	11.02 (77)	14.18 (164)	27.84	58.22	17.79
Pendimethalin 0.5 kg/ha	23.14	0.11	0.56	3.63	11.03 (76)	13.93 (163)	26.17	56.00	14.96
Oxyfluorfen 0.1 kg/ha	29.56	0.14	0.86	4.81	8.30 (41)	11.01 (96)	55.08	71.35	28.47
Imazethapyr 0.1 kg/ha immediate after harvest of Ist and IInd cut	41.61	0.18	1.13	6.90	7.24 (33)	9.61 (78)	63.80	96.52	48.97
Oxyfluorfen 0.1kg/ha *fb* Imazethapyr 0.1 kg/ha immediate after harvest of Ist cut	33.20	0.16	0.97	5.50	6.77 (27)	9.33 (68)	70.28	80.34	33.09
Pendimethalin 0.3 kg/ha *fb* Imazethapyr 0.1 kg/ha immediate after harvest of Ist cut.	28.86	0.14	0.83	4.67	9.15 (52)	(11.90 116)	46.65	70.18	24.57
Pendimethalin 0.4 kg/ha *fb* Imazethapyr 0.1 kg/ha immediate after harvest of Ist cut.	27.82	0.14	0.78	4.38	8.70 (47)	11.78 (113)	51.73	67.44	22.16
Pendimethalin 0.5 kg/ha *fb* Imazethapyr 0.1 kg/ha immediate after harvest of Ist cut.	26.93	0.12	0.73	4.14	8.57 (45)	11.58 (112)	54.01	63.82	18.77
LSD (P=0.05)	3.20	0.01	0.09	0.62	0.62	0.69	6.80	5.43	5.75

(Figures in parenthesis are actual values)

The weed control measures exhibited significant variation in yield and growth parameters. Maximum green forage yield (41.61 t/ha), seed yield (0.18 t/ha), straw yield (1.13 t/ha), dry matter yield (6.90 t/ha) were recorded in the application of imazethapyr 0.1 kg/ha immediate after harvest of Ist and IInd cut. The gross monetary returns of Rs. 96.52 x10^3 Rs/ha and net monetary returns of Rs.48.97 x10^3 Rs/ha with B:C ratio of 2.09 were recorded with imazethapyr 0.1 kg/ha immediate after harvest of Ist and IInd cut.

CONCLUSION

The green forage (41.61 t/ha), dry matter (6.90 t/ha), seed (0.18 t/ha) and straw yield (1.13 t/ha) with significantly higher gross (Rs. 96.52 x10^3 Rs/ha), net (Rs. 48.97 x10^3 Rs/ha) monetary returns and B:C ratio (2.09) were obtained in the application of the imazethapyr 0.1 kg/ha immediate after harvest of I and II cut. Application of **i**mazethapyr 0.1 kg/ha immediate after harvest of I and II cut is effective for control of weeds and obtaining higher green forage, seed and straw yield with higher remunerations in berseem.

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Bio-efficacy of herbicides in controlling problematic weed species of winter season

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Phalaris minor, Medicago denticulata and *Anagallis arvensis* are problematic weeds infesting winter season crops. *P. minor* is most dominant weed in wheat crop mainly in the rice–wheat system in Indo-gangetic plains of India and it alone affects grain yield upto 40% (Walia 2006) **.** *A. arvensis* is also a common weed in wheat and winter vegetables. It produces many thousand seeds per plant which remain viable in the soil for about 10 years. The losses in wheat yield have been reported from 10-50% depending upon the intensity of infestation of weeds (Walia *et al.*, 1990). The present study was carried out to evaluate the efficacy of different pre- and post-emergence herbicides to control these three problematic weed species.

METHODOLOGY

The field experiment was carried out during the winter season of 2014- 15 at the Norman E. Borlaug Crop Research Centre, GB Pant university of Ag. & Tech. Pantnagar. Six different herbicides were evaluated for their efficacy in controlling these three species. These included two pre-emergence (Trifluralin at 1 kg/ha and pendimathalin at 1 kg/ha) and four post-emergence herbicides (Clodinofop at 60 g/ha, clodinofop + metsulfuron-methyl (MSM) at 60 g+ 4.0 g/ha, sulfosulfuran at 25 g/ha and metribuzein at 250 g/ha). The effect of herbicides on biomass and some biochemical parameters of the weed species was evaluated.

RESULTS

The biomass of weed species was recorded at 40 days after herbicide treatment and at harvest. The pre-emergence herbicides pendimethalin and trifluralin effectively controlled the germination of *P. minor* and *A. arvensis*. At 40 days after spray, all the herbicides except sulfosulfuron effectively controlled *P. minor* but at maturity stage, *P. minor* recovered in some treatments. At harvest, the biomass of *P. minor* was 841.3 g/m^2 in metribuzin and 687.3 g/m^2 in pendimethalin treatments. *M. denticulata* was successfully controlled by clodinofop + MSM, sulfosulfuron and metribuzin. The biomass of *M. denticulata* was maximum in trifluralin treatment (154.6 g/m^2) at 40 DAS and in clodinofop-propargyl treatment (892 g/m^2) at harvest. Ready mix of clodinofop-propargyl + MSM, sulfosulfuron and metribuzin were also effective to control *A. arvensis* whereas clodinofop-propargyl alone was found ineffective to control this weed.

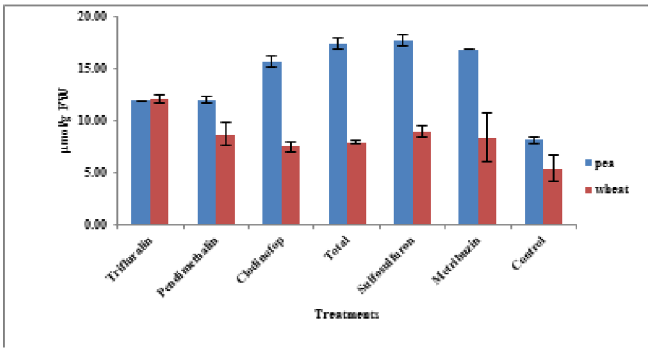

Fig 1. Effect of herbicides on proline content of wheat and pea (µ mol/g FW)

Table1. Effect of herbicides on biomass of weed species (g/m^2) at 40 days after spraying and at harvest

Treatment	*P. minor*		*M. denticulata*		*A. arvensis*	
	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest
Trifluralin at 1 kg/ha	0	0	154.6	630.6	0	0
Pendimethalin at 1 kg/ha	0	687.3	147.1	505.3	0	0
Clodinofop-propargyl at 60 g/ha)	0	0	93.7	892.0	4.96	118.6
Clodinofop-propargyl + metsulfuron methyl at 60 g/ha + 4 g/ha)	0	0	0	0	0	0
Sulfosulfuron at 25 g/ha)	94.6	310.0	0	0	0	0
Metribuzin at 250 g/ha)	0	841.3	0	0	0	0
Control	386.6	1085.3	129.3	694.0	15.8	73.3
LSD (P=0.05)	16.4	82.8	47.4	36	6.96	10

Effect of herbicide on proline content of given crops showed that maximum proline content (12.1 ì mol/g FW) was recorded in wheat under trifluralin whereas under pendimethalin, clodinofop + metsulfuron-methyl, sulfosulfuron and metribuzin, it was at par with each other. In case of pea, the proline content was recorded maximum under sulfosulfuron (17.7ì mol/g FW) which was at par with the pea clodinofop + metsulfuron-methyl and metribuzin treatments. The proline content in pea was found less under pre-emergence herbicides pendimethalin and trifluralin as compared to the post-emergence herbicides.

CONCLUSION

Among the herbicides tested in the present study, the pre-emergence herbicides effectively controlled the germination of *P. minor* and *A. arvensis*. Among post-emergence herbicides, ready mix of clodinafop and metsulfuron-methyl successfully controlled all the three weeds. Application of clodinafop alone seems to be effective against only *P. minor* whereas, sulfosulfuron and metribuzin were effective against the broad-leaved weeds.

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Herbicides combinations for control of complex weed flora in wheat

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In India, wheat (*Triticum aestivum* L.) stands second next to rice crop in area and production but it occupy rank first in productivity among all the cereals. Weed management plays a vital role in boosting up wheat production. Uncontrolled weeds are reported upto 66 per cent reduction in wheat grain yield. Chemical weed control is preferred practice due to higher wages and unavailability of labours at time. Divers weed flora in wheat crop some new ready-mix herbicide are available in the market. Hence, there is a need to test tank mixed herbicide molecules in combination or in sequential application.

METHODOLOGY

The field experiment was conducted at Agronomy Research Farm of N.D. University of Agriculture & technology, Kumarganj, Faizabad during *Rabi* season of 2015-16 to evaluate the herbicides combinations for controlling of complex weed flora in wheat. The experiment was conducted with 12 treatments in randomize block design with three replications. Wheat variety 'NW 1014' was sown in lines at 20 cm apart using seed rate 100 kg/ha.

RESULTS

The wheat crop in experimental field was infested with grassy, broad leaved and sedges weeds and the major weeds recorded at 60 DAS was *viz. Phalaris minor, Chenopodium album, Melilotus alba, Anagallis arvansis, Vicia sativa, Fumaria parviflora* and *Rumex dentatus* in weedy check treatmentHand weeding (HW) twice resulted the lowest weed density and dry weight significantly followed by clodinafop+ metsulfuron (premix) (0.06 + 0.004 kg/ha, 5WAS). The maximum WCE was recorded (95.34%) under 2 HW followed by (81.12%) with pendimethalin (1.0 kg/ha) + metribuzin (0.175 kg/ha) due to effective control of weeds. HW twice being at par with pendimethalin + metribuzin (PE) at 1+0.175 kg/ha recorded significantly the highest values of all growth and yield attribute (Table 2). Application of herbicides in combination produced significantly higher yield over single herbicide application. (Table 1) Among the herbicides mixture, significantly the maximum grain (4350 kg/ha), straw yield (6287 kg/ha), net monetary returns and BCR (Rs.54.66 x10^3/ha and 2.08) was recorded with pendimethalin + metribuzin (1.0 + 0.175 kg/ha) as PE which was followed sulfosulfuron + metsulfuron (0.03+0.002 kg/ha, 5 WAS) and pendimethalin + sulfosulfuron (1.0+0.018 kg/ha, PE and PoE) treatment.

Table 1. Effect of weed control treatments on weed density (no./m^2), weed dry weight (g/m^2) and WCE (%) of wheat (60 DAS)

Treatment	Weed density (no/m^2)	Weed dry weight (g/m^2)	WCE (%)	Grain yield (kg/ha)
Pendimethalin (PE) at 1 kg/ha	(118.15)10.91	(113.8)10.71	68.61	3370
Sulfosulfuron (POE) at 0.025 kg/ha	(112.62)10.65	(110.0)10.50	68.73	3580
Metribuzin (PE) at 0.175 kg/ha	(112.32)10.64	(108.9)10.48	68.69	3400
Clodinafop (POE) at 0.06 kg/ha	(118.32)11.37	(123.65)11.16	67.32	3306
Pendimethalin+metribuzin (PE) at (1 kg + 0.175 kg/ha)	(69.26)8.38	(65.73)8.16	81.12	4350
Pendimethalin (PE) at 1 kg/ha + sulfosulfuron (POE) at 0.025 kg/ha	(101.08)10.10	(84.69)9.25	75.68	4230
Sulfosulfuron+metsulfuron (POE) at (0.025 + 0.004 kg/ha)	(75.92)8.77	(72.71)8.58	79.12	4140
Pinoxaden+metsulfuron (POE) at (0.06 + 0.004)	(107.23)10.40	(95.65)9.83	75.68	4030
Mesoulfuron+ iodosulfuron (POE) at (0.012 + 0.0024 kg/ha)	(101.28)10.16	(93.75)9.73	73.08	3810
Clodinafop+ metsulfuron (POE) at (0.06 + 0.004 kg/ha)	(86.12)9.33	(73.45)8.62	78.91	4270
Hand weeding twice at 20 and 40 DAS	(4.00)2.23	(16.20)4..14	95.34	4090
Unweeded control	(223.57)14.98	(348.27)18.68	0.0	2550
LSD (P = 0.05)	4.15	5.78	-	5.8

Original value in parenthesis, $\sqrt{x+1}$ transformation used.

CONCLUSION

It is concluded that pendimethalin + metribuzin (1.0 + 0.175 kg/ha) as pre-emergence should be applied to control complex weed flora and to obtain higher yield and net profit.

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Effect of herbicide to control weeds in mint

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Japanese mint (*Menta arvensis* L.) oil is often required by the medicine industry and, it is used in balm, cough drops, inhalers, toothpaste, mouthwash etc. With the steam distillation process, mint oil is extracted from the fresh plant foliage. In India yield per unit area as well as oil content in herb of Japanese mint is very much lower as compared to other countries. The crop is affected from weeds of both winter and summer seasons. Mentha was dominated mainly by monocot weeds (i.e. grassy weeds and sedges) and followed by broad leaf weeds (BLWs) during both the seasons. Among grassy weeds *Digitaria sanguinalis*, *Echinochloa colona*, *Brachiaria mutica*, *Cynodon dactylon*, *Dactyloctanium aegypticum* and *Sorghum helepens e*were observed followed by sedge i.e. *Cyperus rotundus*. Whereas among BLWs *Parthenium hysterophorus*, *Euphorbia hirta*, *Amaranthus viridis* and *Digera arvensis* were observed reduction in herbage yield by 80% and essential oil yield by 74% due to weedy condition. It may be due to many factors responsible for low yield. Among them improper weed management especially "grassy weeds management" is one of the important factors which leads to a huge loss to the mint crop every year. Considering the above facts in view the present investigation entitled effect of herbicides to the weeds in mentha was carried out.

METHODOLOGY

The present experiment was conducted during summer season, 2015 and 2016 at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Faizabad (U.P.). There were 8 treatments i.e., haloxyfop 10.8% EC (750ml), haloxyfop 10.8% EC (1000 ml), haloxyfop 10.8% EC (1250 ml), pendimethalin 30% EC (1000 ml), quizalofop-ethyl (750 ml), hand weeding (40 DAS), weed free check, weedy check included in experiment with three replication. Soil composition was recorded O.C. (3.5 kg/ha), available N (182 kg/ha), available P (18.5 kg/ha), K (275 kg/ha), S 11.2 kg/ha.

RESULTS

Weed management methods significantly affected the population and dry matter of weeds in mentha (Table 1). The lowest dose at 750 g/ha of the testing haloxyfop 10.8% EC all other doses were effective to check the population and dry weight of the dominant grassy weed flora. Better efficacy was obtained by increasing the doses of the testing haloxyfop 10.8% EC as against control plot that showed the maximum density of the weeds. All herbicide were found effective against monocot grassy weeds only. Haloxyfop10.8% EC at 1000 ml/ha found best effective on weed flora among the chemicals and statistically at par with 1250ml/ha in menthe crop. Whereas, weed free treatment was recorded best among all treatments. Highest weed control efficiency was recorded with haloxyfop (1000 ml/ha) over other herbicide treatment while weed free treatment was superior weed control efficiency overall other treatment. Maximum herbage yield and oil yield was obtained under with haloxyfop (1000 ml/ha) followed by haloxyfop 1250 ml/ha than other herbicide treatments and weedy check due to higher reduced of grassy weed in menthe crop. Weed free treatment was found higher herbage yield and oil yield over all treatment.

Table 1. Effect of various weed control treatments on weed dry weight (g/m^2), weed dry weight, weed control efficiency at various days after herbicide application on biological yield and oil yield

Treatment	Weed density		Weed dry weight	weed control efficiency	Herbage yield (t/ha)	Oil yield (litres/ha)
	monocots	dicots				
Haloxyfop 750 ml/ha	2.00(1.58)	22.00(4.74)	14.76(217.95)	54.76	15.15	130.32
Haloxyfop 1000 ml/ha	1.44(1.39)	21.75(4.7)	11.14(123.16)	74.43	19.04	182.76
Haloxyfop 1250 ml/ha	1.43(1.39)	21.58(4.70)	11.71(136.28)	71.71	18.46	175.39
Pendimethalin 1000 ml/ha	1.90(1.54)	22.00(4.74)	12.27(149.61)	68.94	17.98	163.59
Quizalofop-ethyl 750 ml/ha	1.98(1.57)	22.00(4.79)	15.24(231.43)	51.96	14.88	126.43
Hand weeding (40 DAP)	1.41(1.38)	3.08(1.89)	11.97(142.33)	70.45	18.29	173.74
Weed free	1.39(1.37)	3.08(1.89)	1.00(0.00)	100	20.28	208.82
Weedy check	18.65(4.37)	24.58(5.01)	21.98(481.80)	00	8.38	69.67
LSD (P=0.05)	0.9	NS	0.78	-	0.49	-

Data in the parenthesis indicate the square root transformed value

CONCLUSIONS

Haloxyfop10.8% EC 1000 ml/ha –1250 ml/ha (108-135 g/ha) was significantly superior to other herbicidal treatments and found effective to control the major grassy weed flora and maximum herbages yield and oil content.

Comparative efficacy of post-emergence herbicides on wheat yield at farmers' fields

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Wheat (*Triticum aestivum* L.) is a major grain crop in India and staple food for billions of people of the world. Among the many factors adversely influencing wheat productivity, weed infestation is one of them and can reduces wheat yield by 37-50%. (Marwat *et al.* 2005). Thus, weed management is indispensable for increasing crop production. Under such circumstances, judicious use of herbicides is the only suitable way for effective and economical weed control. Numerous post-emergence herbicides are available globally to control weeds in wheat crop, that cause plant death by affecting protein or RNA biosynthesis. Keeping this in mind, the present study on bio-efficacy of ACM 9 as post-emergence herbicide against predominant weeds of wheat was conducted to assess the efficiency of this herbicide.

METHODOLOGY

The study was conducted at the fields of different farmers of Moga District located in Central Punjab during *Rabi* season 2015-16. The experiment was conducted at 12 different locations comprising nine different weed control treatments, viz. five different doses of ACM 9 (clodinafop + metribuzin) applied 300, 450, 600, 900 and 1200 g/ha, metribuzin 70% WP 300 g/ha, clodinafop-propargyl 15% WP 400 g/ha, weed free and weedy check as control. Wheat variety 'HD 2967' was sown in 23 cm spacing using 100 kg seed/ha in the first fortnight of November. Herbicides were applied at 2-3 leaf stage of weeds using knapsack sprayer fitted with a flat fan nozzle with the spray volume of water 500 L/ha while hand weeding treatment was practiced twice at 30 and 60 DAS.

RESULTS

Major weed flora at experimental site was *Phalaris minor, Medicago denticulate, Convolvulus arvensis, Fumaria parviflora, Chenopodium album* and *Rumex dentatus*. Weed density and biomass varied under different weed control treatments. Total weed density and fresh weight decreased with increase in dose of ACM 9. Maximum reduction in total weed density was recorded with application of ACM 9 at 1200 g/ha. This treatment was closely followed by ACM 9 at 900 g/ha (Table 1). Maximum weed density was observed in case unweeded control and minimum in case of weed free treatment. Among various herbicides tried, ACM 9 at 1200 g/ha recorded the lowest weed weight followed by its lower dose at 900 g/ha. Application of herbicides increased yield attributes as compared to control. Maximum plant height (90.1 cm) and effective tillers/m^2 (342.1) were observed in case of weed free treatment. Among the herbicidal treatments ACM 9 at 600 g/ha recorded highest effective tillers/m^2 (338.4) followed by ACM 9 at 900 g/ha. The highest grain yield of wheat was recorded with ACM 9 at 600 g/ha (5.62 t/ha). This was followed by weed free treatment (5.56 t/ha) and ACM 9 at 450 g/ha (5.31 t/ha). The post-emergence application of clodinafop 400 g/ha (4.42 t/ha) and metribuzin at 300 g/ha (4.69 t/ha) produced lower grain yield. These results were in accordance with other research workers (Singh *et al*. 2015) The per cent increase in grain yield with application of ACM 9 at 600 g/ha and at 450 g/ha was to an extent of 34.1 and 26.7%, respectively over weedy check.

Table 1. Weed dynamics and productivity of wheat as influenced by various post-emergence herbicides

Treatment	Dose (g/ha)	Weed density /m^2	Weed fresh weight (g/m^2)	Plant height (cm)	Effective tillers/m^2	Grain yield (t/ha)
ACM-9	300	14	35.7	84.9	307.3	4.91
ACM-9	450	15	32.9	86.0	314.3	5.31
ACM-9	600	8	19.3	86.3	338.4	5.62
ACM-9	900	2	4.2	82.2	337.1	5.13
ACM-9	1200	1	2.0	81.8	325.1	4.6
Metribuzin	300	23	55.9	86.0	336.4	4.42
Clodinafop	400	13	28.9	84.6	336.1	4.69
Hand weeding	-	-	-	90.1	342.1	5.56
Weedy check	-	41	81.6	79.9	300.1	4.19

CONCLUSION

On the basis of field study, it can be concluded that ACM 9 (clodinafop + metribuzin) at 600 g/ha was found optimum dose in wheat for effective control of weeds and to attain higher grain yield of wheat without any phytotoxicity to wheat.

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Weed management in turmeric based organic cropping system

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Turmeric (*Curcuma longa* L.) is largely grown as a rainfed crop during *Kharif* season. It is a long duration (8-9 months) and nutrients responsive crop. It is a long duration crop, invaded with a large number of weeds which pose a serious threat to its production. After the *Kharif* season, frequent irrigations are required which further make the weed problem more serious. The crop is infested through both viz., *Kharif* and *Rab*i season weeds. The manual weeding is a serious issue due to less availability of labour and higher wages. Under such situation, an alternative method of weed management through integrated system has to be explored.

METHODOLOGY

A field experiment was conducted during 2015-16 at Agronomy Research Farm of NDUAT Kumarganj, Faizabad. The experiment was laid out with 15 weed control treatment (Table 1) in randomized block design with three replications. The turmeric var. NH-1 was planted on the ridges in a plot size of 5.4 m × 6.0 m at spacing of 45 cm × 10 cm. After planting, 15 weed control treatments were executed in the experiment. Then in the next day, a light irrigation was given in which only 1/3rd ridges were filled with water.

RESULTS

Pendimethalin (PE) at 1.0 kg/ha *fb* straw mulch 10 t/ha *fb* three weeding and metribuzin (PE) 0.7 kg/ha *fb* straw mulch at 10 t/ha *fb* and hand weeding were found equally effective to control weed density and dry weight and also resulted highest weed control efficiency, i.e. 90.79%, 90.72% and 89.79%, respectively. Hand weeding thrice produced the highest fresh rhizome (32.6 t/ha) followed by metribuzin (PE) at 0.70 kg/ha *fb* straw mulch 10 t/ha *fb* one hand weeding treatment. Among the herbicidal treatment, the highest fresh rhizome yield 32.2 t/ha was recorded with treatment with hand weeding. Hand weeding thrice gave the highest net return of Rs. 41.26 X 10^3/ha but BCR was higher with metribuzin (PE) at 0.7 kg/ha + straw mulch 10 t/ha *fb* one hand weeding which was mainly because of low cost of cultivation with hand weeding as compare to unwedded check (Table 1).

Table 1. Effect of weed control treatments on the density of different weed species, total weeds, total dry weight, WCE and phytotoxicity at 60 DAP of turmeric

Treatment	Density of weed spp. (no. m^2)			*Phyto toxicity (%)*	Fresh rhizome yield (t/ha)	Net return (Rs X 10^3/ha)	B:C Ratio
	Total weeds (no/m^2)	Total dry weight (g)	(WCE (%)				
Metribuzin (PE) 0.7 kg/ha *fb* 2 HW	3.5 (12.3)	9.0(80.35)	82.35	0	27.5	33.27	3.10
Metribuzin (PE) 0.7 kg/ha *fb* POE fenozaprop 67 g/ha + met. 4 g/ha + 1HW	4.3(17.4)	9.3(85.5)	81.37	0	23.9	27.71	2.63
Metribuzin (PE) 0.7 kg/ha *fb* SM 10 t/ha fb 1HW	2.8(6.6)	6.8(45.3)	90.72	0	32.2	40.91	3.86
Pendimethalin (PE) 1.0 kg/ha *fb* 2HW	3.5(11.4)	8.4(81.2)	84.33	0	30.0	37.26	3.47
Pendimethalin (PE) 1.0 kg/ha *fb* fenozaprop 67 g/ha + Mets. 4 g/ha 1HW	4.2(16.8)	9.0(81.2)	82.35	0	26.0	31.05	2.94
Pendmethalin (PE) 1.0 kg/ha *fb* SM 10 t/ha fb one HW	2.8(7.5)	6.9(46.0)	89.79	0	30.8	38.66	3.64
Atrazin (PE) 0.75 kg/ha *fb* 2 HW	4.4(18.2)	9.4(80.5)	82.09	0	24.0	27.76	2.61
Atrazin (PE) 0.75 kg/ha *fb* fenozaprop 67 g/ha + Mets. 4 g/ha 1HW	2.9(7.7)	7.1(49.7)	89.11	0	26.9	32.59	3.11
Atrazin (PE) 0.75 kg/ha *fb* SM 10 t/ha *fb* 1 HW	2.9(7.5)	6.9(47.0)	89.70	0	27.1	32.84	3.12
Oxyfluorfen at 0.30 kg/ha *fb* 2 HW	3.5(11.0)	8.7(75.0)	83.56	0	30.3	37.94	3.50
Oxadiargyl 0.25 kg/ha *fb* 1 HW	3.5(11.0)	8.8(75.5)	83.45	0	29.0	35.75	3.35
Glyphosate (POE) 5.0 ml/lit *fb* 1HW	3.6(12.3)	9.0(79.7)	82.68	0	29.2	36.01	3.36
Glyphosate (PEO) 7.5 ml/lit *fb* 2 HW	2.9(6.6)	6.8(45.7)	89.98	0	30.5	37.72	3.51
HW at 25, 45 and 75 DAP	2.9(7.3)	6.6(42.0)	90.79	-	32.6	41.26	3.79
Unweeded check	9.7(92.3)	21.4(456.2)	0.0	-`	8.5	36.55	0.37

fb: Followed by, H: Hoeing. SM= straw mulch (rice), HW: Hand weeding, MSM: Metsulfuron methyl, WCE: Weed control efficiency, DAP: Days after planting, PE: Pre-emergence, POE: Post-emergence

CONCLUSIONS

Metribuzin (PE) at 0.7 kg/ha or pendimethalin (PE) at 1 kg/ha along with rice straw mulch at 10 t/ha + 1 HW were found most effective to control the weeds, and also produced higher yield and more profite of turmeric

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Weed management in organic maize-garlic production system under mid hill conditions of Himachal Pradesh

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Agriculture in Himachal Pradesh needs special focus as it is the main occupation employing 71% of the working population in the state. It accounts for 21.1% of the total domestic product. The main problem in crop production is the occurrence of weeds which interfere with the crop and cause huge losses in yield. Weeds are often recognized as the most serious threat to organic crop production and fear of ineffective weed control is often perceived by farmers as one of the major obstacles to conversion from conventional to organic farming. Since synthetic chemicals are not allowed, weed control is a great challenge for researchers under organic production systems. Keeping in view, the present investigation has been initiated in the maize – garlic cropping system to evolve viable weed management practices for this system under its organic management. Potent methods of non-chemical weed control that could be used in organic systems involves both direct and indirect methods such as intercropping, stale seed bed, raised beds, crop rotations, mulches and cover crops (Bond et al. http://www.organicweeds.org.uk).

METHODOLOGY

Ten treatments viz. Hoeing followed by *fb* earthing up in maize and hoeing twice in garlic ; stale seed bed (SSB) *fb* hoeing and earthing up in maize and SSB *fb* hoeing + hand weeding in garlic ; raised stale seed bed in *fb* hoeing *fb* earthing up in maize and RSSB *fb* hoeing + handweeding in garlic ; mulch in both maize and garlic, SSB + mulch both in maize and garlic ; RSSB + mulch both in maize and garlic; intercropping (soybean in maize and coriander/methi in garlic) ; rotation of crops (maize/soybean in *Kharif* and garlic/pea in rabi) fb hoeing *fb* earthing up in *Kharif* and hoeing and hand weeding in *Rabi* ; intensive cropping i.e mulch + manual weeding in *Kharif fb* autumn of coriander and mulch + manual weeding in *Rabi* fb green manure crop in summer and chemical check (atrazine + pendimethalin in maize and pendimethalin in garlic + hand weeding if required) are being tested in RBD with three replications. The maize crop was sown on 4th June 2016 and harvested by end of August. The subsequent garlic/pea crop was sown on 11 November 2016.

RESULTS

The results of the study revealed significant variation in the count of grassy weeds. Intercropping of soybean with maize resulted in significantly lower count of grassy weeds than most of the other weed control treatments. Sedges were found to be sensitive to intercropping competition and were completely eliminated under T_7. Population of broadleaved weeds was not significantly affected due to weed control treatments. However, treatments brought about significant variation in total weed count. Intercropping treatment resulted in significantly lower total weed count. The other treatments are more or less similar to chemical check. Plant height varied significantly. Treatments under study could not significantly affect number of cobs/plant but the cob weight varied significantly. Intercropping treatment resulted in higher cob weight significantly more than chemical check but it was comparable to most other treatments. The other treatments were more or less similar to chemical check in influencing the maize green cob yield. Intercropping of soybean increased maize green cob yield by 114.2% over the chemical check.

Table 1. Effect of treatments on weed count (m^2) and yield attributes and yield of maize

Treatment	Grasses	Sedges	Broad-leaved	Total weed count	Plant height (cm)	Cobs/plant (No)	Cob weight (g/cob)	Cob yield (kg/ha)
Hoeing *fb* earthing up in maize and hoeing twice in garlic	3.6 (37.7)	2.4 (5.3)	4.2 (17.0)	6.1 (37.7)	173.3	0.87	187.5	4533
SSB *fb* hoeing and earthing up in maize and SSB fb hoeing + HW in garlic	4.0 (45.0)	3.9 (15.3)	3.6 (12.7)	6.7 (45.0)	170.3	0.73	204.2	4250
RSSB fb hoeing fb earthing up in maize and RSSB *fb* hoeing + HW in garlic	3.6 (36.3)	2.5 (7.3)	3.6 (13.0)	6.0 (36.3)	190.0	0.73	162.5	3471
Mulch both in maize and garlic	4.8 (31.0)	1.4 (2.0)	2.0 (5.0)	5.6 (31.0)	169.7	0.80	179.2	4274
SSB + mulch both in maize and garlic	5.6 (53.7)	2.0 (3.7)	4.2 (18.3)	7.3 (53.7)	192.7	0.87	170.8	4179
RSSB + mulch both in maize and garlic	5.3 (41.7)	1.3 (1.3)	3.4 (11.7)	6.4 (41.7)	192.7	1.00	233.3	6800
Intercropping	2.5 (10.0)	0.7 (0.0)	1.8 (3.3)	3.1 (10.0)	176.7	1.00	291.7	8500
Rotation of crops	3.4 (31.7)	2.3 (5.3)	3.3 (11.0)	5.6 (31.7)	174.3	0.87	250.0	6044
Intensive cropping	4.8 (37.0)	2.0 (3.7)	3.0 (10.7)	6.1 (37.0)	187.3	0.80	237.5	5383
Chemical check	3.7 (32.7)	2.2 (4.7)	3.8 (14.0)	5.8 (32.7)	173.7	0.87	162.5	3967
LSD (P=0.05)	1.7	1.2	NS	1.5	16.7	NS	77.1	2095

Data transformed to square root transformation; Figures in parentheses are the means of original values.

CONCLISION

The initial analysis concludes intercropping to the viable proposition for suppressing weeds under organic crop production systems. Thus it must form an integral component for any weed management strategy for any organic weed management programme.

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Evaluation of pyrazosulfuron-ethyl 10% WP against weeds in transplanted rice

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The average productivity of rice in Himachal Pradesh state is low as compared to its productivity at the national level as well as those of the adjoining states. One of the major reasons for this low productivity is the losses caused due to weeds. Though a number of herbicides have been recommended for managing weeds in rice crop in our state (butachlor, oxadiargyl, pendimethalin, bispyribac-sodium, cyhalofop butyl etc.) but most of the farmers are only using a single chemical (butachlor) for managing weeds in rice. This herbicide has been in use for the past many years and of late there are few reports as well as feedback from the farmers that certain weeds are not being controlled by this herbicide. Few other herbicides have been developed and released by the private herbicide manufacturers for efficiently managing weeds in rice crop. One such herbicide pyrazosulfuron-ethyl is a low dose high efficacy herbicide coming under the group of sulfonyl ureas which is effective for controlling a wide range of weeds (all three types of grassy, broadleaved and sedges) (Saini 2003) in transplanted as well as direct seeded low land rice.

METHODOLOGY

Ten treatments comprised of company released samples of pyrazosulfuron-ethyl 10% WP at 10, 15, 20 and 30 g/ha was compared to market samples of pyrazosulfuron-ethyl 10% WP at 10 and 15 g/ha, bispyribac-sodium 20 and 40 g/ha, hand weeding twice and weedy check were tested in randomized block design with three replications.

RESULTS

Echinochloa crusgalli (16.7%), E. Colona (14.8%), *Cyperus difformis* (20.2%), C. Iria (9.5%), and *Ammannia baccifera* (37.7%) were the major weeds found growing in association with transplanted rice during *Kharif* 2016. *Panicum dichoromiflorum* (0.6%), *Paspalum* sp. (0.5%) and *Aechynomene indica* (0.1%) were the other weed species having little infestation in the experimental field. Weed control treatments brought about significant variation in the count of grasses, sedges and broad-leaved weeds (Table 1).

All weed control treatments were significantly superior to weedy check in curtailing the population of grasses, sedges and broadleaved weeds. Hand weeding twice resulted in significantly lower count of all categories of weeds. Control of weeds appeared to be improved with increase in the dose of pyrazosulfuron-ethyl but differences in the doses of pyrazosulfuron-ethyl were not significant. Pyrazosulfuron-ethyl gave control of weeds comparable to that with bispyribac-sodium. All treatments gave significantly higher yield of transplanted rice over the weedy check (Table 2). Pyrazosulfuron-ethyl 20 g/ha remaining at par with pyrazosulfuron-ethyl 15 g/ha gave significantly higher yield over other weed control treatments. Samples of pyrazosulfuron-ethyl obtained directly from the industry had an edge over the market samples. On an average, weeds reduced grain yield of paddy by 53.7%.

Table 1. Effect of treatments on count of grasses, sedges and broad-leaved weeds in transplanted rice

Treatment	Dose (g/ha)	Grasses	Sedges	Broad-leaved	Total
Pyrazosulfuron–ethyl 10% WP	10	5.0(24.7)	5.1(25.7)	5.6(31.3)	9.0(81.7)
Pyrazosulfuron–ethyl 10% WP	15	4.8(22.3)	4.8(22.3)	5.5(30.3)	8.7(75.0)
Pyrazosulfuron–ethyl 10% WP	20	4.9(23.3)	4.6(20.7)	5.5(30.0)	8.6(74.0)
Pyrazosulfuron–ethyl 10% WP	30	4.6(20.3)	4.6(20.7)	5.3(28.0)	8.3(69.0)
Pyrazosulfuron –ethyl 10% WP (matket sample)	10	5.3(27.7)	5.0(24.7)	6.0(35.7)	9.4(88.0)
Pyrazosulfuron –ethyl 10% WP (matket sample)	15	5.0(25.0)	4.7(21.3)	5.0(25.0)	8.5(71.3)
Bispyribac–sodium	20	4.9(24.3)	4.5(20.0)	4.5(19.7)	8.0(64.0)
Bispyribac–sodium	40	4.8(22.3)	4.3(18.0)	5.0(24.3)	8.1(64.7)
Hand weeding twice		0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)
Weedy check		6.6(43.7)	6.3(39.7)	6.9(47.3)	11.4(130.7)
LSD (P=0.05)		0.7	0.5	0.6	0.7

Table 2. Effect of treatments on yield attributes and yield or rice

Treatment	Phyto-toxicity	Tillers (No/hill)	Plant height (cm)	Panicle length (cm)	Grain yield (kg/ha)
Pyrazosulfuron–ethyl 10% WP	1.0	13.2	100.0	19.7	1132
Pyrazosulfuron–ethyl 10% WP	1.2	13.4	101.3	19.8	1937
Pyrazosulfuron–ethyl 10% WP	1.3	14.2	102.6	21.5	2001
Pyrazosulfuron–ethyl 10% WP	1.8	13.9	100.8	20.7	1520
Pyrazosulfuron–ethyl 10% WP (matket sample)	1.3	13.6	99.1	20.5	1626
Pyrazosulfuron–ethyl 10% WP (matket sample)	1.3	13.6	100.5	20.2	1684
Bispyribac–sodium	1.0	13.8	99.8	19.7	1614
Bispyribac–sodium	1.4	14.2	100.1	21.4	1180
Hand weeding twice	0.0	14.4	99.9	19.9	1409
Weedy check	0.0	11.9	95.7	18.3	927
LSD (P=0.05)	0.5	0.9	2.7	1.0	287

CONCLUSION

For effective weed management in transplanted rice pyrazosulfuon-ethyl 20 g/ha can be a better alternative to bispyribac-sodium. Samples of pyrazosulfuron-ethyl obtained directly from the industry had an edge over the market product.

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Effect of sequential and mixed applications of herbicides against different weeds in wheat

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Wheat crop is generally infested with grassy as well as broad-leaved weeds and cause yield loss of 7 to 50% depending upon weed flora and their intensity (Singh *et al.*, 2004). Sequential and combination or mixed application of herbicides is used for effective and economical weed control. It offers certain advantage like broad spectrum of herbicidal action, enhance herbicide efficiency through synergistic effect, reduce cost of weed management, arrest weed shifts, prevent herbicide resistance in weeds and facilitate improvement in overall weed management (Bharat and Kachroo, 2010). Hence, an experiment was conducted to evaluate the effect of sequential and mixed application of herbicides on weeds in wheat under Jammu conditions of northern India.

METHODOLOGY

A field experiment was conducted in *Rabi* 2015-16 at AIRCP-Weed Management, Division of Agronomy, SKUAST-Jammu. The experiment comprising of seven treatments was laid out in randomized block design with three replications. Pendimethalin was applied as pre-emergence on the next day of sowing in 500 litres of water/ha. In the treatment having sulfosufuron with surfactant followed by (*fb)* 2,4-D, sulfosulfuron was applied at 35 DAS and 2,4-D was applied on the next day of application of sulfosulfuron. All other herbicides were applied at 35 DAS in 500 litres of water using flat fan nozzle.

RESULTS

The most dominant weed species found in experimental field during crop growth period were *Phalaris mionr and Avena spp.* amongst grassy weeds*; Rumex spp., vicia spp., Anagallis arvensis and Melilotus indica* amongst broad-leaved weeds and *Rananculus arvensis, Chenopodium album* and *medicago denticulata* amongst other weeds. All the herbicidal treatments significantly reduced the density of grassy and broad-leaved weeds in comparison to weedy cheek. The lowest grassy weed density and weed biomass was recorded in clodinafop + metsulfuron 0.06 kg/ha. The lowest density of broad-leaved weeds and biomass was recorded with pendimethalin 0.75 kg/ha *fb* 2,4-D 0.5 kg/ha which was statistically at par with clodinafop + metsulfuron 0.06 kg/ha and sulfosulfuron 25 g/ha *fb* 2,4-D 0.5 kg/ha. The lowest biomass of broad-leaved weeds was recorded with clodinafop + metsulfuron 0.06 kg/ha which was statistically at par with pendimethalin 0.75 kg/ha *fb* 2,4-D 0.5 kg/ha, clodinafop 0.06 kg/ha + 2,4-D 0.06 kg/ha and sulfosulfuron 25 g/ha *fb* 2,4-D 0.5 kg/ha. The lowest biomass of total weeds was recorded with clodinafop + metsulfuron 0.06 kg/ha which was statistically at par with clodinafop 0.06 kg/ha + 2,4-D 0.06 kg/ ha and sulfosulfuron 25 g/ha *fb* 2,4-D 0.5 kg/ha.

Table 1. Density of weeds (no./m^2) as influenced by different weed management treatments in wheat at 60 DAS

Treatment	Grassy weeds		Broad leaved weeds					
	Phalaris minor	*Avena* spp.	*Rumex spp.*	*Vicia spp.*	*Anagallis arvensis*	*Melilotus indica*	Others	Total
Pendimethalin 0.75 kg/ha	3.60 (12)	2.83 (7)	2.83 (7)	2.45 (5)	3.87 (14)	3.16 (9)	2.64 (6)	7.81 (60)
Pendimethalin 0.75 kg/ha *fb* 2,4-D 0.5 kg/ha	3.46 (11)	2.65 (6)	1.00 (0)	1.00 (0)	1.99 (3)	1.41 (1)	1.99 (3)	4.99 (24)
Clodinafop + metsulfuron 0.06 kg/ha	1.73 (2)	1.00 (0)	1.99 (3)	1.00 (0)	1.73 (20)	1.00 (0)	1.72 (2)	3.16 (9)
Clodinafop 0.06 kg/ha + 2,4-D 0.5 kg/ha	1.87 (3)	1.00 (0)	1.41 (1)	1.73 (2)	2.24 (4)	1.72 (2)	1.41 (1)	3.67 (13)
Sulfosufuron 25 g/ha	1.99 (3)	1.00 (0)	4.12 (16)	2.64 (6)	3.60 (12)	2.83 (7)	2.23 (4)	7.00 (48)
Sulfosufuron 25 g/ha *fb* 2,4-D 0.5 kg/ha	2.23 (4)	1.00 (0)	1.99 (3)	1.00 (0)	1.73 (2)	1.73 (2)	1.41 (1)	3.60 (12)
Weedy check	4.80 (22)	3.74 (13)	4.36 (18)	3.16 (9)	4.90 (23)	4.00 (15)	4.00 (15)	10.77 (115)
LSD (p=0.05)	0.25	0.12	0.22	0.16	0.28	0.21	0.24	0.32

Data was subjected to square root transformation " X+1. Original values are in parentheses

Table 2. Weed biomass and grain yield of wheat as influenced by different weed management treatments in wheat

Treatment	Weed biomass (g/m^2) at 60 DAS			Grain yield (kg/ha)	Net returns (Rs./ha)	B: C ratio
	Grassy	Broad-leaved	Total			
Pendimethalin 0.75 kg/ha	5.08 (24.9)	5.18 (25.9)	7.19 (50.8)	3597	43533	1.88
Pendimethalin 0.75 kg/ha fb 2,4-D 0.5 kg/ha	5.11 (25.2)	2.66 (6.1)	5.68 (31.3)	4154	53614	2.25
Clodinafop + metsulfuron 0.06 kg/ha	1.88 (2.5)	2.48 (5.2)	2.95 (7.8)	4367	58663	2.55
Clodinafop 0.06 kg/ha + 2,4-D 0.5 kg/ha	1.98 (2.9)	2.86 (7.2)	3.34 (10.1)	4272	57255	2.56
Sulfosufuron 25 g/ha	2.38 (4.7)	5.45 (28.8)	5.86 (33.5)	3996	52163	2.34
Sulfosufuron 25 g/ha fb 2,4-D 0.5 kg/ha	2.21 (3.9)	2.77 (6.8)	3.41 (10.7)	4193	55438	2.41
Weedy check	6.30 (38.7)	8.04 (63.6)	10.16 (102.4)	3076	35353	1.67
LSD (P=0.05)	0.37	0.39	0.46	490	-	-

Different weed management treatments recorded highest grain yield with clodinafop + metsulfuron 0.06 kg/ha which was significantly superior to pendimethalin 0.75 kg/ha and weedy check. The highest B: C ratio was also recorded with clodinafop 0.06 kg/ha + 2,4-D 0.5 kg/ha which was followed by clodinafop + metsulfuron 0.06 kg/ha and sulfosulfuron 25 g/ha *fb* 2,4-D 0.5 kg/ha.

CONCLUSION

It was concluded that mixed application of clodinafop 0.06 kg/ha + 2,4-D 0.5 kg/ha and clodinafop + metsulfuron 0.06 kg/ha were most economical for controlling weeds and improving grain yield of wheat.

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Effect of crop geometry and weed management practices on weed dynamics and yield of soybean

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Soybean (*Glycine Max*. L. Merrill.) grown in rainy season faces severe weed competition. Weed competition in soybean at early stage of crop growth is critical, as it causes yield losses up to 35 to 50%. The incessant rains do not permit timely inter-cultivations and manual control of weeds is also difficult on large scale on account of high cost and labour shortage during weeding peaks. Therefore, there is a need for alternative methods of reducing the weed load during crop weed competition period of soybean i.e. first 30-45 DAS. Therefore, present investigation was conducted to study the effect of crop geometry and weed management practices on growth and yield of soybean.

METHODOLOGY

The experiment was conducted during *Kharif* season, 2015 at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri. The experiment was laid out in FRBD consisted of two factors, first crop geometry second factor was weed management practices as in table.

RESULTS

The crop geometry of 45 x 5 cm spacing recorded significantly the lowest total weed density (3.22/m^2) and dry matter production of weed (5.28 g/m^2) at harvest as compared to 30 x 10 cm spacing. Among the weed management practices pendimethalin 38.7% CS pre-emergence (PE) at 0.750 kg/ha followed by *(fb)* tank mix imazethapyr 10% SL + propaquizafop 10% EC at (80 + 60 g/ha) at 25 DAS recorded significantly lowest weed density and at 28 DAS and pendimethalin 38.7% CS (PE) at 0.750 kg/ha *fb* one hand weeding at 30 DAS recorded lowest weed count at harvest. The crop geometry 45 x 5 cm recorded significantly the highest soybean grain yield (2.08 t/ha), straw yield (2.85 t/ha) as compared to 30 cm x 10 cm spacing. Among the weed management treatments weed free check treatment recorded significantly highest soybean grain yield (2.19 t/ha) and straw yield (2.71 t/ha) but was at par with treatments pendimethalin 38.7% CS (PE) at 0.750 kg/ha *fb* one hand weeding at 30 DAS (2.17 t/ha), (2.71 t/ha), respectively and pendimethalin 38.7% CS (PE) at 0.750 kg/ha *fb* tank mix imazethapyr 10% SL + propaquizafop 10% EC at 80 + 60 g/ha at 25 DAS (2.15 t/ha), (2.70 t/ha), respectively. Between the crop geometry 45 x 5 cm spacing recorded significantly the highest net monetary returns (₹ 38205 ha) and B:C Ratio (1.96) of soybean crop as compared to 30 cm x 10 cm crop geometry (30411 ha) and (1.81), respectively. Among the weed management treatments pendimethalin 38.7% CS PE 0.750 kg/ha *fb* tank mix Imazethapyr 10% SL + Propaquizafop 10% EC (80 + 60 g/ha) at 25 DAS recorded significantly highest net monetary returns (44362/ha) and B: C Ratio (2.21) but was at par with Pendimethalin 38.7% CS PE 0.750 kg/ha *fb* one hand weeding at 30 DAS (43858/ha) and (2.16).

Table 1. Effect of crop geometry and weed management practices on weed dynamics

Treatment	Total weed count (no./m^2)			Weed dry matter (g/m^2)
	28 DAS	56 DAS	At harvest	
Crop geometry(S)				
30 x 10 cm	3.76(20.06)	3.45(17.79)	3.46(17.99)	5.63(49.91)
45 x 5 cm	3.55(18.65)	3.21(16.38)	3.22(16.59)	5.28(46.25)
LSD (P=0.05)	0.15	0.19	0.19	0.07
Weed management practices				
Pendimethalin 38.7% CS (PE) at 0.750 kg/ha *fb* one hand weeding at 30 DAS.	3.89(14.66)	2.44(5.49)	2.44(5.49)	4.04(15.85)
Pendimethalin 38.7% CS (PE) at 0.750 kg/ha *fb* tank mix imazethapyr 10% SL + propaquizafop 10% EC at 80 + 60 g/ha at 25 DAS	1.67(2.33)	2.59(6.32)	2.59(6.32)	4.39(18.88)
One hoeing at 15 DAS *fb* hand weeding at 30 DAS.	3.96(15.32)	2.74(7.15)	2.74(7.15)	4.47(19.60)
Weedy check.	8.06(64.48)	8.18(66.48)	8.24(67.48)	13.66(186.07)
Weedy free check.	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)
LSD(P=0.05)	0.24	0.30	0.30	0.10

Table 2. Effect of crop geometry and weed management grain, straw yield and economics of soybean

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Cost of cultivation (`/ha)	Net returns (x 10^3 `/ha)	B : C Ratio
Crop geometry					
30 cm x 10 cm	1.829	2.234	38394	30.41	1.81
45 cm x 5 cm	2.080	2.850	40185	38.20	1.96
LSD(P=0.05)	0.026	0.030	-	961.06	0.03
Weed management practices					
Pendimethalin 38.7% CS (PE) at 0.750 kg/ha *fb* one hand weeding at 30 DAS.	2.166	2.705	37649	43.85	2.16
Pendimethalin 38.7% CS (PE) at 0.750 kg/ha *fb* tank mix imazethapyr 10% SL + propaquizafop 10% EC at 80 + 60 g/ha at 25 DAS	2.153	2.701	36649	44.36	2.21
One hoeing at 15 DAS *fb* hand weeding at 30 DAS.	2.004	2.452	37829	37.55	1.99
Weedy check.	1.261	2.139	31329	16.40	1.52
Weedy free check.	2.189	2.712	52989	29.36	1.55
LSD(P=0.05)	0.041	0.048	-	1519.57	0.05

CONCLUSION

It was concluded that sowing of soybean crop at 45 x 5 cm and weed management through pre-emergence application of pendimethalin 38.7% CS 0.750 kg/ha *fb* tank mix imazethapyr 10% SL + propaquizafop 10% EC at 80 + 60 g/ha at 25 DAS or pre-emergence application of pendimethalin 38.7% CS (PE) at 0.750 kg/ha *fb* one hand weeding at 30 DAS was found most effective for controlling weeds, improving grain yield and profitability of soybean crop under labour constraints.

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Purple nut sedge management in *Rabi* onion

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Onion is one of the important commercial crops grown in Odisha during winter season covering an area of 35.8 thousand hectares with production of 432 thousand tones and productivity of 12.07 tones/ha . It is highly vulnerable to weed infestation due to its slow initial growth, non branching habit, upright leaves, shallow root system. During cold season, perennial sedges especially purple nut sedge (*Cyperus rotundus* L.) is a serious problem as light and frequent irrigation cause their underground propagules to germinate in flushes. The present investigation was undertaken to study the effect of sequential application of different herbicide on control of purple nut sedge control and onion productivity.

METHODOLOGY

A field experiment was carried out during *Rabi* 2014 - 15 and 2015 - 16. Six treatments consisting of glyphosate at 1500 g/ha sprayed on purple nutsedge 10 days before planting onion, oxyfluorfen at 200 g/ha as pre-plant application, glyphosate at 1500 g/ha 10 days before planting onion followed by oxyfluorfen at 200 g/ha as post-emergence application at 20 days after planting onion, post emergence application of oxyfluorfen at 200 g/ha + quizalofop-ethyl at 50 g/ha at 20 days after planting (farmer's practice), weed free, weedy check were tried in randomized block design with 4 replications. Recommended package of practices for this region were followed. Data were recorded on weed growth (density and biomass) at 50 DAT, yield attributes and yields at harvest. Data on individual and total weed density and weed dry weight were subjected to square root transformation "x+0.5.

RESULTS

Among the treatments, glyphosate followed by post emergence application of oxyfluorfen recorded less number of nut sedge. Repeating the glyphosate application in both year, it was noticed that purple nut sedge population in 2nd year was drastically reduced in comparison to the 1st year with application of glyphosate in same dose. The cost effectiveness of stale seed bed using glyphosate for nut sedge control in rice–vegetable cropping system was reported by Islam *et al* (2009). Post emergence application of oxyfluorfen after glyphosate was found to show spectacular inhibitory effect on 2nd flushes of nut sedge and its multiplication and this treatment recorded the highest percentage of reduction (41 and 87% respectively in 1st and 2nd year respectively) in nut sedge population. Among different weed management practices the pooled data of 2 years indicated that pre plant application of glyphosate 1500 g/ha at 10 days before planting with post emergence application of oxyfluorfen 200 g/ha at 20 days after planting recorded significantly higher bulb yield of 21.89 t/ha followed by sole application of glyphosate 1500 g/ha. The lowest bulb yield was observed in weedy check (10.5 t/ha). Higher yield might be due to increase in bulb length (6.8cm), bulb diameter (5.9 cm) and bulb weight (78.18 g) under weed free treatments. All the herbicide treatment showed significantly higher bulb yield over weedy check (30.48 to 61.6%). This was due to the fact that the less competition for moisture, light and nutrient uptake by crop plants. The higher assimilation of photosynthesis in weedicide treated plots may be the reason for higher yield.

Treatment	Nutsedge density (no./m^2) 2014	Nutsedge dry matter (g.m2)			Plant height (cm)	Bulb length (cm)	Bulb diameter (cm)	Neck length (cm)	Neck thickness (cm)	Bulb weight (g)	Bulb yield (t/ha)		
		2015	2014	2015							2014	2015	Pooled
Glyphosate(T1)	35 (5.9)	9(3.0)	4(2.0)	1.6(1.4)	42.8	5.9	5.3	5.76	1.34	70.34	18.13	21.32	19.73
Oxyfluorfen(T2)	36(6.0)	22(4.7)	4.8(2.3)	1.8(1.5)	35.9	4.9	4.5	5.42	1.26	48.93	12.88	17.54	15.21
T1 fb T2 (T3)	27(5.2)	5(2.3)	3.5(2)	1.2(1.3)	45.3	6.8	5.9	5.98	1.39	78.18	20.81	22.97	21.89
Oxyfluorfen + Targasuper(T4)	38(6.2)	27(5.2)	4.1(2.1)	1.8(1.5)	38.6	5.1	4.6	5.63	1.31	52.77	16.15	19.21	17.68
Weed free(T5)	0(0.7)	0(0.7)	0(0.7)	0(0.7)	48.6	8.1	6.3	6.24	1.45	84.36	23.11	23.54	23.33
Weedy check(T6)	46(6.8)	39(6.2)	6(2.5)	5.2(2.3)	32.4	3.6	3.3	5.42	1.26	37.93	12.22	14.87	13.55
(P=0.05)	0.92	0.78	0.41	0.32	4.17	0.88	0.92	0.67	NS	19.31	3.9	3.6	3

Values in parentheses are squre root transformed value

CONCLUSION

Pre plant application of glyphosate 1500 g/ha at 10 days before planting followed by oxyfluorfen 200 g/ha at 20 days after planting was the most effective treatment in controlling purple nut sedge (*Cyperus rotundus*) in onion as compared to sole application of glyphosate at same dose.

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Effect of weed management measures in greengram

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Green gram is an important pulse crop of India. Being a rainfed *kharif* crop, weed infestation is one of the most important factors of low productivity besides other constraints. Weeds are the silent competitors/removers of natural and man-made resources like nutrients, water and light, which could have been otherwise for boosting up crop productivity (Singh and Sheoran 2008). Weeding and hoeing are common cultural and manual weed management methods for greengram. Manual weeding at optimum stage is difficult, time consuming and expensive due to intermittent rainfall during rainy season and scanty labour. Under such situation, herbicides use with suitable dose remains the pertinent choice for controlling the weeds. Herbicides in isolation, however, are unable to control complete weed infestation because of their selective kill. Their use can be made more effective if one or two herbicides were mixed together to control diversified weed flora.

METHODOLOGY

A field study was conducted during *Kharif* season of 2015 at Research farm of Agriculture Research Station, Swami Keshwanand Rajasthan Agricultural University, Bikaner. The treatments consisting of pendamethalin 1000 g/ha and imazethapyr + pendamethalin at 800-1000g/ha as pre-emergence. Post-emergence treatments included different doses of imazethapyr (Ready mix) at 50 and 70g/ha, imazethapyr + imazamox (Ready mix) at 60 and 70g/ha and compared with two hand weeding at 20 & 40 DAS and weedy check were evaluated in randomized block design with three replications. Greengram 'SML-668' was sown on 02 July 2015 at 30 cm row to row spacing using seed rate of 20 kg/ha. Recommended dose of fertilizers (20 kg N + 40 kg P + 40 kg K/ha) was applied as basal dose.

RESULTS

The density and dry weight of weeds were significantly reduced by all weed control treatments compared to weedy check, however, two hand weeding recorded lowest weeds compared to rest of the weed control treatments (Table 1). Among the different herbicidal treatments, pre-emergence application of imazethapyr + pendamethalin 1000 g/ha as pre sown was found effective in reducing the density and dry weight of weeds followed by its lower dose (imazethapyr + pendamethalin 900 and 800 g/ha), imazethapyr + imazamox 60 g and 70 g/ha were found next best chemical. The highest value of number of branches per plant was under treatment two hand weeding, which was at par with imazethapyr + pendamethalin 800, 900 and 1000 g/ha. This might have

Table 1. Effect of weed control measures on weeds, yield and economics of greengram

Treatment	Weed density/m^2	Weed dry weight (g/m^2)	Branches/ plant	Pods/ plant	Seeds/ pod	Seed yield (kg/ha)	Straw yield (kg/ha)
Pendimethalin	6.02 (35.77)*	5.95 (35.00)	3.93	58.33	5.62	810	1682
Imazethapyr	4.07 (16.20)	2.60 (6.33)	3.69	54.20	5.38	759	1643
Imazethapyr	3.50 (11.80)	2.02 (3.67)	3.72	54.27	5.41	783	1696
Imazethapyr + pendimethalin 800g (PE)	2.25(4.60)	1.17 (1.00)	4.14	64.33	5.83	902	1745
Imazethapyr + pendimethalin 900g (PE)	1.83 (2.97)	1.05 (0.67)	4.10	65.47	5.79	928	1784
Imazethapyr + pendimethalin 1000g (PE)	0.92 (0.40)	0.88 (0.33)	4.04	62.43	5.73	890	1712
Imazethapyr +imazamox 60 g	3.08 (9.00)	2.11 (4.33)	3.88	55.73	5.57	805	1636
Imazethapyr +imazamox 70 g	1.92 (3.23)	1.05 (0.67)	3.77	56.80	5.46	803	1654
Two hand weeding	0.85 (0.23)	0.71 (0.00)	4.25	68.70	5.98	1031	1812
Weedy check	8.52 (72.33)	7.67 (58.33)	2.95	43.67	4.64	665	1202
LSDCD (P=0.05%)	0.62	0.68	0.53	7.44	0.13	151	250

*Values in parentheses are original. Data transformed to square root transformation

resulted in better availability of moisture and nutrients to the crop in absence of weeds. Moreover increased nutrient and water uptake by crop, which could be increased photosynthate which supply more carbohydrates, resulted in increase cell division and elongation of cells resulted to increase number of branches. Among different treatments, imazethapyr + pendimethalin 800 g/ha recorded higher pods/plant, seeds/pod, seed and straw yield over weedy check and was at par with its upper doses and two hand weeding. Kantar *et al.* (1999) also observed 63.6% higher seed yield over unweeded check with application of imazethapyr. The reduced crop weed competition caused significant increase in growth characters and yield ultimately led to higher seed yield of greengram.

CONCLUSION

It was concluded that application of imazethapyr + pendimethalin 800g (pre-mix) was more effective in controlling all weeds, increasing seed and straw yield and economically feasible in greengram in arid regions.

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Response of weed control measures to weeds, yield and economics of groundnut

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Groundnut (*Arachis hypogaea* L.) is the major oilseed crop and king of vegetable oilseeds in India and is a rich source of protein (26%) and contains 45% oil. The low yields of groundnut are attributed to many factors like losses caused by weeds are of serious nature. Weeds reduce yields by competing with the groundnut plant for resources, such as sunlight, moisture, space, and nutrients not only throughout the growing season, but also create problem during digging and inverting procedures and reduce harvesting efficiency. In the initial growth of crop there is relatively shallow canopy and it slowly shades the inter-row area, which allows bumper weeds growth and thus groundnut crop becomes more susceptible to weed crop competition in the earlier growth period of the crop.

METHODOLOGY

A field study was conducted during *Kharif* season of 2015 at Research farm of Agriculture Research Station, Swami Keshwanand Rajasthan Agricultural University, Bikaner. Fourteen weed control treatments comprising of *viz*. pendimethalin 1.0 kg/ha (PPI), pendimethalin 1.0 kg/ha (PE), imazethapyr + pendimethalin 800 g/ha, imazethapyr + pendamethalin 900 g/ha, imazethapyr + pendamethalin 1000 g/ha, imazethapyr 50 g/ha, imazethapyr 70 g/ha, imazethapyr + imazemox 60 g/ha, imazethapyr + imazemox 70 g/ha, oxyfluorfen 40 g/ha, fenoxaprop-ethyl 50 g/ha, propaquizafop 62 g/ha, 2 hand weeding at 20 & 40 DAS and weedy check were evaluated in randomized block design with three replications. Groundnut 'HNG-10' was sown on 26 June 2015 at 30 cm row-to row spacing and was harvested on 28 October 2015.

RESULTS

All the treatments were responsible for significant reduction in weed density and dry weight of weeds over weedy check (Table 1). Weed free treatment resulted in lowest weed density and dry weight of weeds. However, among the different treatments, pre-emergence application of imazethapyr + pendamethalin 800g and its higher doses, imazethapyr 50 and 70g, imazethapyr + imazemox 60 and 70g were found to be at par with each other in respect of these weed parameters. Lower density of weeds by imazethapyr + pendamethalin in reducing weed dry matter might be primarily appeared due to broad spectrum activity of herbicidal combination particularly on establishment of plants of both broad leaf and grassy weeds and its greater efficiency to retard cell division of meristems as a result of which weeds dry rapidly All weed management practices significantly enhanced pods/plant, kernel/pod, pod and haulm yield over weedy check and higher yield was obtained in weed free treatment. Higher profitable pod yield of summer groundnut was also reported by Raj *et al.* (2008) with keeping the crop in weed free condition. Higher net returns and B:C ratio was recorded in imazethapyr + pendimethalin 800g/ha closely followed by its higher doses. This was due to higher pod yield and subsequently lower cost of cultivation (Mene *et al.* 2003) of groundnut crop which was increased in treatment weed free due to the higher need of human labours and their higher wages.

Table 1. Effect of weed control measures on weeds, yield and economics of groundnut

Treatment	Weed count/m^2	Weed dry weight (g/m^2)	Pods/ Plant	Kernel/ pod	Pod yield (kg/ha)	Haulm yield (kg/ha)	Net return (x10^3 \`/ha)	B:C ratio
Imazethapyr + Pendimethalin 1.0 kg/ha (PPI)	7.52 (56.17)*	12.38	24.37	1.67	2569	7033	69940	2.03
Pendimethalin 1.0 kg/ha (PE)	7.59 (57.21)	9.93	24.81	1.63	2530	6887	67633	1.99
Imazethapyr + Pendimethalin 800g/ha (PE)	3.06 (8.91)	0.93	28.44	1.67	2906	7900	86227	2.24
Imazethapyr + Pendimethalin 900g/ha (PE)	2.48 (5.72)	0.53	28.77	1.70	2943	7967	88053	2.27
Imazethapyr + Pendimethalin 1000g/ha (PE)	1.92 (3.23)	0.41	28.84	1.77	2951	7933	88193	2.27
Imazethapyr 50 g/ha	3.37 (10.94)	6.51	25.57	1.57	2686	7233	75593	2.11
Imazethapyr 70 g/ha	3.06 (8.93)	4.45	26.16	1.57	2739	7367	78393	2.15
Imazethapyr + Imazemox 60 g/ha	3.08 (9.07)	5.34	27.03	1.63	2834	7633	82527	2.20
Imazethapyr + Imazemox 70 g/ha	2.58 (6.28)	0.71	27.34	1.67	2806	7533	80920	2.17
Oxyfluorfen 40 g/ha	5.88 (34.34)	11.81	22.67	1.67	2360	6367	58247	1.86
Fenoxaprop p-ethyl 50 g/ha	5.78 (32.91)	11.64	20.36	1.53	2260	6167	53247	1.78
Propaquizafop 62g/ha	6.00 (35.63)	9.40	21.31	1.57	2275	6133	53653	1.79
Weed free (2 HW)	2.12 (4.16)	0.35	30.31	1.77	3016	8133	91307	2.30
Weedy check	8.07 (64.73)	19.86	16.28	1.57	1776	4733	29707	1.46
LSD (P=0.05)	5.52	1.61	6.37	0.11	494	675	-	-

*Values in parentheses are original. Data transformed to square root transformation

CONCLUSION

It was concluded that application of imazethapyr + pendimethalin 800 g (pre-mix) was more effective in controlling all weeds, increasing yields and economically feasible in groundnut in arid regions.

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Effect of weed management on productivity and economics of clusterbean

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Clusterbean (*Cyamopsis tetragonoloba)* commonly known as guar and is an important drought hardy leguminous crop that is cultivated mostly in the arid and semiarid areas. Being a rainy season crop, it suffers badly due to severe competition by mixed weed flora. Yield reduction due to weed infestation is of the tune of 53.7 per cent (Saxena *et al.* 2004). Hand weeding is a traditional and effective method of weed control, but untimely rains, unavailability of labour at peak time and increasing labour cost are the main limitations of manual weeding. Under such situations, the only alternative that needs to be explored is the use of suitable herbicide/ herbicides which may be effective and economically viable. Application of fluchloralin and pendimethalin at 0.75-1.0 kg/ ha as pre emergence were effective against weeds in clusterbean but inadequate moisture and westerly winds blowing at time of sowing in this region left little moister for soil applied herbicide to act effectively and results in to poor efficiency of these herbicides in most of the time in arid zone soils (Punia *et.al.* 2011).

METHODOLOGY

A field experiment was carried out during *Kharif* season of 2014 at SK Rajasthan Agricultural University Farm, Bikaner to test the efficacy of different weed control measures against weeds. There are seven treatments consisting of imazethapyr 40 g/ha, quizalofop-ethyl 37.5 g/ha, fenoxaprop-p-ethyl 50g/ ha, imazethapyr + imazamox 40 g/ha, pendimethalin 0.75 kg/ha as pre-emergence (PE), hand weeding twice at 20 and 40 DAS and weedy check. The treatments were arranged in randomized block design (RBD) with four replications. Clusterbean variety RGC-1066 was sown on 16 July 2014 with crop geometry of 30 cm x 10 cm with recommended package of practices. Fertilizers were applied uniformly through urea and DAP at 20 kg N and 40 kg P_2O_5/ha. Above ground weed biomass was sampled at 60 DAS using a quadrant of 0.5 x 0.5 m.

RESULTS

Imazethapyr + imazamox (factory mix) 40 g/ha, imazethapyr alone at 40 g/ha applied at 3-4 leaf stage (around 20 DAS) and pendimethalin at 0.75 kg/ha as pre-emergence significantly reduced the density and dry weight weeds in clusterbean as compared to weedy check and other herbicidal treatments during the experimental period (Table 1). Application of imazethapyr + imazamox at 40 g/ha and imazethapyr alone at 40 g/ha at 20 DAS (3-4 leaf stage) and pendimathalin at 0.75 kg/ha PE significantly increased the pods/plant and consequently seed and straw yield of clusterbean compared to weedy check and quizalofop ethyl at 37.5 g/ha and fenoxaprop-p-ethyl 50g/ha at 3-4 leaf stage (around 20 DAS) but statistically at par with two hand weeding. The results are in closed conformity with the finding of Yadav *et al.* (2011). This might be due to the fact that imazethapyr + imazamox at 40 g/ha significantly controlled both broad leaved and grassy weeds while imazethapyr alone at 40 g/ha controlled only broad leaved and not of grassy weeds and consequently produced significantly lower yield attributes particularly of pods/ plant. The net return and benefit: cost ratio was maximum for imazethapyr + imazamox at 40 g/ha. It was followed by hand weeding twice at 20 and 40 DAS and pendimethalin.

Table 1. Effect of weed control measures on weeds, yield and economics of clusterbean

Treatment	Weed density (no./m^2)	Weed Dry weight (g/m^2)	Pods/ plant	Seed yield (kg/ha)	Straw yield (kg/ha)	Net Return (Rs / ha)	B:C ratio
Imazethapyr 40 g/ha	3.20 (9.25)*	6.10	64.2	935	3435	30986	2.81
Quizalofop ethyl 37.5 g/ha	4.53 19.50)	20.77	48.7	407	1963	4150	1.24
Fenoxaprop-p-ethyl 50 g/ha	4.30 17.50)	19.07	45.2	481	2111	7639	1.43
Imazethapyr +Imazamox 40 g/ha	3.10 (8.50)	2.42	67.7	1120	3398	39050	3.26
Pendimethalin 0.75 kg/ha PE	4.00 (15.00)	7.46	53.0	722	2925	19580	2.09
2 Hand weeding	2.34 (4.50)	1.30	66.7	826	3388	23599	2.21
Weedy check	5.43 (28.75)	24.28	47.7	407	1648	4699	1.28
LSD at (0.05)	0.66	0.61	5.4	163	756	-	-

*Values in parentheses are original. Data transformed to square root transformation

CONCLUSION

It was concluded that application of imazethapyr + imazamox (pre-mix) 40g/ha at 20 DAS (3-4 leaf stage) was more effective in controlling weeds, increasing yield and economically feasible in clusterbean in arid regions.

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Bioefficacy of imazethapyr against weeds in soybean

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The chemical weed control has become the potent tools for curbing the weed menace since last two decades. Several herbicides were in use for controlling weeds associated in soybean but these have not been found much effective in controlling all sort of weeds. Presently, imazethapyr is a very effective post emergence herbicide for controlling most of the grassy and broad leaf weeds in soybean. But information on efficacy of imazethapyr against weeds in soybean for Kymore Plateau and Satpura hills zone is very meager. Therefore, a comprehension study was under taken.

METHODOLOGY

A field experiment was conducted during *Kharif* season of 2014 at Research Farm JNKVV, Jabalpur to study the efficacy of imazethapyr against weeds in soybean. The field experiment comprising of nine weed control treatments were laid out in randomized block design with 3 replications. The present experiment was carried out on sandy-loam-clay soil which was medium in organic carbon (0.65%), available nitrogen (351 kg/ha) and phosphorus (16.50 kg/ha) but high in potassium (339.70 kg /ha) and neutral in reaction (7.2). Out of nine treatments, six treatments comprised of different doses of imazethapyr applied thereof 50, 75, 100, 125, 150 and 200 g/ha as post-emergence, one of the treatment comprised of hand weeding twice at 20 and 40 DAS and imazethapyr 100 g/ha and rest 62 of the treatments were hand weeding twice at 20 and 40 DAS and weedy check. Weed density and their dry weight was recorded under all at 30 DAA. Yield attributing traits, *viz.* branches, pods per plant and seeds per pod at harvest, seed and stover yields were recorded treatment wise.

RESULTS

In the experimental field, *Echinochloa colona* (35.14%) was the dominant weed closely followed by *Dinebra retroflexa* (27.80%). However, other monocot weeds like *Cyperus iria* (8.95%) and *Cynodon dactylon* (8.70%) and dicot weeds like *Alternanthera philoxeroides* (9.07%) and *Eclipta alba* (10.34%) were also present in less numbers with soybean in weedy check plots. Application of imazathapyr at 50 g/ha the lowest rate (50 g/ha) curbed the weed biomass production marginally (48.16%) which was increased with corresponding increase in a application rates being higher when it was applied at 150g/ha (65.10%) an higher rate 200 g/ha (80.76%) and proved significantly superior over weedy check. But did not surpassed integrated weed management treatment (imazethapyr 100 g/ha + 1 HW) and mechanical weed management (2 HW at 20 and 40 DAS) which curtailed the weed growth the maximum extent (99%). Patil *et al.* (2014) reported that post-emergence application of imazethapyr 100 g/ha was best in terms of weed control efficiency but after 30 DAS, weed control efficiency was improved with combine use of herbicide and HW as compared to herbicide alone. The maximum weed control efficiency was recorded under hand weeding treatment due to complete check on weed, confirming the view of Shete *et al.* (2007).

Table 1. Influence of weed control treatments on seed yield, stover yield, harvest index weed index and weed control efficiency of soybean

Treatment	Branches/ Plant	Pods/ plants	Seeds/ pods	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest Index (%)	Weed Index	WCE (%)
Imazethapyr (50 g/ha)	3.40	35.57	2.00	538.67	2007.53	21.16	76.52	48.16
Imazethapyr (75 g/ha)	3.45	41.86	2.00	1130.00	2487.89	31.23	50.78	53.86
Imazethapyr (100 g /ha)	3.54	43.40	2.00	1282.67	2521.21	33.72	44.12	55.87
Imazethapyr (125 g /ha)	3.61	46.90	2.67	1477.33	2757.23	34.88	35.67	57.48
Imazethapyr (150 g /ha)	3.69	50.80	2.33	1546.67	2771.11	35.82	32.62	65.10
Imazethapyr (200 g /ha)	4.00	52.80	2.67	1835.00	2896.06	38.78	20.07	80.76
Imazethapyr (100 g/ha) + Hand weeding	4.64	67.70	2.33	2296.33	3229.26	41.55	0.00	99.16
Hand weeding (20 and 40 DAS)	4.48	58.90	2.00	1888.00	2987.69	38.62	18.11	99.23
Weedy check	3.27	16.40	2.00	33.33	416.44	7.35	98.56	0.00
LSD (P=0.05)	0.64	21.10	NS	492.99	1134.27	-		

All the yield attributes trait; seed and stover yields attained the minimum values under weedy plots when weeds were not controlled throughout the season. Application of imazethapyr at the lowest rate (50 g/ha) slightly improved the values of yield attributing traits, Seed and stover yield. However; further increase in application rate of imazethapyr enhance the value of yield parameters being superior when it was applied at 150 g/ha at higher rate (200 g/ha) and proved superior over weedy plots. However, integrated weed management (imazethapyr + 1HW) and mechanical weed control (2 HW at 20 and 40 DAS) excelled to all the herbicidal treatments in terms of yield attributing traits seed and stover yield.

CONCLUSIONS

Integrated weed management involving early post emergence application of imazathapyr with one hand weeding at 40 DAS found more productivity than alone application of imazethapyr at different rate.

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Effective weed management in soybean through pre-emergence application of herbicides

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Soybean, an important oilseed crop is known for its higher yield potential. It is called as 'miracle bean' because of high protein and oil content. It is cultivated under assured rainfall conditions where weeds pose a major problem. In soybean reduction in the yield due to weeds varies from 35-80%, depending upon the type of weeds, their intensity and time of crop weed competition. Hand weeding is traditional and effective method of weed control, but untimely and continuous rains as well as unavailability of labour during peak period of demand, are main limitations of manual weeding. Under such circumstances, use of effective herbicide gives better and timely weed control (Meena *et al.* 2009). Therefore, need was felt to explore the possibility of new herbicides for effective control of weed in soybean.

METHODOLOGY

A field experiment was carried out during *Kharif* season of 2015 at Instructional Farm of Rajasthan College of Agriculture, MPUAT, Udaipur. Six treatments including weedy check were replicated four times in a randomised block design. Soybean variety '*JS-9560*' was used in the experiment. The data on weed density and dry weight of weeds/m^2 were recorded at different growth stages crop. Weed control efficiency (%) was computed using the dry weight of weeds.

RESULTS

The experimental plot was infested with grassy, broad leaf weeds and sedges. The prominent weed species are *C. rotundus and C. difformis* among sedge; *Commelina benghalensis; Digera arvensis; Euphorbia hirta; Amaranthus viridis* among broad leaf; *Echinochloa sp.; Panicum sp.; Digitaria sp.; Eleusine indica* among grassy weeds.

The lowest count and dry weight of weeds was registered under hand weeding twice at 20 and 40 DAS. Among the herbicidal treatments, lowest weed density and weed dry matter at 45 DAS was observed with metolachlor 50% EC 2400 ml/ha which was statistically at par with metolachlor 50% EC 2000 ml/ha. Among the weed management treatments, twice handed weeding was recorded the lowest dry weight of total weeds population irrespective of weed categories sedges, broad leaf, grassy. Twice hand weeded treatment on par with Metolachlor 50% EC 2400 ml/ha. metolachlor 50% EC at 2400 ml/ha and 2000 ml/ha were statistically at par with each other. At 45 DAS the highest WCE (94.8 %) was recorded with the twice hand weeding. Metolachlor 50% EC applied at 2400 ml/ha and 2000 ml/ha were statistically at par with each other and recorded highest 94.0% and 92.2% WCE among herbicides, respectively, at 45 DAS and similar trend of WCE was observed at 75 DAS. Among weed management treatments metolachlor 50% EC 2400 ml/ha gave significantly higher grain yield of soybean over weedy check which was found at par with metolachlor 50% EC 2000 ml/ha (Table 1).

Table 1. Weed dry weight, weed control efficiency and grain yield as influenced by post emergence applications of herbicides in soybean at 45 DAS

Treatment	Dose (ml/ha)	Total Weed population/ m^2			Weeds total dry weight (g/ m^2)			WCE (%)	Grain yield (t/ha)
		Sedge	Grassy	Broad-leaved	Sedge	Grassy	Broad-leaved		
Metolachlor 50% EC	1600	5.00(2.45)	24.00(5.00)	15.00(4.00)	2.60	8.60	12.20	70.1	1.42
Metolachlor 50% EC	2000	1.67(1.63)	7.66(2.94)	5.33(2.52)	0.55	2.54	3.00	92.2	1.58
Metolachlor 50% EC	2400	0.67(1.29)	6.67(2.77)	3.34(2.08)	0.26	1.46	2.95	94.0	1.67
Pendimethalin 30% EC	3300	9.67(3.27)	27.67(5.35)	15.67(4.08)	3.20	9.40	11.00	69.8	1.40
Hand weeding (15 and 30 DAS)	-	1.33(1.53)	6.33(2.71)	1.99(1.73)	0.18	0.45	3.47	94.8	1.74
Weedy check	-	14.67(3.96)	63.67(8.04)	29.67(5.54)	11.20	38.00	29.00	0.0	0.06
LSD (P=0.05)	-	0.50	1.20	1.50	1.70	2.10	1.50	-	1.95

CONCLUSION

It was concluded that pre-emergence application of metolachlor 50% EC 2400 ml/ha at 45 and 75 DAS to be a promising and effective weed management practice for managing grassy as well as broad spectrum weeds and obtaining higher seed yield and profitability of *Kharif* soybean.

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Chemical weed management in wheat

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A field experiment was conducted during *Rabi* 2014 at Research Farm, Agronomy Section, College of Agriculture, Dhule. The control of weeds manually is difficult on large scale due to high cost and shortage of labour. The only alternative is the combine or tank mix application of herbicides i.e. sulfosulfuron + metasulfuron methyl (25 + 4 g/ha) and clodinafop + metasulfuron-methyl (60 + 4 g/ha) was more consistent in weed control instead of single post-emergence herbicides. This control broad spectrum weeds and maximum growth and yield of wheat. Hand weeding is a traditional and effective method of weed control, but untimely and continues rains as well as unavailability of labour during peak period of demand, are the main limitations of manual weeding.

METHODOLOGY

The present investigation was conducted during *Rabi* 2014 at Research Farm, Agronomy Section, College of Agriculture, Dhule. Experiment consisted of ten treatments laid out in randomized block design with three replications. The soil of the experimental field was clay in the texture, with low in available nitrogen and available phosphorus and rich in available potassium.

RESULTS

Weed free check registered less weed population and dry weight of weeds followed by application of tank-mix herbicides, *i.e.* sulfosulfuron + metasulfuron-methyl (25 + 4 g/ha) and clodinafop + metasulfuron methyl (60 + 4 g/ha). Both the treatments of tank mix application of herbicides are at par with each other and significantly superior over the rest of treatments under study. The dry weight of weeds found to be reduced by combine use of two post-emergence herbicides when compared with the use of solo post-emergence herbicides only.

Numerically lower weed index was recorded in weed free check followed by application of tank-mix herbicides, *i.e.* sulfosulfuron + metasulfuron-methyl (25 + 4 g/ha). The weedy check recorded the maximum weed index. The weed control efficiency index (WCE) was found higher in weed free check and the lowest value in weedy check treatment at harvest stage of wheat crop. Among the herbicide treatments, the highest weed control efficiency index was found under combine application of sulfosulfuron + metasulfuron-methyl (25 + 4 g/ha) followed by clodinafop + metasulfuron-methyl (60 + 4g/ha). Onward weed control efficiency index was significantly maximum in combine use of two herbicide treatment as compared to application of solo herbicides only.

Table 1. Effect of weed management on weed density, dry weight, weed index and weed control efficiency at harvest stage of wheat

Treatment	Weed intensity (no/m^2)	Dry weight of weed (kg/ha)	Weed index (%)	Weed control efficiency (%)	Grain yield (kg/ha)	Net returns (`/ha)	B:C ratio
Weedy check	115.33	1303.3	51.92	-	2282	7139	1.25
Weed free check	00	00.00	00.00	100	4746	54891	2.47
Clodinafop (60 g/ha)	55.99	507.0	31.56	51.45	3248	34257	2.19
Sulfosulfuron (25 g/ha)	51.83	466.7	24.97	55.05	35610	40519	2.42
Metasulfuron methyl (4 g/ha)	53.50	445.1	25.64	53.61	3529	40022	2.40
Metribuzin (100 g/ha)	55.66	480.0	29.75	51.73	3334	36219	2.27
Clodinafop + metasulfuron-methyl (60 + 4 g ha^{-1})	34.66	189.0	13.31	70.38	4115	50867	2.76
Sulfosulfuron + metasulfuron methyl (25 + 4 g/ha)	30.83	146.6	9.30	73.26	4304	54782	2.91
LSD (P=0.05)	9.294	63.77	-	8.871	405	-	-

The grain and straw yield (kg/ha) of wheat was found to be significantly higher (4746.86 and 5966.86 kg/ha, respectively) in treatment of weed free check. The next best among the herbicides treatment was combine application of sulfosulfuron + metasulfuron-methyl (25 + 4 g/ha), (4304.46 and 5418.66 kg/ha, respectively) recorded higher grain and straw yield as compared to rest of herbicide treatments for weed control. Among the herbicide treatments tried in the experiment, application of tank mix herbicides treatments were found significantly better than their solo application in respect of grain and straw yield of wheat. The grain and straw yield of wheat was significantly the lowest under weedy check treatment. However, the net monetary returns were maximum under weed free treatments but lowest B:C ratio as compared to application of sulfosulfuron + metasulfuron-methyl (25 + 4 g /ha) due to higher cost of manual labour for weeding. These results are in conformity with those of Yadav *et al.* (2014).

CONCLUSION

The combine or tank mix application of herbicides, *i.e.* sulfosulfuron + metasulfuron-methyl (25 + 4 g/ha) and clodinafop + metasulfuron-methyl (60 + 4 g/ha) was more consistent in weed control instead of single post - emergence herbicides. This control broad spectrum weeds and maximum growth and yield of wheat.

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Integrated weed management in summer blackgram

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Black gram is mostly grown in Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Uttar Pradesh, West Bengal, Punjab, Haryana, Tamil Nadu, Karnataka, Orissa and Gujarat with an area of about 3.5 million ha with a total production of 1.5 to 1.9 million tones with an average productivity of 500 kg/ha. Black gram often suffers severe weed competition especially during early growth phases. Being a short duration and initially slow growing, blackgram is heavily infested with narrow and broad leaved weeds and sedges (Mishra1997).

METHODOLOGY

A field experiment was conducted during summer 2015 at AICRP on Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra). The experiment was laid out in a factorial randomized block design with three replications. Eighteen treatment combinations consisting of three levels of sowing times and six levels of weed management as given in table. Blackgram variety 'TAU-1' was sown at 30 × 10 cm spacing using a seed rate of 12 kg/ha and post emergence application done at 20 days after sowing.

RESULTS

The major weed flora observed in the experimental field included *Cynodon dactylon*as monocot weed while *Digera arvensis, Parthenium hysterophorus, Euphorbia geneculata*, Dicot weed *and Cyperus rotundus* as sedge weed. It was observed that dicot weeds found the maximum than monocot and sedges in each treatment. The most dominating weeds were *Parthenium hysterophorus,Euphorbia geneculata* at all stage of crop growth.

There was significant impact of sowing time and weed management treatments on reduction of density and biomass of weeds under the study. Minimum density and biomass of weeds were recorded with second sowing time 1st week of March. Weed population and dry weight of total weeds were markedly higher under weedy check. Significantly lower weed population at 14 DAS was observed in pendimethalin at 1 kg/ha (PE) *fb* imazethapyr at 75 g/ha (PoE) at 20 DAS followed by pendimethalin at 1 kg/ha (PE).

Table 1. Effect of different sowing time and weed management practices on weed count, dry weight of weed, weed control efficiency and weed index of weeds at harvest

Treatment	Total weed density (no/m²)	Dry weight of weeds (g/m²)	Weed control efficiency (%)	Weed index	Seed yield (t/ha)	Stover yield (t/ha)	B:C ratio
Sowing time							
3rd week of Feb. (16th Feb.)	4.51(24.98)	5.68(39.33)*	58.66	29.52	1.05	1.39	1.91
1st week of March (2nd March)	4.16(21.37)	5.43(36.13)	60.17	23.52	1.10	1.44	1.97
3rd week of March (17th March)	4.82(28.53)	5.83(41.40)	58.28	37.00	0.90	1.29	1.58
LSD (P=0.05)	0.15	0.17	NS	NS	0.08	0.10	-
Weed management							
Weedy check (control)	7.83(60.98)	9.96(98.87)	0.00	74.43	0.73	1.08	1.45
Weed free up to harvest	0.71(0.00)	0.71(0.00)	100.00	0.00	1.22	1.60	1.92
Pendimethalin at 1 kg/ha (PE)	5.26(27.31)	6.16(37.56)	55.03	35.24	0.95	1.31	1.72
Pendimethalin at 1 kg/ha (PE) *fb* imazethapyr at 75 g/ha (PoE) at 20 DAS	4.64(21.20)	5.56(30.47)	65.31	15.92	1.15	1.48	2.02
Imazethapyr at 75 g/ha (PoE) at 20 DAS	5.78(33.09)	6.69(44.27)	45.56	45.67	0.88	1.24	1.70
One hoeing at 20 DAS *fb* one hand weeding at 40 DAS	2.76(7.20)	4.79(22.57)	88.32	8.84	1.17	1.54	2.05
LSD (P=0.05)	0.21	0.23	3.49	18.65	0.11	0.14	-

The highest (1.22 t/ha) seed yield was recorded by the treatment weed free check but it was at par with treatments one hoeing at 20 DAS and one hand weeding at 40 DAS and pendimethalin at 1 kg/ha (PE) *fb* imazethapyr at 75 g/ha at 20-25 DAS. Maximum weed index was recorded in 17th March (37.00) and weedy check (control) (74.43). Maximum weed control efficiency was recorded in 2nd March (60.17) and weed free up to harvest was (74.43). From the economics point of view, 2nd March sowing registered higher net returns of Rs 25923/ha with benefit : cost ratio was of 1.97 which was closely followed by treatment 16th February sowing with net returns of Rs 23760/ha and benefit : cost ratio was 1.91. The highest net returns of Rs 28,492/ha with benefit: cost ratio was 2.05 obtained from treatment one hoeing at 20 DAS *fb* one hand weeding at 40 DAS followed by pendimethalin at 1 kg/ha (PE) *fb* imazethapyr at 75 g/ha (PoE) at 20 DAS ('27671) and B: C ratio (2.02) and treatment weed free up to harvest with net monetary returns (Rs 27785/ha) and B: C ratio (1.92).

CONCLUSION

It was concluded that sowing of summer black gram on 1st week of March with one hoeing at 20 DAS *fb* one hand weeding at 40 DAS and pre emergence application of pendimethalin at 1 kg/ha *fb* post-emergence of imazethapyr 75 g/ha at 20 DAS was most effective for controlling weeds, improving grain yield and profitability of summer black gram.

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Bioefficacy of imazethapyr and its readymix combination with imazamox against weeds in pea

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Weeds are the major threat to the productivity of garden pea. They can be controlled by manual, mechanical and chemical methods. Manual method of weed control is labour intensive, cumbersome and time consuming. The mechanical methods cause injury to roots. Various pre-plant incorporation and pre-emergence herbicides have been tested under different agro-climatic conditions of Himachal Pradesh (Rana 2002). Many times, extension workers and farmers of the state demand information on post-emergence herbicides particularly when they fail to apply pre-emergence herbicides due to one or the other reason. Post-emergence herbicides are also required when pre-emergence fail to give satisfactory weed control. New post-emergence herbicides *viz.*, imazethapyr alone and in combination with imazamox have been introduced. Therefore, the present investigation was carried out for having information of comparative efficacy of pre-and post-application of imazethapyr alone and with imazamox.

METHODOLOGY

Field investigation was carried out during winter season of 2014-15 and 2015-16 at Palampur. Garden pea '*Palam Priya'* was sown manually keeping the row to row distance of 45 cm at 60 kg/ha seed rate during the first week of November. The experiment was laid out in randomized complete block design with three replications. Twelve treatments, *viz.* pendimethalin 750 g/ha, imazethapyr at 60 and 70 g/ha pre-emergence and at 70 and 80 g/ha early post; pendimethalin + imazethapyr at 800 and 900 g/ha pre-emergence, imazethapyr + imazamox at 50, 60 and 70 g/ha post-emergence, hand weeding twice and weedy check were tested to evolve an effective treatment for the season long control of weeds in this crop. Power operated knapsack backpack sprayer fitted with a flat fan nozzle was used for spraying the herbicides. The herbicides were sprayed using a spray volume of 600 litres of water/ha. Harvesting was completed in three pickings by third week of April each year.

RESULTS

Avena fatua, *Phalaris minor* and *Lolium temulentum* were the major grassy weeds found growing in association in association with garden pea. *Anagallis arvensis*, *Vicia sativa* and *Coronopus didymus* were the major broad-leaved weeds. *Circium arvense* had also shown its introduction in the experimental field. Weed control treatments brought about significant variation in the dry weight of weeds (Table 1). All the weed control treatments were significantly superior to weedy check in reducing total weed dry weight. Hand weeding twice effectively reduced dry matter accumulation by weeds over other treatments during both the years. Application of imazethapyr at 80 g/ha early post being at par with pendimethalin + imazethapyr at 800 or 900 g/ha pre-emergence resulted in significantly lower dry weight of weeds over other herbicidal treatments. Imazethapyr 80 g/ha early post remaining at par with imazethapyr 70 g/ha early post gave significantly higher green pea yield over the other weed control treatments. Imazethapyr + pendimethalin 800 or 900 g/ ha were comparable to hand weeding twice. Among all the weed control treatments, poor green pea yield was realized under imazethapyr + imazamox at all the doses 50-70 applied early post. On an average, weeds reduced green pea yield by 80.2% over imazethapyr 80 g/ha early post.

Table 1. Effect of weed management on weed dry weight and pod yield of garden pea

Treatment	Dose (g/ha)	Time of application	Weed dry weight (g/m^2)		Green pod yield (t/ha)	
			2014-15	2015-16	2014-15	2015-16
Pendimethalin	750	Pre	137.5	130.6	4.82	5.00
Imazethapyr	60	Pre	128.4	125.7	5.13	5.32
Imazethapyr	70	Pre	122.3	120.4	5.31	5.54
Pendimethalin + imazethapyr	800	Pre	116.7	113.3	5.62	5.75
Pendimethalin + imazethapyr	900	Pre	115.6	112.3	5.72	5.96
Imazethapyr	70	Early post	115.7	108.4	5.95	6.32
Imazethapyr	80	Early post	102	95	6.13	6.87
Imazethapyr + imazamox	50	Post	156.7	170.4	4.05	4.50
Imazethapyr + imazamox	60	Post	156.4	150	4.25	4.66
Imazethapyr + imazamox	70	Post	148.5	140	4.45	4.86
Hand weeding twice		30& 60 DAS	90	78.6	5.73	5.97
Weedy check			475	378	1.02	1.56
LSD (P=0.05)			16	12	0.30	0.35

CONCLUSION

For the effective management of weeds in pea, early post-emergence application of imazethapur 80 g/ha has been found an effective alternative to pendimethalin.

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Integrated weed management in soybean + pigeonpea intercropping system under rainfed condition

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The critical period of crop-weed competition for Soybean or pigeonpea is up to 40 days. One of the reasons for low productivity of soybean + pigeonpea intercropping is more weed infestation during early growth period of the crop. It is observed that there are certain weed which cannot be controlled properly either by hoeing or hand weeding in an advance stage of its growth and they again come up with profuse branching and suppressing crop growth and yield. In such cases, chemical method of weed control can be very effective in controlling the weeds before their emergence as well as after emergence. Considering above facts, an attempt was made to study the "Integrated weed management in soybean + pigeonpea (3:1) intercropping system under rainfed condition".

MATERIALS

An experiment was conducted during *Kharif* season of 2009-10 to study the Integrated weed management in soybean + pigeonpea (3:1) intercropping system under rainfed condition. The Experiment was laid out in randomized block design with eleven treatments replicated thrice. The gross and net plot size 5.0 x 4.8 m^2, 4.60 x 3.60 m^2, with spacing for sole Soybean – 30 x 10 cm^2, Pigeonpea 60 x 20 cm^2. The fertilizer dose for sole Soybean 50: 75 NP kg/ha and sole Pigeonpea 25 : 50 NP kg/ha. The soil was medium black with pH – 8.7.

RESULTS

1 H.W. + 2 hoeing upto 45 DAS showed maximum and significantly higher soybean grain equivalent yield (**G.E.Y.)** (3.63 t/ha), gross and net monetary returns of Rs.79853/ha and Rs 40819/ha respectively followed by treatment pendimethalin as pre-emergence at 1.0 kg/ha + 1 hoeing at 20 DAS + 1 HW at 45 DAS which was at par. Among the integrated weed management treatments pendimethalin pre-emergence at 1.0 kg/ha + hoeing at 20 DAS + 1 H.W.at 45 DAS was found significantly superior in soybean grain equivalent yield (3.40 t/ha), gross monitory returns(Rs.74874/ha) , net monetary returns (Rs. 34, 887/ha) and B: C ratio (1.87) followed by fluchloralin as PPI at 1.0 kg /ha + 2 hoeing at 20 and 40 DAS.

Table 1. Yield and economics as influenced by various weed management treatments in soybean + pigeonpea (3:1) intercropping system

Treatment	Soybean G.E.Y. (t/ha)	GMR (Rs/ha)	NMR (Rs/ha)	Cost of cultivation (Rs/ha)	B:C ratio
Weedy check (sole soybean)	1.24	27218	5786	21432	1.26
Weed free sole soybean (upto 45 DAS)	2.55	56068	31435	24633	2.27
Weedy check inter cropping (3 : 1)	1.11	24313	-11519	35833	0.67
Weed free intercropping (upto 45 DAS)	3.63	79853	40819	39034	2.04
One hoeing at 20 DAS + 1 H.W. 30 DAS	3.02	66548	28127	38421	1.72
Pendimethalin as pre-emergence at 1.0 kg/ha	2.40	52854	15454	37400	1.41
Fluchloralin as PPI at 1.0 kg/ha	2.39	52491	15618	36873	1.42
Pendimetahlin as pre emergence at 1 kg /ha + 2 hoeing at 20 and 40 DAS	2.81	61908	23282	38626	1.60
Fluchlorin as PPI at 1.0 kg/ha + 2 hoeing at 20 and 40 DAS	2.95	64805	26706	38099	1.69
Pendimethalin as pre emergence at 1.0 kg/ha + hoeing at 20 DAS + 1 H.W. at 45 DAS	3.40	74874	34887	39988	1.87
Fluchlorin as PPI at 1.0 kg/ha + 1 hoeing at 20 DAS + 1 H.W. at 45 DAS	2.66	58409	18948	39461	1.47
LSD (P=0.05)	0.46	10114.35	10114.35	-	0.27

Effect of sequential application of herbicides on weed growth and yield of rainy-season mungbean

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Mungbean (*Vigna radiata* L. Wilczek), which has been referred as ' golden bean' is the third most important pulse crop of India. It is cultivated on 3.50 million ha with production of 1.55 million tonnes (Anonymous 2016). Weeds are one of the major limiting factors of mungbean, cause severe yield losses in mungbean ranging from 30–40% (Kumar *et al*. 2016). Pendimethalin is effective in controlling weeds only during initial stage of crop growth, but crop suffers considerably during later part of the crop growth. Thus, late-season emerging weeds need to be controlled, effectively to achieve higher mungbean yield. Sequential application of pendimethalin and imazethapyr is known to be effective against many narrow-leaved and broad-leaved weeds including sedges in urdbean, which is quite akin to mungbean (Rao *et al*. 2010). However, meager information is available for sequential application of these herbicides in mungbean; hence, the present study was undertaken.

METHODOLOGY

A field experiment was conducted during *Kharif* season of 2013 at ICAR-Indian Agricultural Research Institute to effect of sequential application of herbicides on weed flora and yield of mungbean. Twelve treatments consisting of imazethapyr and quizalofop at varying doses applied alone and sequentially with pendimethalin along with pendimethalin followed by (*fb)* hand weeding (HW) were arranged in randomised block design with three replications. Variety '*Pusa Ratna'* was sown in the experimental field with recommended package of practices. A uniform recommended dose of 20 kg N/ha and 40 kg P_2O_5/ha were applied through diammonium phosphate. The crop was sown in lines spaced 30 cm apart, using a seed rate of 15 kg/ha. Herbicides were applied with the help of a manually operated knapsack sprayer fitted with flat-fan nozzle at spray volume of 500 litres/ha.

RESULTS

Broad-leaved weeds were predominant (48%), followed by narrow-leaved (30%) and sedges (22%). *Digitaria sanguinalis* among the grassy weeds and *Trianthema portulacastrum* among the broad-leaved weeds were more dominant. Herbicidal treatments significantly influenced the population and dry matter production of weeds. Among the herbicidal treatments, the lowest weed density (7.06/m^2) was observed under pendimethalin 1 kg/ha as pre-emergence (PE) + 1 HW at 30 days after sowing (DAS), followed by pendimethalin 0.75 kg/ha as PE + imazethapyr 75g/ha at 30 DAS (7.93/m^2). The minimum weed dry weight (6.02 g/m^2) was recorded under pendimethalin 1 kg/ha as PE + 1 HW at 30 DAS, followed by pendimethalin 0.75 kg/ha as PE + imazethapyr 75g/ha at 30 DAS (8.03 g/m^2). These results are in conformity with the findings of Rao *et al*. (2010) and Kumar *et al*. (2016). The highest content and uptake of N, P and K in weeds was found in weedy check treatments. The minimum N, P and K uptake by weeds was recorded in those plots treated with pendimethalin at 1 kg/ha as PE followed by hand weeding at 30 DAS. Among weed control treatment pendimethalin at 1 kg/ha as PE followed by hand weeding at 30 DAS brought the highest NPK uptake in both seed and stover of mungbean which, however followed by pendimethalin at 0.75 kg/ha as PE followed by imazethapyr at 75g/ha at 30 DAS. The highest grain yield (1.10 t/ha) and straw yield (1.85 t/ha) were recorded with pendimethalin at 1 kg/ha as PE + 1 HW at 30 DAS, and was comparable with pendimethalin 0.75 kg/ha as PE + imazethapyr 75g/ha at 30 DAS. Herbicidal treatments resulted in considerably lower cost of cultivation compared with pendimethalin + HW treatment. The B: C ratio was found maximum (2.91) with pendimethalin 1 kg/ha as PE + 1 HW at 30 DAS, followed by pendimethalin 0.75 kg/ha as PE + imazethapyr 75g/ha at 30 DAS (2.49).

CONCLUSION

It was concluded that pre-emergence application of pendimethalin at 1kg/ha *fb* 1 HW at 30 DAS and pendimethalin at 0.75 kg/ha as PE *fb* imazethapyr at 75g/ha at 30 DAS were equally effective in controlling weeds and improving mungbean productivity and thus sequential application of herbicides can be an efficient alternative to control weeds in mungbean, particularly under labour constrained conditions.

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Effect of nutrient sources and weed control measures on quality and yield of baby corn

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Maize is the third most important cereal crop of India as well as the world. It is used both as food for human and feed for livestock especially poultry industry. In late 1970's people in USA and western countries started to consume raw cobs called baby corn. Though the baby corn is more popular worldwide, agro-techniques to achieve higher production is the need of the day. Baby corn being a rich source of phosphorus, iron, vitamin A and C, high fiber concentration and no cholesterol gained popularity as a vegetable corn is being a exhaulting crop. The applied nutrients may not be helpful in increasing the productivity of maize until unless other constraints like competition offered by weeds is removed with suitable method. Owing to congenial weather condition and wider row spacing maize suffers heavily due to severe weed infestation (Malviya and Singh, 2007). Yield loss due to weeds in maize (*Zea mays* L.) varies from28–93%, depending on the type of weed flora and the intensity and duration of crop-weed competition. Maize crop is very much sensitiveto weed competition between 20 to 40 days after sowing. Therefore, it isnecessary to adopt a suitable weed control measure to reduce the yield loss due to weed competition.

METHODOLOGY

A field experiment was conducted during *Kharif* season at the Experimental Farm of Division of Agronomy, Indian Agricultural Research Institute, New Delhi. The soil of experimental field was sandy loam in texture, poor in organic carbon, low in available N (162 kg/ha), medium in available P (16.2 kg/ha) and K (198.2 kg/ha) and neutral in reaction with Ph 7.6. Crop received 342.8 mm precipitation in 17 rainy days. The experiment was laid out in a factorial randomized block design and replicated thrice with the combination of 4 nutrient sources:120-26.4-41.7 kg N-P-K/ha through fertilizers,120 kg N through FYM, 120 kg N through leafcompost and 120 kg N through vermicompost; and four weed management practices: unweededcontrol, weed free check, two hand weeding at20 and 40 days after sowing (DAS) and application of atrazine 0.5 kg andpendimethalin 0.75 kg/ha tank mixed as pree mergence (PE). Baby corn variety 'PEHM 2' wassown on the ridges spaced at 60 cm using 20 kgseed/ha.

RESULTS

The husked cob yield wassignificantly higher for application of N through vermicompost (4.43 t/ha) as compared to its application through FYM (3.80 t/ha) or leaf compost (3.67 t/ha) or fertilizer (3.30 t/ha) (Table 1). Application of N through vermicompost (2.15 t/ha) being at par with N application through FYM (2.09 t/ha) and leaf compost (2.01 t/ha) produced significantly higher yield of dehusked cob as compared to application through fertilizer (1.80 t/ha). Among the weed management practices, husked cob yield was significantly higher for weed free treatment (4.29 t/ha) as compared to remaining weed management practices. The highest dehusked cob yield (2.18 t/ha) was also recorded in weed free treatment and significantly lower value was found in unweeded control (1.68 t/ha). This higher cob yield in weed free treatment was due to lack of competition for different growth factors between baby corn and weeds (Singaram and Kamala, 1999). The significantly higher protein and sugar concentration were obtained from the application of N through vermicompost over N applied through leaf compost and recommended dose of nutrients applied through fertilizers. Weed control treatment affect protein and sugar concentration and maximum concentration was recorded from weed free treatment. Higher protein and sugar concentration in weed free treatment might be due to more concentration of nitrogen owing to less weed competition.

Table 1. Effect of nutrient sources and weed control measures on cob, green fodder yield and protein and sugars

Treatment	Yield (t/ha)			Protein (%)	Sugars (%)
	Cob		Green fodder		
	Husked	Dehusked			
Nutrient sources					
120-26.4-41.7 kg N-P-K/ha through fertilizers	3.30	1.80	21.50	12.60	7.43
N through FYM	3.80	2.09	27.27	14.25	8.14
N through leaf compost	3.67	2.01	26.14	13.28	7.79
N through vermicompost	4.43	2.15	28.05	14.44	8.43
LSD (P=0.05)	0.32	0.24	4.62	0.63	0.50
Weed control measures					
Unweeded control	3.05	1.68	21.07	12.68	6.86
Weed free check	4.29	2.18	30.22	14.80	8.49
Two hand weeding at 20 & 40 DAS	3.92	2.08	26.32	13.55	8.18
Atrazine 0.5 kg + pendimethalin 0.75 kg/ha as PE	3.94	2.09	25.75	13.54	8.24
LSD (P=0.05)	0.32	0.24	4.62	0.63	0.51

CONCLUSION

Based on the above results it may be concluded that highest quality produce in terms of protein and sugar concentration may be obtained with the application of 120 kg N through vermicompost followed by same amount of N through FYM. In weed control measures, two hand weeding at 20 and 40 DAS or application of atrazine 0.5 kg + pendimethalin 0.75 kg/ha as PE were equally effective as weed free check in respect to yield and quality of baby corn and green fodder.

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Nutrient uptake studies in soybean and weeds as affected by weed management and fertilization

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Soybean is a crop of multiple qualities as it is both pulse and oil seed crop. It is the first largest oil seed crop of India. It being a rainy season crop and intense weed competition during active phase of growth is one of the constraints in realizing its potential yield and losses due to weeds may range from 12 to 85 per cent. Weeds through competition with crop, deprive crops of limited essential resources and prominent amongst them are nutrients. Moreover, weeds grow faster than crop and absorb the nutrients earlier resulting into lack of nutrients for the growth of the plants. Control of the weeds is important not only to check the yield losses but also to increase the fertilizer use efficiency. The present investigation was therefore under taken to study the extent of nutrient depletion by the crop and weeds under various weed management practices and fertility levels and to minimize these losses by controlling weeds.

METHODOLOGY

A field experiment was conducted at Agriculture Research Station, Ummedganj, Kota (Rajasthan) during *kharif* seasons of 2013 and 2014 to evaluate the effect of weed management and fertilization on nutrient uptake by soybean crop and weeds. The soil of the experimental field was clay loam, alkaline in reaction, medium in organic carbon, available nitrogen and phosphorus, high in available potash and low in available sulphur. The experiment was laid out in split plot design comprising of seven weed management practices *viz.* [(W 1)=weedy check, (W 2)= two hand weeding 20 & 40 DAS, (W 3)= pendimethalin 1.0 kg/ha + one hand weeding 30 DAS, (W 4)= imazethapyr 100 g/ha POE 15DAS, (W 5)= imazamox + imazethapyr 75 g/ha POEat 15 DAS, (W 6)= clodinafop–propargyl 60 g/ha POE 15 DAS and (W 7)= quizalofop–ethyl 50 g/ha POE at 15 DAS] in main plot and four fertility levels [100 and 125% N, P & K with and without sulphur levels (F1, F2, F3 & F4)] in sub plots replicated thrice.Soybean verities RKS 45 was sown following standard package of the zone. The RDF for soybean in zone is 40 kg each of N, P_2O_5 and K_2O while sulphur was applied 30 kg/ha through gypsum. All the fertilizers were applied at sowing time. Observation on different parameters was taken by following the standard procedures.

RESULTS

Data indicate that all the weed management practices significantly decreased total weed dry matter at harvest compared to weedy check. Data further indicate that amongst the weed management practices hand weeding twice and application of ready mix of imazamox + imazethapyr 75 g/ha 15 DAS were found significantly superior in lowering down the total weed dry matter compared to rest of the treatments. The corresponding mean reduction in total weed dry matter under both of these treatments is 83.7 and 77.2 per cent compared to weedy check (2391 kg/ha). Weed dry matter under the influence of fertility levels is affected significantly and compared to 100 per cent N, P and K without sulphur application all the treatments of fertility enhanced these parameters. The per cent increase in weed dry matter was more pronounced under 100 per cent N, P and K alongwith sulphur application. All the weed management treatments significantly minimized the nutrient removal by total weeds compared to weedy check. The minimum removal of total N, P and S by the weeds (5.10, 0.61 and 0.66 kg/ha) were observed in W_2 which was followed by W_5 (7.10, 0.84 and 0.91 kg/ha). The maximum total removal of N, P and S (30.49, 3.59 and 3.89 kg/ha) was observed under weedy check. Significantly higher removal of N, P and S by total weeds was observed under F2, F3 and F4 compared to F1. The uptake of N, P and S by the crop and weeds could be mainly attributed to the extent of their dry matter production. It is a apparent from the data that whenever the removal of nutrient by weeds was more, corresponding uptake by the crop was less and vice versa. Therefore, for efficient utilization of applied nutrients weeds should be kept under control.

All the weed management treatments significantly increased the biological yield of soybean. The pronounced effect of increased yield was observed under to two hand weeding followed by application of ready mix of imazamox + imazethapyr 75g /ha at 15 DAS. The per cent increase in biological yield under the influence of these treatments was 144.83 and 124.0 compared to weedy check. On pooled basis application of recommended dose of N, P and K alongwith sulphur significantly produced higher biological yield over 100 per cent N, P and K in absence of sulphur. Data pertaining to N, P and S uptake by the crop indicate higher uptake of these nutrients under the influence of weed management compared to weedy check. Two hand weeding recorded 145.55, 15.05 and 9.29 kg/ha uptake of N, P and S, respectively followed by post emergence application of imazamoz + imazethapyr 75g /ha at 15 DAS (130.53, 13.19 and 8.14 kg/ha). This might be due to the fact that higher weed control efficiency under these treatments regulated more favourable environment for growth and development of crop plants. The results confirm the findings of Singh *et al.* (2014). All the treatments of fertility on the other hand resulted in significantly higher uptake on N, P and S compared to 100 per cent N, P and K without sulphur. The nutrient uptake by the crop is mainly the function of crop yield. Therefore, considerable increase in N, P and S was attributed to higher biological yield at higher fertility levels.

Table1. Effect of weed management practices and fertility on total weed dry matter and biological yield of soybean and nutrient drain by weeds and crop (pooled data)

Treatment	Total weed dry matter at harvest (kg/ha)	Total nutrient removal by weeds (kg/ha)			Biological yield (kg/ha)	Total nutrient removal by crops (kg/ha)		
Weed management		N	P	S		N	P	S
W1	2391	30.49	3.59	3.89	2264	55.17	5.28	3.14
W2	390	5.10	0.61	0.66	5543	145.55	15.05	9.29
W3	857	11.0	1.31	1.40	4793	122.71	12.35	7.58
W4	626	7.97	0.95	1.05	4904	125.81	12.67	7.80
W5	546	7.10	0.84	0.91	5072	130.53	13.19	8.14
W6	1624	20.79	2.45	2.64	3871	96.75	9.47	5.79
W7	1570	20.9	2.36	2.57	4171	104.59	10.29	6.30
LSD (P=0.05)	69	0.93	0.11	0.17	253	6.87	0.75	0.45
Fertility Levels								
F1	1057	12.87	1.53	1.66	4041	101.00	9.99	6.08
F2	1155	14.86	1.75	1.89	4379	111.89	11.24	6.92
F3	1170	15.13	1.79	1.94	4504	115.41	11.64	7.14
F4	1192	15.74	1.84	2.00	4572	118.05	11.89	7.32
LSD (P=0.05)	42	0.57	0.08	0.08	147	4.33	0.65	0.27

CONCLUSION

On medium fertility clay loam soils of South – Eastern Rajasthan both two hand weeding and post emergence application of ready mix of imazamox and imazethaypr 75 g/ha were found superior to their treatments in saving of nutrients compared to other treatments. Compared to weedy check both these treatments saved N, P and S to the extent of 25.39, 2.98 and 3.23 and 23.39, 2.75 and 2.98 kg/ha, respectively.

Response of Sorghum cultivars to weed management

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Sorghum [*Sorghum bicolor* (L.) Moench] is also known as the king of millets. In Rajasthan, Sorghum occupies and area of about 0.58 million ha with production of 0.33 million tonnes and productivity is 577 Kg/ha (Ministry of Agriculture GOI 2008-09). Like other rainy season crops, sorghum also suffers stress from weeds. Wide range yield reduction in the crop- on account of weeds is well documented. Weeds in general causes 45% annual lose of agriculture production (Singh 1999) farmers do not pay attention to control weeds, because of heavy rain fall in Kharif season and unavailability of labour. Application of herbicide at time of sowing may be more effective in controlling weeds at early stages. This necessitates the use of chemicals measure3 to reduce the early weed crop completion and check the losses caused by weeds. Atrazine, a selective herbicide is widely use in sorghum during rainy season. Hence, present investigation was undertaken to work out different weed management practices and cultivars.

METHODOLOGY

The field experiment was carried out during Kharif Season of 2010 at Rajasthan College of Agriculture, Udaipur (Rajasthan). To test the different weed management practices and cultivars 20 treatments combinations of various dodges of Atrazine. Atrazine + inter cropping of cowpea along with conventional method of weeding with different sorghum cultivars were arranged in split plot deign with three replications, followed by recommended package of practices. Fertilizers were applied uniformly through urea, diammonium phosphate and muriate of potash @ 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha respectively.

RESULTS

The results revealed that among weed management treatment inter cropping of sorghum with cow pea accompanied with one hand weeding significantly reduced density and dry matter accumulation of weeds 61.58/m^2 and 276.11 g/m^2 over weedy check by 49.95% and 52.75% reduction with minimum weed index of 8.51. Highest grain and stover yield of 3446.47 and 9742.87 kg/ha respectively obtained with the same weed management practice with highest net returns and B/C ratio of Rs. 23672 /ha and 1.77 respectively, however among cultivars lowest weed density dry matter accumulation and weed index of 68.20/m^2, 281.38 g/m^2 and 22.26 respectively was found with CSH 23. Cultivar CSH 16 obtained highest grain and stover yield of 3347.59 and 8816.89 kg/ha with net returns and highest B/C ratio of Rs. 22080 /ha and 1.70 respectively.

Table1.Weed growth, yield and economics of sorghum cultivars as influenced by different weed control treatments

Treatment	Weed density no./m^2	Weed dry matter g/m^2	Weed index	Grain yield kg/ha	Stover yield kg/ha	B:C ratio
Weed Management						
Weedy check	11.59(134.0)	523.48	50.81	1866.2	8321.2	1.13
Weed free	0.71(-)	0.00	0.00	3797.0	10299.9	1.76
Atrazine 0.5 kg/ha	9.12(82.75)	318.60	21.20	2991.1	8822.6	1.74
Atrazine 0.5 kg/ha + 1 HW	8.40(70.08)	291.01	15.64	3204.4	9179.1	1.63
Intercropping + 1 HW	7.87(61.58)	276.11	8.51	3446.5	9742.9	1.77
LSD (P=0.05)	0.143	8.100	6.367	234.52	561.0	0.089
Cultivars						
CSH 16	7.52(69.13)	283.56	16.24	3347.6	8816.9	1.70
CSH 23	7.46(68.20)	281.38	22.26	3262.6	8216.3	1.58
CSV 20	7.68(72.27)	281.65	17.04	2837.6	10214.4	1.61
CSV 23	7.50(69.13)	280.76	21.38	2796.5	9845.1	1.54
LSD (P=0.05)	0.142	NS	3.633	185.0	418.5	0.112

Note: *HW = Hand weeding* at 30 DAS, Figures in parenthesis are original value and * transformation value (x + 0.5)

CONSLUSION

It was concluded that inter cropping of cow pea with sorghum followed by one hand weeding at 30 DAS was most effective for controlling weeds, improving grain and stover yield. Cultivar CSH 16 was found best for grain, stover yield with highest net return and B/C ratio.

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Theme 2

Weed management for higher input-use efficiency

Impact of year round conservation tillage and weed management on weed growth and productivity of rice in direct seeded rice-yellow sarson- greengram cropping system

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Adoption of conservation tillage systems is increasing in the world because of savings in time and economic inputs. Weed control in conservation agriculture is a greater challenge than in conventional agriculture as changes in tillage practices can affect weed population dynamics, including weed seed distribution and abundance in soil seed bank (Tuti and Das 2013). Residue retentions serve as physical barrier to emergence of weeds, moderate soil temperature, conserve soil moisture, add organic matter and improve the nutrient-water interactions (Duary *et al*. 2015). Research work has been carried out on weed management in direct-seeded rice in eastern India. But little information is available on conservation tillage especially in direct-seeded rice based cropping system. With this perspective the present study was undertaken to study the effect of tillage and weed management practices on growth of complex weed flora and productivity of direct seeded rice after one year of conservation tillage practices in direct-seeded rice-yellow sarson - greengram cropping system.

METHODOLOGY

Field experiment was conducted from *Kharif* 2015 to *Kharif* 2016 at Agriculture Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal. The experiment was laid out in strip plot design with three replications. Four tillage practices comprising of conventional tillage (CT) (direct-seeded rice) — CT (yellow sarson) — CT (greengram), CT (direct-seeded rice) — Zero tillage (ZT) (yellow sarson) — ZT (greengram), ZT (direct-seeded rice) — ZT (yellow sarson) — ZT (greengram), ZT + residue (R) (direct-seeded rice) — ZT + R (yellow sarson) — ZT + R (greengram) were allocated to the horizontal strip and three weed management practices *viz.* recommended herbicides (pendimethalin at 1.0 kg /ha followed by bispyribac-Na at 25 g /ha in direct-seeded rice, pendimethalin at 0.75 kg/ha each in yellow sarson and greengram), recommended herbicides + manual weeding at 35 DAS, Unweeded control were assigned to the vertical strip. Crop varieties *'MTU-1010'*, *'B-9'* and *'Samrat'* were used for rice, yellow sarson and greengram respectively. Recommended NPK at 80:40:40 kg/ha in rice, 80:40:40 kg/ha in yellow sarson and 20:40:40 kg/ha in greengram were applied. The data on weed density and dry weight was recorded at 45 DAS of direct-seeded rice.

RESULTS

Echinochloa colona, Digitaria sanguinalis, Cynodon dactylon and *Ludwigia parviflora* were predominant in the experimental field at 45 DAS. Year round practice of conservation tillage along with or without weed management in direct seeded rice - yellow sarson - greengram showed significant variation in density and dry weight of different weed species in succeeding direct-seeded rice. Dominance of perennial weeds like *Cynodon dactylon* was observed in conservation tillage systems. Conservation tillage *i.e* zero tillage along with residue registered the lowest density and dry weight of different weed species at 45 DAS. This might be due to no or minimal soil disturbance and proper land cover by the residue which acted as a physical barrier resulting in poor emergence and growth of composite weed flora. Application of recommended herbicides and hand weeding at 35 DAS registered the lowest dry weight of different weed species at 45 DAS (Table 1). Conservation tillage recorded the highest grain yield which might be due to cumulative effects of residue retention of the preceding crops and effective suppression of weeds which facilitated higher soil moisture conservation, availability of higher organic carbon and other nutrients to the crop. Conservation tillage practice along with recommended herbicides and hand weeding resulted in the highest grain yield of direct-seeded rice.

Table 1. Density and dry weight of major weed species and grain yield of rice as influenced by year round conservation tillage and weed management practices

Treatment	Weed density (no./m^2) at 45 DAS				Weed dry weight (g/m^2) at 45 DAS				Grain yield (t/ha)
	E. colona	*D. sanguinalis*	*C. dactylon*	*L. parviflora*	*E. colona*	*D. sanguinalis*	*C. dactylon*	*L. parviflora*	
Tillage practices									
CT (DSR) CT (yellow sarson) - CT (greengram)	6.22	14.40	7.60	6.66	9.24	25.52	1.99	8.55	2.77
CT (DSR) ZT (yellow sarson) - ZT (greengram)	6.31	13.93	8.23	6.73	9.12	25.30	2.18	8.06	2.80
ZT (DSR) ZT (yellow sarson) - ZT (greengram)	6.31	13.62	23.62	3.99	8.28	24.11	6.48	4.97	2.85
ZT (DSR)+R - ZT (yellow sarson) + R - ZT (greengram) + R	4.98	11.02	21.58	3.31	6.66	19.55	5.88	3.85	3.12
LSD (P=0.05)	1.03	1.82	2.41	0.58	1.22	3.24	0.75	0.68	0.21
Weed management practices									
Recommended herbicides	5.58	6.91	14.06	3.30	6.95	11.65	3.77	3.43	3.37
Recommended herbicides + manual weeding	1.03	2.00	7.69	0.71	1.41	3.73	2.06	0.74	4.33
Unweeded control	11.25	30.81	24.02	11.51	16.62	55.47	6.56	14.91	0.97
LSD (P=0.05)	1.59	2.13	3.29	1.00	2.02	3.38	0.99	1.15	0.23

CT- Conventional tillage, ZT-Zero tillage, R- Residue, *E- Echinochloa, D- Digitaria, C-Cynodon, L-Ludwigia,* DSR - Direct seeded rice

CONCLUSION

Year round conservation tillage (zero tillage with residue) with recommended herbicides and hand weeding appeared to be promising in suppressing composite weed flora and obtaining higher yield of rice in direct-seeded rice-yellow sarson-greengram cropping system in the lateritic belt of West Bengal.

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Weed dynamics as influenced by different rice establishment methods under puddled soil

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Rice *(Oryza sativa* L.*)*, a high calorie *Kharif* cereal is most important staple food of Jharkhand which is cultivated on 1.49 million hectares with a productivity of 2.57 t/ha (Anonymous, 2015). Rice is largely grown in Jharkhand by transplanting seedlings under puddled soil, which is labour, water, and energy intensive. Although direct-seeding of rice is advantageous over transplanting but weeds are the major constraints, which ultimately reduces the yield of direct seeded rice up to 90% depending upon the severity of weed infestation (Yadav *et al*. 2009). Hence, the present investigation was undertaken to observe the effect of different rice establishment methods under puddled condition on weed density and weed dry matter at all the growth stages.

METHODOLOGY

A field experiment was conducted during *Kharif* season of 2015 at Birsa Agricultural University, Ranchi (Jharkhand) to study the effect of different rice establishment methods under puddled soil on weed dynamics. Experiment was laid out in Randomized Block Design with four replication and the rice variety used was '*Naveen*'. The treatments comprised of five different rice establishment methods – conventional transplanting (seedlings raised by wet nursery method , 2-3 seedlings/hill (21 days old) were transplanted at 20 x 15 cm spacing), mechanical transplanting (seedlings prepared on mat type nursery, 4-5 seedlings/hill (15 days old) were transplanted at 25 x 15 cm spacing), drum seeding of sprouted seeds (20 cm row spacing), broadcasting of sprouted seeds and broadcasting of dry seeds and bispyribac-sodium was used in all the treatments 25 g/ha (10% SC) at 20 days after sowing/transplanting. Direct seeding was done on the same day i.e. the day seeds were placed in nursery. Puddling was done 5 days before as well as on the day of sowing/ transplanting. Uniform fertilization (120: 60: 40 kg N: P_2O_5: K_2O / ha) was done for all the rice establishment methods through urea, diammonium phosphate and muriate of potash, respectively. Whereas, in nursery fertilizers was applied 12: 6: 4 kg N: P_2O_5: K_2O /1000 sq m. Data on weed growth and yield were recorded.

RESULTS

Different rice establishment methods and the use of herbicide had a significant influence on weed growth. Conventionally transplanted rice having minimum weed density (31.48 /m2) was significantly 43.5, 33.8 and 29.4% lower than broadcasting of dry seeds, broadcasting of sprouted seeds, and mechanical transplanting respectively. Whereas drum seeded rice (34.33/m^2) also recording minimum weed density was 31.6 and 22.7% lower than broadcasting of dry seeds and that of sprouted seeds, respectively. Conventional method of transplanting recorded the minimum dry matter of weed (187.08 g/m^2) and was significantly lower by 18.5, 15.9 and 15 % than broadcasting of sprouted seeds, broadcasting of dry seeds and mechanical transplanting, respectively. Under submerged condition transplanting rice seedlings of 21 days was stouter and stronger in suppressing weed population as compared to 15 days aged seedlings in mechanical transplanting which in turn reduced the weed dry matter accumulation in case of conventional transplanting. Also the desired spacing in drum seeded rice suppressed the weed population to thrive, resulting in reduced weed density and weed dry matter. Whereas, total density and dry weight of weeds were higher under direct seeded rice (sprouted and dry seeds) under puddled condition (Yadav *et al.* 2009) which might be due to failure to maintain flooded conditions in field and non submergence of crop in the initial stages, as crop and weeds germinate simultaneously so competition exists (Parameshwari and Srinivas 2014).

Table 1. Density of weeds and weed dry matter as influenced by rice establishment methods under puddled condition

Treatment	Weed density(no./m2)	Weed dry matter(g/m2)	Grain yield (t/ha)	Straw yield (t/ha)	Benefit: cost ratio
Conventional Transplanting	31.48	187.05	4.42	6.84	1.80
Mechanical Transplanting	40.73	215.08	3.98	6.38	1.51
Drum seeding ofsprouted seeds	34.33	201.59	4.37	6.79	2.34
Broadcasting of sprouted seeds	42.13	221.26	3.71	6.02	1.94
Broadcasting of dry seeds	45.18	216.85	3.65	5.93	1.89
LSD (P=0.05)	7.67	26.42	5.82	8.05	0.39
CV%	12.89	8.26	9.42	8.20	13.42

Note: Bispyribac –sodium 25 g/ha (10% SC) used as herbicide in all treatments

Rice crop established through conventional transplanting recorded highest grain and straw yield (4.42 and 6.84, respectively) which was on par with drum seeding of sprouted seeds and mechanical transplanting (Table 1) whereas, among the direct seeded rice, broadcasting of dry seeds being similar to that of sprouted seeds recorded the lowest grain and straw yield (3.65 and 5.93t/ha, respectively) due to uncontrolled growth of weeds. While B: C ratio (2.34) under drum seeded rice was higher than all other methods of rice establishment and had significant edge by 20.6, 23.8, 30 and 55% over broadcasting of sprouted seeds, broadcasting of dry seeds, conventional transplanting, and mechanical transplanting, respectively.

CONCLUSION

It can be concluded that the desired spacing and use of bispyribac-sodium, a post-emergence herbicide in drum seeding of sprouted seeds suppressed the weed growth as compared to other direct seeding methods of rice establishment, hence for higher productivity, establishment of rice through drum seeding can be a feasible alternative of conventional transplanting.

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Phyto-toxic effect of weed management on maize

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Maize (*Zea mays* L.) is one of the most versatile crops having wider adaptability under diverse soil and climatic conditions. Globally, maize is known as the '*Queen of Cereals*' because it has the highest genetic yield potential amongst the cereals owing to its better dry matter accumulation efficiency in a unit area and time. In India, the presence of weeds, in general reduces the maize yield by 27-60%, depending upon the growth and persistence of weed population in maize crop (Singh *et al*. 2015). It is the third most important crop of India after rice and wheat and being a wide spacing cereal crop weeds are the major problem. Herbicides plays important role to control weed efficiently but in some extent it causes phyto-toxic effect like yellowing, scorching, curling, chlorosis, wilting and etc. This experiment is conducted with the objective of Study the phyto-toxic effect of chemical weed management on maize plant and yield.

METHODOLOGY

A field investigation was conducted at BAU experimental Farm, Ranchi during *Kharif* season 2015 on sandy clay loam soil. The experiment was laid out in a RBD with 13 treatments: atrazine 0.5 + pendimethalin 0.5 kg/ha PE, two hand weeding at 20 and 40 DAS, two mechanical weeding at 20 and 40 DAS, atrazine 1.0 kg/ha PE, pretilachlor 0.5 + metribuzin 0.175 kg/ha PE, metribuzin 0.35 kg/ha at 15 DAS, pendimethalin 1.0 kg/ha PE, atrazine 1.0 kg/ha at 15 DAS, metribuzin 0.35 kg/ha PE, pretilachlor 1.0 kg/ha PE, pretilachlor 1.0 kg/ha at 15 DAS, green manuring by *Sesbania* 80 kg/ha *fb* 2, 4-D 0.625 kg/ha at 30 DAS and weedy check, replicated thrice. Phyto-toxicity cause due to application of herbicide was recorded in the scale of 1 - 10 at 5, 10 and 15 days after application of herbicide. Phyto-toxicity symptoms involve yellowing, scorching, epinasty, necrosis, as well as stunting growth of crop. Plants showing slight photo-toxic effect at 1st observation and later on recovered with normal growth were not considered for phyto-toxic effect. However plants prolonged shows phyto-toxic effect were noted. Number of plants showing phyto-toxic symptoms observed from 10 plants averaged and accordingly the grading was done. Grain yield of each net plot was recorded after threshing, cleaning and drying of grains (12% moisture). Weight of grain in each plot was converted to kg/ha.

RESULTS

Phyto-toxic effect and grain yield

In general, the phyto-toxic effect on maize plant was not visible at any stage of crop except post-emergence application of metribuzin 0.35 kg/ha. This particular treatment showed some yellowing and scorching effect on maize leaves for 6-7 days which disappeared slowly and plants recovered, grain yield not affected. Application of atrazine 0.5 + pendimethalin 0.5 kg/ha PE (T_6) recorded significantly higher grain yield (5.09 t/ha) being at par with two hand weedings at 20 and 40 DAS, two mechanical weedings at 20 and 40 DAS, atrazine 1.0 kg/ha PE and pretilachlor 0.5 + metribuzin 0.175 kg/ha PE. Weedy check produced significantly lowest grain yield (2843 kg/ha). Barla *et al.* (2016) and Kumar *et al.* (2015) also found similar results.

Table 1. Phyto-toxic effect of weed management practices on maize plant (*var.* Suwan) at different crop growth stages during *kharif*, 2015

Treatment	Phyto-toxic effect (0-10)			Grain yield (t/ha)
	05 DAAS	10 DAAS	15 DAAS	
Pretilachlor 1.0 kg/ha PE	0	0	0	3.62
Atrazine 1.0 kg/ha PE	0	0	0	4.29
Pendimethalin 1.0 kg/ha PE	0	0	0	3.82
Metribuzin 0.35 kg/ha PE	2	1	0	3.64
Pretilachlor 0.5 + metribuzin 0.175 kg/ha PE	0	0	0	4.26
Atrazine 0.5 + pendimethalin 0.5 kg/ha PE	0	0	0	5.09
Pretilachlor 1.0 kg/ha at 15 DAS	0	0	0	3.56
Metribuzin 0.35 kg/ha at 15 DAS	7	4	1	3.88
Atrazine 1.0 kg/ha at 15 DAS	3	1	0	3.66
Green manuring fb 2, 4-D 0.625 kg/ha at 30 DAS	-	-	-	3.39
Mechanical weeding at 20 and 40 DAS	-	-	-	4.44
Hand weeding at 20 and 40 DAS	-	-	-	4.61
Weedy check	-	-	-	2.84
				0.40
				1.17
				0.02

CONCLUSON

Phyto-toxic effect due to use of different chemicals in management practices was not visible at any stage of maize crop except post-emergence application of metribuzin 0.35 kg/ha, where it showed little yellowing and scorching effect on leaves for 6-7 days duration which disappeared slowly and plants recovered from early shock.

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Impact of tillage and weed control practices on weed flora and productivity of rice under irrigated ecosystem

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Rice (*Oryza sativa*) is the widely cultivated crop in the world. Traditionally, it is grown by transplanting in puddled situation which is associated with various constraints like labour availability, weeds, water, insects *etc*. Among the several production constraints, weeds are most important with great genetic diversity. But, current production system can hardly compensate the food demand of increasing population with a fatigue natural resource base (Saharawat *et al*. 2010). Therefore, sustaining and improving the production system of rice, it is essential by resource conserving technologies like direct seeding, zero-till with retention of residues. Hence, the present investigation was undertaken to evaluate the alternative tillage with appropriate weed management opportunities to increase the yield potential of rice crop.

METHODOLOGY

A field experiment was conducted at NEB Crop Research Centre of G.B. Pant University of Agriculture & Technology, Pantnagar (UK) during *Kharif* 2015 and 2016. The experiment was laid out in strip plot design with 15 treatments, comprising 5 tillage methods in vertical strip (CT rice and wheat, CT rice and ZTW with inclusion of *Sesbania* as green manure, DSR and CTW *fb Sesbania* inclusion as brown manure, ZTR- ZTW *fb Sesbania* as brown manure and ZTR- ZTW with retention of residues of previous crop fb *Sesbania* as brown manure); and 3 weed control measures in horizontal strip (unweeded control, recommended herbicide *i.e.* Bispyribac-Na 20 g/ha as post-emergence and integrated weed management *i.e.* herbicide application *fb* 1 hand weeding at 45 DAS/DAT), replicated thrice in clay loam soil. Seeds of '*Pant dhan-12*' were sown with recommended fertilizer dose through urea and NPK mixture. Data against complex weed flora, dry matter production and yield were recorded and pooled statistically following standard methods.

RESULTS

Weed spectrum observed during *Kharif* were *Echinochloa colona, E. crusgalli, L. chinensis, C. axillaris, A. sessilis, A. baccifera, C. rotundus, C. iria, C. difformis* and *F. miliaceae*. Establishment methods significantly influenced total weed density, dry matter and yield of rice except total weed density in 2015 (Table 1). Among establishment methods, lowest weed density was recorded under ZTR and wheat with residue retention and *Sesbania* brown manuring in 2016 which was at par with TPR (CT)-Wheat (ZT)-*Sesbania* and DSR (CT)-Wheat (CT)- *Sesbania*. While, in 2015, total weed dry matter was found lowest under zero-till rice and wheat without residue retention and *Sesbania* brown manuring followed by DSR (CT)-Wheat (CT)- *Sesbania*, which also recorded significantly lowest dry biomass in 2016. The grain yield was found highest with TPR (CT)-Wheat (ZT)-*Sesbania* (ZT) as green manure followed by conventional TPR during both the years. Different weed management practices significantly influenced total weed density, dry matter and yield of rice, recording lowest density including dry matter with highest grain yield under integrated approaches followed by sole herbicidal application over the unweeded situation (Table 1).

Table 1. Effect of establishment methods and weed management on weeds at 60 DAS and yield of rice

Treatment	*Total weed density (no./m^2)		*Total weed dry wt. (g/m^2)		Grain yield (t/ha)	
	2015	2016	2015	2016	2015	2016
Establishment system						
TPR (CT)-Wheat (CT)	8.2 (70.7)	7.9 (70.3)	9.3 (90.2)	9.7 (103.2)	5.1	4.6
TPR (CT)-Wheat (ZT)-*Sesbania* (ZT)	7.9 (69.6)	7.4 (57.8)	9.6 (99.3)	9.1 (86.1)	5.2	5.4
DSR (CT)-Wheat (CT)- *Sesbania* (ZT)	7.9 (83.4)	7.4 (81.6)	8.0 (87.2)	8.1 (96.3)	3.7	3.0
DSR (ZT)-Wheat (ZT)- *Sesbania* (ZT)	7.8 (66.3)	8.1 (71.3)	7.6 (63.8)	8.7 (82.5)	2.9	2.3
DSR (ZT)+R-Wheat (ZT)+R- *Sesbania* (ZT)	7.7 (75.1)	7.3 (70.7)	9.4 (111.5)	8.8 (101.7)	3.7	3.4
LSD (P=0.05)	NS	0.5	0.4	0.2	0.4	0.7
Weed management						
Rec. herb. (Bispyribac- Na 20 g/ha)	7.2 (50.9)	6.8 (46.3)	7.9 (63.0)	7.7 (60.8)	4.8	4.5
IWM (Rec. herbicide *fb* one hand weeding)	4.3 (18.4)	4.0 (16.4)	5.1 (27.1)	5.1 (27.0)	5.4	4.8
Unweeded	12.2 (149.7)	12.1 (148.3)	13.4 (181.0)	13.9 (194.1)	2.1	2.0
LSD (P=0.05)	0.2	0.3	0.2	0.1	0.3	1.1

* Original data is indicated in parentheses; Data transformed to square root transformation; CT- Conventional Tillage, ZT- Zero Tillage, TPR- Transplanted Rice, DSR- Direct Seeded Rice, R- Residue, Rec. herb.- Recommended herbicide, IWM- Integrated Weed Management

CONCLUSION

It can be concluded that adoption of conventional TPR-zero-till wheat- *Sesbania* inclusion as green manure along with integrated approaches of weed management (herbicide *fb* 1 hand weeding at 45 DAS) was found effective in respect to attaining higher productivity of rice crop under rice-wheat cropping system.

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Impact of crop establishment on weed shift and yield of rice and wheat in rice-wheat cropping system

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Rice (*Oryza sativa*)-Wheat (*Triticum aestivum*) cropping system is the predominant system of Indo-Gangetic plains (IGP) in India. It is the "food bowl" or "food basket" of India having 13.5 mha area. In recent years, rice-wheat has started suffering a production fatigue in productivity despite the application of optimum levels of inputs due to weeds, causing enormous losses in yield. Conventional weed control method is weather dependent, laborious and expensive. Thus, conservation agriculture is being promoted in rice-wheat cropping system, which requires less water, labour, energy *etc*. This change in establishment method also lead to the shift in weed species with adoption of ZT and dry seeding (Shahzad *et al.* 2016) which is needed to be controlled and is absent in conventional till systems. Hence, the present investigation was undertaken to study the shift of weed flora and crop yields with adoption of alternative tillage and weed management practices in rice-wheat cropping system.

METHODOLOGY

A field experiment was conducted at NEB CRC of G.B. Pant University of Agriculture & Technology, Pantnagar (UK) during 2012-15. The experiment was laid out in strip plot design with 15 treatments, comprising 5 tillage methods in vertical strip *i.e.* conventional till (transplanted) rice (CT) and wheat, CT rice- zero-till (ZT) wheat with *Sesbania* as green manure, conventional till direct seeding of rice (DSR)- CT wheat- *Sesbania* incorporation, ZT rice- ZT wheat- *Sesbania* brown manuring and ZT rice- ZT wheat with retention of residues of previous crop- *Sesbania* brown manuring; and 3 weed control measures in horizontal strip *i.e.* unweeded control, recommended herbicide *i.e.* bispyribac-Na 20 g/ha in rice and ready mix of clodinafop (15%) + MSM (1%) 60+4 g/ha in wheat and integrated weed management *i.e.* herbicide application *fb* 1 hand weeding at 45 days after sowing/ planting), replicated thrice in clay loam soil. Seeds of rice '*Pant dhan-12*' and wheat '*UP-2572*' were sown with recommended dose of fertilizers (150:60:40 kg N:P:K/ha) through urea and NPK mixture. Data against complex weed flora shift, where *Kharif* 2012 and *Rabi* 2012-13 was considered as base year and *Kharif* 2014 and *Rabi* 2014-15 as final; and yield were recorded and pooled statistically following standard methods.

RESULTS

Among different establishment methods of rice, the density of *E. colona, L. chinensis, A. sessilis* and *C. iria* was more in conventional TPR during 2012 which greatly reduced in the year 2014. However, no shifting in *L. chinensis* and *A. sessilis* species in conventional TPR along with utilization of *Sesbania* as green manure. While, the density of *E. colona, L. chinensis, A. sessilis* and *C. rotundus* was less in DSR (ZT)+R-Wheat (ZT)+R -*Sesbania* (ZT) in base year which accentuated in 2014. The density of *E. crus-galli, A. baccifera* and *C. difformis* was completely controlled in all the establishment methods of rice as conventional direct seeded and zero tilled compared to the base year. *C. axillaris* appeared in conventional TPR with or without *Sesbania* incorporation as green manure compared to the base year *Kharif* 2012, as no appearance of this species. Among different establishment methods of wheat, *P. minor* was dominanting in CTW and least in ZTW, while among the BLWs, there was a huge increment in the density of *M. denticulata* and *P. plebejium* in both the establishment methods of wheat compared to the base year *Rabi* 2012-13. The density of *C. didymus* and *R. acetosella* was completely controlled under CTW, whereas, increases under ZTW as compared to the base year *Rabi* 2012-13. Also, accentuated amount was recorded in the density of *C. album* and *V. sativa* in both the establishment methods of wheat.

Research results showed that, tillage and weed management practices significantly influenced yield of rice while non significant effect was found in the yield of wheat under both the tillage methods (Fig. 1). Conventional TPR along with *Sesbania* as green manure recorded highest grain yield followed by conventional TPR. However, maximum wheat yield was achieved by DSR (ZT)+R-Wheat (ZT)+R -*Sesbania* (ZT). Over 3 years study, maximum total yield was achieved by DSR (ZT)+R-Wheat (ZT)+R -*Sesbania* (ZT). Among weed management practices, highest grain yield were found with IWM followed by sole herbicidal application over the unweeded situation (Fig.1). These results are in close conformity with Chauhan and Abhugo 2013.

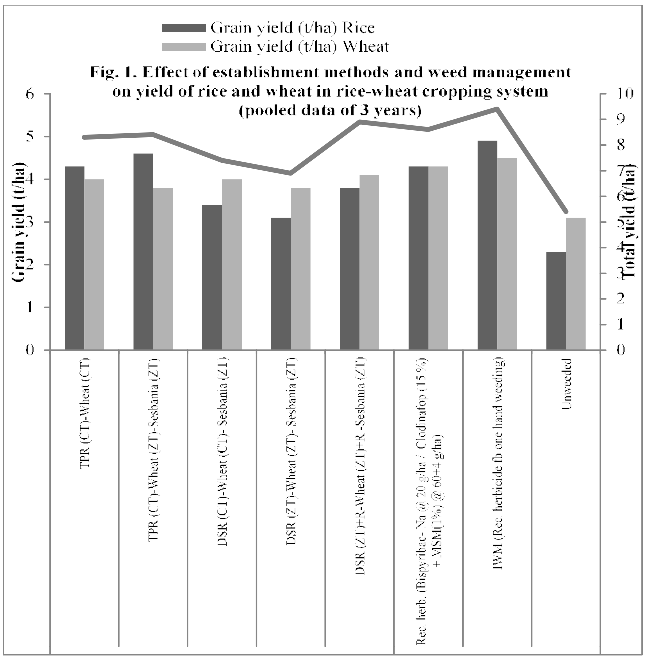

Fig. 1. Effect of establishment methods and weed management on yield of rice and wheat in rice-wheat cropping system (pooled data of 3 years)

CONCLUSION

The findings of the present investigation conclusively inferred that weeds are dynamic in nature with genetic diverse population that are influenced by different tillage adopted. Thus, conventional system could be replaced with zero-till-based crop establishment along with residue retention and *Sesbania* introduction to save labour, energy, time, cost and fuel to attain sustainability.

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Weed management of dry-seeded rice under different crop establishment methods

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Globally, rice is the most important crop as it feeds about 70 per cent of the world's population. Transition in crop establishment method of rice from traditional method of transplanting to dry seeding of rice (DSR) has been observed especially in Asian countries as it saves both labour and water that are becoming scarce day by day. Weeds are the main cause for low productivity in DSR. Adoption of only one weed management practice (like herbicide application, brown manuring etc) can not suppress weed infestation successfully Keeping these points in view, the investigation was carried out to find out the suitable weed management practice and crop establishment method for DSR.

METHODOLOGY

The present study was carried out during *Karif* season of 2011 and 2012 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) in split-plot design keeping three crop establishment methods *viz*., conventional planting (followed by dry seeding of rice in thoroughly prepared field), bed planting (two lines of rice planted in each bed of 37 cm width with 30 cm width furrow between two beds) and no-till planting (glyphosate 1 kg/ha before-planting for weed control followed by dry seeding of rice) in the main plot and eight weed management practices. A uniform dose of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare was applied through urea, DAP and MOP, respectively. Rice variety '*Sarjoo 52'* was sown at the rate of 30 kg/ha on 25th June maintaining 20 cm row-to-row spacing during both the years.

RESULTS

Bed planting had significantly lowest weed density and dry weight of all weed species – grasses, sedges and BLW at 90 DAS among crop establishment methods. Also, no-till method registered markedly lower weed density and weed dry weight at 90 DAS than conventional planted DSR. Pre-emergence herbicide pendimeth-alin controlled the growth of weeds at initial stage while post-emergence herbicide bispyribac checked the weed growth at subsequent flushes. This is in conformity with the findings of Walia *et al.* (2009).

The influence of crop establishment methods on grain yield was non-significant among various crop establishment methods. However, no-till method gave highest BCR (1.66) among crop establishment methods owing to saving in labour, power and capital as land preparation was excluded in this treatment.

A close analysis of data revealed that pendimethalin *fb* bispyribac-sodium *fb* brown manuring had maximum value of grain yield (4.21 t/ha), which was significantly higher than other weed management practices, except pendimethalin *fb* brown manuring (4.20 t/ha). Increment in grain yield in treatments, pendimethalin *fb* brown manuring and pendimethalin *fb* bispyribac-sodium *fb* brown manuring over the weedy check was in the tune of 187.67 and 188.36%, respectively. Higher BCR (1.90) was recorded under application of pendimethalin *fb* brown manuring than other weed management practices.

Table 1. Influence of crop establishment methods and weed management practices on density and dry weight of grasses, sedges and broad leaf weeds at 90 DAS, their control efficiency, grain yield and BCR under DSR (mean and pooled data of two years)

Treatment	Total density of weeds (No./m²)			Dry weight of weeds (g/m²)			WCE (%)			Grain yield (t/ha)	BCR
	Grasses	Sedges	BLW	Grasses	Sedges	BLW	Grasses	Sedges	BLW		
Crop establishment methods											
Conventional	10.4 (107)	6.9(46.7)	3.6(12.2)	11.0(121.1)	7.7(58.84)	3.6(12.23)	-	-	-	3.46	1.50
Bed planting	9.2 (84.5)	6.1(36.6)	3.4(11.1)	9.3(86.6)	6.7(44.48)	3.0(8.35)	-	-	-	3.45	1.46
No-till	9.8 (95.4)	6.3(39.7)	3.7(12.9)	10.2(103.1)	7.2(51.43)	3.1(9.13)	-	-	-	3.73	1.66
LSD (P=0.05)	0.75	0.32	0.11	0.71	0.37	0.14	-	-	-	NS	-
Weed management practices											
Pendimethalin 1.0 kg/ha	10.3 (105.2)	7.3(52.3)	3.7(13.5)	11.2(124.5)	8.3(68.15)	3.7(13.13)	51.32	49.09	55.75	3.29	1.54
Bispyribac-NA 0.025 kg/ha	9.7 (93.9)	6.9(47.6)	3.5(11.8)	10.2(103.6)	7.6(57.81)	3.3(10.56)	59.70	56.83	64.11	3.50	1.60
Brown manuring	11.3 (127.2)	6.4(40.9)	3.3(10.5)	11.8(139.2)	7.1(50.24)	3.0(8.72)	45.58	62.50	70.35	3.12	1.52
Pendimethalin fb brown manuring	7.5 (55.4)	5.4(29.0)	2.9(8.0)	7.4(54.9)	6.1(36.19)	2.6(6.36)	78.66	72.90	78.46	4.20	1.90
Pendimethalin fb bispyribac	8.5 (71.7)	5.7(32.2)	2.9(7.8)	9.2(84.8)	6.3(39.38)	2.7(6.95)	66.98	70.54	76.37	3.76	1.61
Pendimethalin fb bispyribac fb Brown manuring	8.1 (64.5)	4.7(21.4)	2.4(5.5)	8.2(66.3)	5.3(27.67)	2.1(4.06)	74.20	79.34	86.26	4.21	1.75
Weed free	0.7 (0.0)	0.7(0.0)	0.7(0.0)	0.7(0.0)	0.7(0.00)	0.7(0.00)	-	-	-	4.82	1.52
Weedy check	15.8(249.2)	10.2(104.6)	6.3(39.5)	16.0(255.7)	11.6(133.24)	5.5(29.43)	-	-	-	1.46	0.76
LSD (P=0.05)	0.34	0.17	0.09	0.40	0.32	0.12	-	-	-	0.20	

Data were subjected to square root $\sqrt{x+0.5}$ transformation; Figures in parentheses are original values

CONCLUSION

It was concluded that no-till method of crop establishment by application of pre-planting herbicide glyphosate 1.0 kg/ha for control of perennial and other annual weeds and weed management by pre-emergence application of pendimethalin 1.0 kg/ha along with brown manuring of *Sesbania* at 25 DAS by spraying 2,4-D 0.5 kg/ha could be adopted for achieving higher yield and benefit-cost ratio for DSR.

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Effect of irrigation schedules, sowing methods and weed control on weed density and grain yield of wheat

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Wheat is the second most important cereal in India after rice contributing substantially to the national food security by providing more than 50% of the calories to the people who mainly depend on it. In chronological perspective, India has made spectacular advancement in productivity and sustainability of wheat over the years. The production of wheat grain in the year 2013-14 was estimated to be 95.91 mt from acreage of 31.19 mha at a yield level of 3.07 t/ha. During this period, Rajasthan accounted for about 9.01% of the national area and 9.3% of production with average productivity of 3.17 t/ha (Govt. of India, 2014). Weed is one of the major biotic constraints in wheat production as they compete with crop for nutrients, moisture, light and space Wheat is infested with grassy as well as broad-leaved weeds, control of which requires a variety of herbicides (Sharma *et al.* 2015). To control mixed population of weeds and also to avoid herbicides resistance by continuous use of single herbicide, compatible mixtures can be employed to widen the spectrum of weed control. A review on the effect of weed growth on yield suggested losses in the range 15–80% in wheat. Improving weed control in farmer's field has shown to increase wheat yield by 15–30% (Mahajan *et al.* 2012).

METHODOLOGY

The experiment was conducted during *Rabi* 2013-14 and 2014-15 seasons at the Instructional Farm (Agronomy) Rajasthan College of Agriculture, MPUAT, Udaipur. Twenty seven treatment combinations comprising of three irrigation levels (0.8, 1.0, 1.2 IW/CPE), three sowing methods (line sowing at 22.5 cm, crisscross sowing at 22.5 cm, FIRB system) and three weed control methods (weedy Check, isoproturon + 2,4-D (TM) 750 g + 500 g/ ha, sulfosulfuron + metsulfuron (RM) 30 g + 2 g/ha at 35 DAS were tested in split – plot design with three replications. irrigation scheduling treatments assigned in main plots and sowing methods and weed control in sub plots. Wheat variety Raj-4037was used as test crop.

RESULTS

Different IW/CPE ratio significantly affects the density of dicot, monocot and total weeds at 90 DAS. IW/CPE ratio at 0.8 recorded significantly lower densities of dicot, monocot and total weed by 30.71 and 31.80, 26.74 and 28.86 and 29.43 and 30.83 % in comparison to IW/CPE ratio at 1.0 and 1.2, respectively. Further, IW/CPE ratio at 1.2 and 1.0 found at par with each other. Data indicate that crisscross sowing and FIRB system produced 12.55 and 10.16% higher grain yield over line sowing (4.57 t/ha). Significantly lower weed density of dicot, monocot and total weeds were recorded under crisscross sowing method followed by FIRB system of sowing, however, both these methods were at par with each other. Crisscross sowing and FIRB system brought about reduction in dicot, monocot and total weed density by 11.81 and 10.04, 26.84 and 22.22 and 16.36 and 13.77% as compared to line sowing, respectively. Application of sulfosulfuron + metsulfuron (RM-ready mix formulation) significantly decreased the density of dicot, monocot and total weeds by 86.99 and 5.72, 81.29 and 6.27 and 85.30 and 5.93% over weedy check and isoproturon + 2,4-D (TM), respectively. Maximum grain yield was recorded under sulfosulfuron + metsulfuron (RM) which was statistically at par with isoproturon + 2, 4-D (TM). On pooled basis application of sulfosulfuron + metsulfuron (RM) and isoproturon + 2, 4-D (TM) gave significantly higher grain yield by 24.06 and 21.81% over weedy check (4.27 t/ha), respectively.

Table 1. Effect of irrigation schedules, sowing methods and weed control on weed density at harvest and grain yield (pooled data)

Treatment	Weed density 90 DAS (no/m^2)			Grain yield (t/ha)
	Dicot	Monocot	Total weeds	
Irrigation schedule (IW/CPE)				
0.8	6.08(47.35)	4.43(22.14)	7.45(69.50)	4.57
1.0	7.04(61.89)	5.01(28.06)	8.58(89.95)	5.05
1.2	7.21(62.41)	5.01(28.53)	8.72(90.93)	5.15
LSD (P=0.05)	0.12	0.14	0.15	0.24
Sowing method				
Line sowing	7.11(61.24)	5.24(30.20)	8.78(91.44)	4.57
Crisscross sowing	6.60(54.77)	4.57(23.81)	7.96(78.58)	5.15
FIRB system	6.62(55.65)	4.64(24.71)	8.02(80.37)	5.04
LSD (P=0.05)	0.07	0.08	0.07	0.16
Weed control				
Weedy check	11.66(135.36)	7.58(56.77)	13.87(192.14)	4.27
Isoproturon + 2,4-D (TM)	4.40(18.68)	3.49(11.33)	5.53(30.01)	5.20
Sulfosulfuron + metsulfuron (RM)	4.27(17.61)	3.38(10.62)	5.36(28.23)	5.30
LSD (P=0.05)	0.07	0.08	0.07	0.16

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original weed count/m^2

CONCLUSION

It was concluded that combination of irrigation scheduling at 1.0 IW/CPE ratio, criss cross method of sowing and sulfosulfuron + metsulfuron (RM) gave higher grain yield of wheat.

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Performance of weed control treatments on mustard productivity

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Indian mustard [*Brassica juncea* (L.) Czern and Coss] is a major *Rabi* crop grown under conserved soil moisture and irrigated condition of Rajasthan. Rajasthan has the highest area of 3.08 million hectares with the highest production of 3.83 million tonnes and a productivity of 1243 kg/ha (Agricultural Statistics 2014) contributing 48.1% to total mustard seed production of the country (Economic Survey 2014-15). As this crop is grown in poor soils with poor management practices, weed infestation is one of the major causes of low productivity (Banga *et al.* 2004). Yield losses due to crop weed competition in rapeseed and mustard have been estimated to the tune of 10-58% (Kaur *et al.* 2014) or even beyond 23-70% depending upon the type, intensity and duration of competition in gobhi sarson (Chopra and Saini 2007). The most common weeds of rape and mustard crop are *Chenopodium album*, *Lathyrus spp.*, *Melilotus indica*, *Cirsium arvense*, *Cyperus rotundus* and *Fumaria parviflora.* The invasion of *Orobanche* (broom rape) has devastating effect on its cultivation in Rajasthan. The most common herbicidal weed control measure recommended in Indian mustard is the pre-emergence application of pendimethalin. Farmers and extension functionaries require information on post-emergence herbicidal weed control due to one or other reason, if pre-emergence application of herbicide was not made.

METHODOLOGY

A field experiment was conducted at Instructional Farm, Rajasthan College of Agriculture, Udaipur during *Rabi*, 2014-15 to find out the suitable method of weed control in mustard. The experiment consisted of 10 treatments were replicated four times in randomized block design. Mustard variety '*Pusa Jai Kisan (Bio- 902)*' with seed rate of 3 kg/ha was sown at spacing of 40 x 10 cm. The soil of experimental field was clay loam in texture and slightly alkaline in reaction and calcareous in nature. It was medium in available nitrogen, phosphorus and potassium. A uniform dose of 60 kg N and 35 kg P_2O_5/ha was given through urea and DAP after adjusting the quantity of nitrogen supplied through DAP.

As per treatment, fenoxaprop-p-ethyl and fluazifop-p-butyl were applied 10 days after the sowing of crop while quizalofop-p-ethyl and isoproturon were applied 30 days after sowing.

RESULTS

At 20 DAS, the lowest weed density was recorded with fluazifop-p-butyl 0.055 kg/ha followed by fenoxaprop-p-ethyl 0.075 kg/ha at 10 DAS. At 60 days stage of crop growth, two hand weeding 20 and 40 DAS recorded the lowest total weed density which was closely followed by post-emergence application of fluazifop-p-butyl 0.055 kg/ha as well as fenoxaprop-p-ethyl 0.075 kg/ha along with hoeing 40 DAS (5.4 and 5.5 weeds/m, respectively). These treatments were statistically at par with each other and significantly superior over weedy check. The maximum seed yield was recorded under weed free check and found statistically at par with two hand weeding, post-emergence application of fluazifop-p-butyl 0.055 kg/ha *fb* hoeing 40 DAS and fenoxaprop-p-ethyl 0.075 kg/ha *fb* hoeing 40 DAS. The per cent increase in seed yield due to these treatment was 69.47, 67.58, 64.05 and 63.94, respectively over weedy check.

Table 1. Effect of weed control on weed density and seed yield of mustard

Treatment	Weed density (m^2)									Seed yield (t/ha)
	20 DAS			40 DAS			60 DAS			
	Monocot	Dicot	Total	Monocot	Dicot	Total	Monocot	Dicot	Total	
Weedy check	9.14*(83.00)	8.45(71.00)	12.43(154.00)	9.22(84.50)	9.72(94.0)	13.38(178.5)	8.57(73.00)	9.28(85.75)	12.62(158.75)	1.17
One hand weeding at 20 DAS	9.20(84.25	8.44(70.75)	12.47(155.00)	2.83(7.50)	2.44(5.50)	3.67(13.00)	3.43(11.25)	6.44(41.00)	7.26(52.25)	1.66
Two hand weeding at 20 and 40 DAS	8.84(77.75)	8.48(71.50)	12.23(149.25)	2.76(7.25)	2.34(5.00)	3.56(12.25)	1.60(2.08)	1.86(3.00)	2.36(5.08)	1.96
Fenoxaprop-p-ethyl 0.075 kg/ha 10 DAS	1.86(3.00)	6.76(46.00)	6.97(49.00)	4.24(17.50)	7.56(56.75)	8.64(74.25)	3.62(12.72)	6.79(45.75)	7.67(58.47)	1.49
Fluazifop-p-butyl 0.055 kg/ha 10 DAS	1.64(2.25)	6.71(44.50)	6.87(46.75)	4.12(16.50)	7.42(54.50)	8.46(71.00)	3.62(12.59)	6.72(44.75)	7.60(57.34)	1.50
Quizalofop-p-ethyl 0.050 kg/ha 30 DAS	8.68(75.00)	8.44(70.75)	12.08(145.75)	1.64(2.25)	6.09(36.75)	6.28(39.00)	3.23(10.00)	6.70(44.50)	7.41(54.50)	1.52
Fenoxaprop-p-ethyl 0.075 kg/ha 10 DAS *fb* one hoeing 40 DAS	1.89(3.25)	6.80(45.75)	7.03(49.00)	4.21(17.25)	7.54(56.50)	8.61(73.75)	1.56(2.00)	1.98(3.50)	2.42(5.50)	1.91
Fluazifop-p-butyl 0.055 kg/ha 10 DAS *fb* one hoeing 40 DAS	1.73(2.50)	6.85(46.50)	7.03(49.00)	4.12(16.50)	7.58(57.00)	8.60(73.50)	1.63(2.15)	1.89(3.25)	2.40(5.40)	1.91
Isoproturon 1.25 kg/ha 30 DAS	8.98(80.25)	8.79(76.75)	12.55(157.00)	2.74(7.00)	4.90(23.50)	5.56(30.50)	4.37(18.60)	6.36(40.00)	7.68(58.60)	1.39
Weed free check	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	0.71(0.00)	1.98
LSD (P=0.05)	0.46	0.61	0.65	0.32	0.41	0.40	0.28	0.43	0.43	0.184

CONCLUSION

It is concluded that the application of either fenoxaprop-p-ethyl 0.075 kg/ha 10 DAS or fluazifop-p-butyl 0.055 kg/ha 10 DAS *fb* one hoeing 40 DAS recorded the lower weed density and the higher seed yield of mustard over rest of the treatments, however, it is found at par with with two hand weeding at 20 and 40 DAS.

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Effect of conservation tillage and weed management practices on weed growth and yield of maize

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Maize is cultivated in sequence with different crops under various agro-ecologies of the country. Among different maize based, cropping systems, maize-wheat ranks first having 1.8 mha area mainly concentrated in rainfed ecologies. Intensive tillage leads to increase in production cost and deterioration of soil structure (Kumar *et al*. 2013). Another problem is heavy infestation of weeds which leads to decline in productivity. Conservation agriculture has emerged as an effective strategy to enhance sustainable agriculture worldwide. Crop residues are good sources of plant nutrients and are important components of the stability of agricultural ecosystem. Minimum soil disturbance with crop rotation and effective use of herbicide to overcome weeds problem are some criteria based on which this research was undertaken.

METHODOLOGY

A field experiment was carried out during *Kharif* season of 2016 at Directorate of Weed Research, Jabalpur (M.P.) The soil of the experimental field was clayey in texture, neutral in reaction and normal electrical conductivity. The treatments comprised of five tillage-residue recycling, *viz*. conventional tillage (CT) in maize-CT in wheat-CT in greengram, CT in maize-zero tillage in wheat-ZT in greengram, ZT with greengram residue (GR) in maize-ZT in wheat- ZT with wheat residue (WR) in greengram, ZT in maize- ZT with maize residue (MR) in wheat-ZT with wheat residue in greengram and ZT with greengram residue in maize- ZT with maize residue in wheat- ZT with wheat residue in greengram; and four weed management practices, *viz.* atrazine followed by (*fb*) tembotrione, atrazine fb topramezone, atrazine fb one hand weeding (HW) and weedy check in maize under maize-wheat-greengram cropping system. Thus, 20 treatment combinations were laid out in a thrice replicated split-plot design, keeping tillage and residue recycling in main plots and weed management practices in sub-plots. After the harvest of summer greengram in the month of June, land preparation was done as per treatment and sowing of maize was done in the last fortnight of June. Hybrid 4214 of maize was taken as the test crop. Fertilizers were applied through urea, single super phosphate and muriate of potash 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha, respectively. Data on weed growth and yield performance were recorded.

RESULT

Major weed infesting the experimental field were: *Echinochloa colona, Dinebra retroflexa, Paspalidium geminicatum, Phyllanthus niruri, Physalis minima, Commelina bengalensis* and *Cyperus rotundus*. Grassy weeds (54%) were predominant followed by broad-leaved (34%) and sedges (12%). Tillage-residue recycling and weed management practices significantly influenced the population and dry matter production of weeds. The lowest weed density (5.73g/m^2) was observed under ZT+GR-ZT+MR-ZT+WR followed by ZT–ZT+MR-ZT+WR (6.25g/m^2) among tillage and residue recycling treatments in (Table 1). The minimum weed dry weight was also recorded in same treatments, which was significantly lower than all other treatments. Among weed management practices atrazine followed by topramezon greatly suppressed weed density (4.27 g/m^2) and biomass (3.30 g/m^2) in (Table 1). These results are in conformity with findings of Soltani *et al.* (2012). The highest weed density (8.68g/m^2) and weed biomass (8.49g/m^2) was observed under weedy check.

Table 1. Weed growth and yield of maize as influenced by different tillage-residue recycling and weed management practices

Treatment	Weed density (no./m^2)	Weed biomass (g/m^2)	Grain yield (t/ha)	Straw yield (t/ha)
Tillage and residue recycling				
CT-CT-CT	7.03(74.22)*	7.80(33.26)*	4.38	4.76
CT-ZT-ZT	7.69(62.44)	6.55(25.14)	4.51	5.01
ZT + GR-ZT-ZT+WR	6.25(38.88)	4.00(16.02)	4.78	5.28
ZT-ZT+MR-ZT+WR	5.99(32.77)	3.72(19.24)	4.98	5.48
ZT+GR-ZT+MR-ZT+WR	5.73(33.11)	3.70(18.31)	5.35	5.79
LSD (P=0.05)	0.55	0.58	0.36	0.33
Weed management practices				
Atrazine 500 g/ha *fb* tembotrione 120 g/ha	7.20(47.66)	5.52(29.13)	4.81	5.24
Atrazine500 g/ha *fb* topramezone 70 g/ha	4.27(18.87)	3.30(14.03)	5.13	5.59
Atrazine 500 g/ha *fb* 1 HW	8.14(78.33)	6.22(31.83)	4.46	4.96
Weedy check	8.68(191.77)	8.49(77.78)	4.13	4.39
LSD (P=0.05)	0.36	0.31	0.24	0.26

*Values in parentheses are original. Data transformed to square root transformation

The highest grain yield (5.35 t/ha) and straw yield (5.79 t/ha) was recorded in ZT+GR-ZT+MR-ZT+WR among tillage and residue recycling practices. Among weed management practices the highest grain yield (5.13 t/ha) and straw yield (5.59 t/ha) was recorded with atrazine followed by topramezone and the lowest grain yield (4.13 t/ha) and straw yield (4.39 t/ha) was under weedy check data presented in (Table 1).

CONCLUSION

It was concluded that zero tillage with residue recycling reduced weed density as well as biomass. Application of atrazine 500 g/ha as pre-emergence followed by topramezon 70 g/ha was most effective for controlling weeds and improving grain yield in maize grown in maize-wheat-greengram cropping system.

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Silver nanoparticles on phenolics and stored starch content tuber of *Cyperus rotundus*

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Cyperus rotundus is a perennial and most noxious weed in temperate and tropical regions and greatly reduces the crop yields. Accumulation of phenolic compounds during the stress condition prevents the germination of tubers to tide over the unfavourable condition. Therefore the nutsedge management strategies must include a long-term commitment to prevent new tuber formation, breaking the dormancy and killing viable tubers. Hence, the present study was carried out to evaluate silver (Ag) nanoparticles mediated breaking of dormancy and exhausting the food reserve in the tubers of *Cyperus rotundus*.

METHODOLOGY

Lab experiment was conducted in the Department of Nano Science and Technology, TNAU during 2011-12. Silver nanoparticles was prepared by chemical reduction method characterized with Transmission Electron Microscope (TEM), Scanning Electron Microscope (SEM), Particle size analyzer, Raman spectroscopy and their effect on the degradation of phenol, starch and germination of dormant buds with different concentrations in wet (liquid form) and dry (powder form) methods.

RESULTS

Silver nanoparticles were synthesized and characterized with Particle Size Analyzer for estimating the average particle size and size distribution pattern (diameter of 197.4 nm and the width of 30.20 nm (Fig. 2), Scanning Electron Microscope to determine the surface morphology (Fig.1a) with spherical in shape with a smooth surface morphology. Diameter of the nanoparticles is found to be approximately 400 nm. Silver nanoparticles were scanned using TEM to determine the internal structure (Fig. 1b) and showed spherical shape with a smooth surface morphology**.** Diameter of the nanoparticles is found to be approximately 16 nm. Raman spectrum of silver nanoparticles relative intensities of the peaks was used to know the information on the composition of a mixture and that the intensity of peaks 371.2/cm (Fig.3).

It is evident from the experiment on the effect of silver nanoparticles on biochemical components, germination and vigor index in wet and dry methods (Table 1), that the presence of high amount of phenol (10.3 mg/g) in the control treatment and no germination (0%). Whereas Ag treated tubers at the rate of 1250 mg/kg registered lower content of phenol (6.2 mg/g) and higher germination (60%) and higher vigour index (1200). The Ag nanoparticles significantly

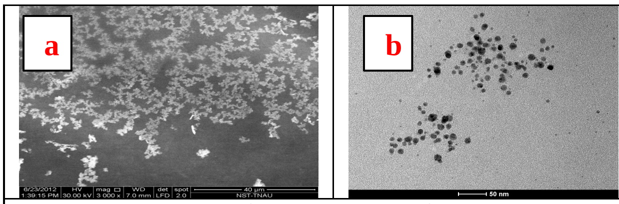

Fig 1. Micrograph of Ag nanoparticles of a) SEM b)TEM

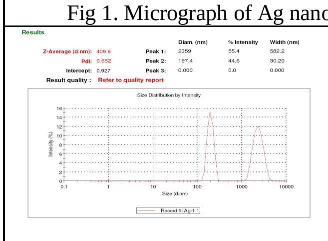

Fig 2. Particle analysis of Ag nanoparticles

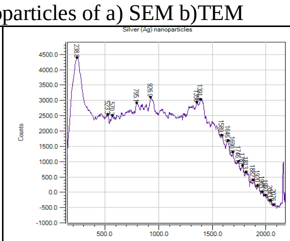

Fig 3. Ramanspectroscopy of Ag nanoparticles

Table 1. Silver nanoparticles on the biochemical composition, germination and growth of *Cyperus rotundus* (dry method and wettmethod)

Ag conc. (mg/kg)	Dry method					Wettmethod				
	Starch (mg/g)	Amylose (mg/g)	Phenols (mg/g)	*Germination (%)	Vigor index	Starch (mg/g)	Amylose (mg/g)	Phenols (mg/g)	*Germination (%)	Vigor index
0 (Control)	142	11	10.3	0 (0.28)	0	154	12	9.9	0 (0.28)	0
1000	119	27	8.2	40 (39.23)	536	112	38	7.6	33 (35.06)	237
1250	103	46	6.2	60 (50.76)	1200	126	29	8.4	33 (35.06)	396
1500	107	43	6.8	47 (43.28)	528	100	50	6.0	53 (46.72)	1065
2000	112	33	7.7	40 (39.23)	412	132	26	8.6	33 (35.06)	190
2250	133	15	9.4	20 (26.56)	281	110	40	7.3	40 (39.23)	450
2500	139	13	9.7	20 (26.56)	144	148	18	9.7	27 (31.30)	362
LSD (P=0.05)	4.03	0.89	0.27	1.07	14.62	4.16	1.00	0.27	1.03	12.73

reduced the starch content and the reduction of starch was noticed upto 1250 mg/kg concentration, there after the trend was not sustained. The same trend for the other parameters like amylose and phenols were also observed in dry method. Higher amylose content (50 mg/g), lower content of starch (100.0 mg/g), phenol (6.0 mg/g) with 53 % germination and higher vigour index (1065) were recorded at the concentration of 1500 mg/kg. Higher amount of phenol (9.9 mg/g) and starch content (154.0 mg/g) with no germination (control treatment) was recorded in wet method. Based on this estimation, when the silver nitrate is converted to silver nanoparticles the active surface area get increased and became more reactive in chemical reaction. This may be due to the large surface to volume ratio of nanomaterials led to surprising surface and quantum size effects. Ag nanoparticles having the antimicrobial activity, does not change the biochemical compounds of the tubers which resulted in lesser germination (Seif Sahandi *et al.* 2011).

CONCLUSION

Dry method was quicker (1250 mg/kg) than the wet method (1500 mg/kg) to break the dormancy of purple nutsedge tuber and enhanced the germination with increased shoot and root length recording reduced phenolic content.

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Weed dry matter and grain yield of wheat as affected by irrigation, sowing methods and weed control practices

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India has made spectacular advancement in productivity and sustainability of wheat over the years. The production of wheat grain in the year 2013-14 was estimated to be 95.91 m t from acreage of 31.19 m ha at a yield level of 3.07 kg/ha. During this period, Rajasthan accounted for about 9.01% of the national area and 9.3% of production with average productivity of 3.17 t/ha. Weed is one of the major biotic constraints in wheat production as they compete with crop for nutrients, moisture, light and space. Weeds suppress the crop and result in reduction of yield (Verma *et al.* 2015). Wheat is infested with grassy as well as broad-leaved weeds, control of which requires a variety of herbicides. To control mixed population of weeds and also to avoid herbicides resistance by continuous use of single herbicide, compatible mixtures can be employed to widen the spectrum of weed control (Das and Yaduraju 2012).

METHODOLOGY

The experiment was conducted during *Rabi* 2013-14 and 2014-15 seasons at the Instructional Farm (Agronomy) Rajasthan College of Agriculture, MPUAT, Udaipur. Twenty seven treatment combinations comprising of three irrigation levels (0.8, 1.0, 1.2 IW/CPE), three sowing methods (line sowing at 22.5 cm, crisscross sowing at 22.5 cm, FIRB System) and three weed control methods (weedy check, isoproturon + 2,4-D (TM) 750 g + 500 g/ ha at 35 DAS, sulfosulfuron + metsulfuron (RM) 30 g + 2 g/ha at 35 DAS were tested in split – plot design with three replications. The experiment constituted in split plot design with irrigation scheduling treatments assigned in main plots and sowing methods and weed control in sub plots. All treatment combinations were replicated thrice. Wheat variety Raj-4037 was used as test crop and crop was raised as per package of practices recommended for this agro climatic zone.

RESULTS

IW/CPE ratio at 0.8 recorded significantly lower weed dry matter accumulation at 60, 90 DAS and at harvest in comparison to IW/CPE ratios 1.0 and 1.2 and register 55.81 and 60.31,55.44 and 60.79 and 48.11 and 51.63% lower weed dry matter accumulation, respectively. on pooled basis crisscross sowing and FIRB system gave 6.99 and 6.35, 11.84 and 10.69 and 16.20 and 13.48% lower weed dry matter accumulation than at 60, 90 DAS and at harvest compared to line sowing, respectively. Data indicate that crisscross sowing and FIRB system produced 12.55 and 10.16% higher grain yield over line sowing (4.57 t/ha). On pooled basis application of sulfosulfuron + metsulfuron (RM) and isoproturon + 2,4-D (TM) gave significantly higher grain yield by 24.06 and 21.81% over weedy check (4.27 kg/ha), respectively.

Table 1. Effect of irrigation, sowing methods and weed control practice on weed dry matter (pooled data)

Treatment	Weed dry matter (g/m^2)			Grain yield (t/ha)
	At 60 DAS	At 90 DAS	At Harvest	
Irrigation schedule (IW/CPE)				
0.8	11.11	12.32	11.66	4.57
1.0	17.31	19.15	17.27	5.05
1.2	17.81	19.81	17.68	5.15
LSD (P=0.05)	0.53	0.73	0.62	0.24
Sowing method				
Line sowing	16.08	18.33	17.00	4.57
Crisscross sowing	15.03	16.39	14.63	5.15
FIRB system	15.12	16.56	14.98	5.04
LSD (P=0.05)	0.41	0.46	0.50	0.16
Weed control practic				
Weedy check	28.19	32.68	28.90	4.27
Isoproturon+2,4-D (Tank Mix)	9.17	9.49	9.08	5.20
Sulfosulfuron + Metsulfuron (Redi Mix)	8.87	9.12	8.63	5.30
LSD (P=0.05)	0.41	0.46	0.50	0.16

CONCLUSION

It is concluded that combination of irrigation scheduling at 1.0 IW/CPE ratio, criss cross sowing and application of sulfosulfuron + metsulfuron (RM) at 35 DAS gave higher wheat grain yield. However, lower dry matter of weed was obtained at 0.8 IW/CPE ratio with same combination.

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Efficacy of different herbicide on weed management and productivity of chandrasur

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Chandrasur (*Lepidium sativum* L.) has been considered as important medicinal plant since Vedic era. It belongs to Brassicaceae family (English name: Garden cress and Hindi name: Asalio) has great medicinal value. It is fast growing edible winter season annual herbs, which is botanically related to mustard sharing their peppery, rangy and aroma. The seed of chandrasur are mainly used in medicines to cure diseases like stomach disorder, indigestion, cough, cold, seminal weakness, rheumatism, diarrhoea *etc*. It is also used as blood purifier and used with great benefit to alleviate the hiccup and increasing height (Maiti 2010). Seeds are also fed to cattle to enhance the quality and quantity of milk. It is estimated that total area under this crop in India is about 8450 hectare. The average productivity of crop is very low (3.2 t/ha) mainly on account of lack of appropriate agro-techniques. Amongst different agro-techniques, weed management is of prime importance for enhancing productivity of chandrasur. Hence the present investigation was under taken.

METHODOLOGY

A field experiment was conducted during 2015-16 with ten weed management practices (Table 1) and rreplicated three times. The field was prepared by giving one ploughing with tractor drawn M.B. plough followed by two cross harrowing and planking. After opening furrow at 30 cm, sowing was done manually by placing seeds at 10 cm spacing in each row. Thinning was done at 15 days after sowing in order to remove extra plants. Chandrasur variety "*MC-1*" was used as test variety. As per treatments herbicides were prayed as pre-emergence. The plastic sheets were used on both side of plot to avoid shifting of spray droplets in adjoining plots. Total weed count recorded at harvest and expressed as number/m^2. The data were subjected to square root transformations to normalize their distribution. Weeds collected at harvest were dried at 70^0 C for 24 hours and weighed. The crop was raised under irrigated condition. As per recommendation 60 kg N and 40 kg P_2O_5/ha was applied to crop. The crop was harvested when more than 90 per cent crop became yellow. Before harvesting the plants under each experimental unit, border row were harvested and removed from experimental field. After through drying the seed were separated from plant through threshing, weighed and expressed in t/ha.

Table 1. Effect of weed control methods on weed dynamics, yield and economics of Chandrasur

Treatment	At harvest weed		Yield (t/ha)		Net returns (`/ha)	B:C ratio
	Intensity (m^2)	dry matter (t/ha)	Seed	Straw		
Pend.0.75 kg/ha PE	12.2 (3.56)*	1.41	2.03	10.04	70200	3.37
Pend.0.75 kg/ha PE *fb* HW at 35 DAS	6.0 (2.54)*	0.80	2.32	10.22	77350	3.39
Oxyflurofen 125 g/ha PE	8.0 (2.91)*	1.41	1.91	8.83	63410	3.10
Oxyflurofen 125 g/ha PE *fb* HW at 35 DAS	2.0 (1.58)*	0.84	2.21	9.02	70900	3.16
Oxadiargyl 75 g/ha PE	14.0 (3.81)*	3.15	1.82	9.24	61890	3.02
Oxadiargyl 75 g/ha PE *fb* HW at 35 DAS	5.0 (2.34)*	2.43	2.03	9.41	66520	2.95
Isoproturon 0.5 kg/ha PE	15.0 (3.94)*	3.03	1.63	8.90	54530	2.60
Isoproturon 0.5 kg/ha PE *fb* HW at 35 DAS	5.0 (2.34)*	1.01	1.83	9.08	59060	2.57
Two HW at 25 and 50 DAS	5.0 (2.35)*	0.50	2.33	10.39	75860	3.00
Weedy Check	22.0 (4.74)*	3.74	1.42	6.61	43110	2.23
LSD(P=0.05)	0.17	0.13	0.16	0.71	7961	0.36

* Values in parentheses are square root transformation of original

RESULTS

Amongst different weed control treatments, application of pendimethalin 0.75 kg/ha (PE) *fb* one hand weeding (HW) and hoeing at 35 DAS and two hand weeding and hoeing at 25 DAS and 50 DAS proved statistically at par and recorded lower weed intensity and dry matter at successive stages and higher seed, straw yield and net returns compared to rest of the weed control treatments. However, in terms of BC ratio, application of pendimethalin 0.75 kg/ha (PE) *fb* one hand weeding (HW) proved best compared to rest of the treatments.

CONCLUSION

On the basis of one year findings it was concluded that for weed minimization and higher yield, net returns and BC ratio, application of pendimethalin 0.75 kg/ha (PE) *fb* one hand weeding (HW) proved best.

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Residue mulching effects on weeds, crop productivity and profitability in zero tillage sown maize

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Weeds severely infest the *Kharif* maize crop owing its wide spacing, slow early vegetative growth, vagaries of monsoon and congenial growing conditions *i.e.* high temperature and humidity. Hence, management of weeds is most critical for higher production and better returns. Raised bed sowing is the conventional method of establishment of maize crop. Zero tillage in combination with residue retention and herbicide use can be the alternative technology for weed management (Dahal and Karki 2014). However, information on weed dynamics under different planting methods and residue management is lacking. Therefore, the present study was undertaken.

METHODOLOGY

A field experiment was conducted at Regional Research Station, Karnal of CCS Haryana Agricultural University during *Kharif* 2015 to study the effect of residue mulching and zero tillage on weeds, crop productivity and profitability in *Kharif* maize. The experiment was laid out in split plot design with three replications. Main plot treatments comprised of four planting methods *viz*., raised bed with residue, raised bed without residue, zero tillage with residue and zero tillage without residue. Three maize hybrids *viz*. *HQPM-1*, *HM-4* and *HM-10* in combination with two weed control treatments *viz*. atrazine 750 g/ha pre-emergence (PRE) followed by (*fb*) 1 hand weeding (HW) at 30 days after sowing (DAS) and unweeded check were kept as sub-plots. Nitrogen, phosphorus and potassium were applied as per the recommendation *i.e.* 150, 60 and 60 kg/ha, respectively. Atrazine was applied as PRE spray to the soil surface as per treatments at 0-3 DAS with flat fan nozzle using a spray volume of 500 l water/ha. Density of weeds was recorded at 60 DAS.

RESULTS

Maize sown in zero tillage (ZT) with residue recorded lowest density of grassy and broadleaf weeds (BLW); highest grain yield and net returns as compared to other methods; but benefit-cost ratio (B: C) was maximum under ZT without residue as compared to other methods (Table 1). This was due to counting the cost of wheat straw used as residue in this experiment, which could improve by use of less costly crop residue. Density of sedges in raised bed with residue and zero tillage with residue were at par with each other. ZT in general was statistically similar to raised bed in respect of grain yield.

Table 1. Effect of planting methods, residue and weed management on density of weeds at 60 DAS, grain yield and economics of different maize hybrids

Treatment	Density of weeds (no./m^2)*			Grain yield (t/ha)	Net returns (Rs/ha)	Benefit-cost ratio
	Grassy weeds	Broad-leaf weeds	Sedges			
Planting method						
Raised bed with residue	2.97 (8.4)	8.75 (86.2)	5.50 (30.2)	6.99	50866	1.88
Raised bed without residue	4.12 (17.3)	12.86 (182.4)	8.80 (79.1)	6.29	50791	2.08
Zero tillage with residue	2.28 (4.4)	5.94 (44.9)	5.57 (33.4)	7.32	59958	2.13
Zero tillage without residue	3.23 (9.7)	12.85 (185.7)	10.67 (119.7)	6.42	57474	2.35
LSD (P= 0.05)	0.20	0.10	0.15	0.43	-	-
Maize hybrid						
HQPM-1	3.39 (11.9)	8.17 (77.0)	8.17 (77.0)	6.40	49230	2.01
HM-4	3.22 (10.3)	7.16 (61.8)	7.59 (61.8)	7.04	58749	2.18
HM-10	2.83 (7.7)	7.59 (58.0)	7.16 (58.0)	6.83	56388	2.14
LSD (P= 0.05)	0.15	0.08	0.08	0.184	-	-
Weed management						
Atrazine 750 g/ha (PRE) *fb* 1 HW at 30 DAS	2.54 (5.8)	7.54 (67.6)	7.52 (67.3)	7.70	66593	2.29
Unweeded check	3.76 (14.1)	12.66 (182.0)	12.57 (179.8)	5.81	42951	1.93
LSD (P= 0.05)	0.12	0.07	0.07	0.150	-	-

*Original values in parenthesis were subjected to square root transformation (Ö X+1) before statistical analysis

Residue retention resulted in lower weed density; and higher grain yield and better net returns as compared to without residue, whereas B: C was less under residue than without residue. The hybrid *'HM-4'* recorded lower density of BLW, maximum grain yield, net returns and B: C than other hybrids. However, lowest density of grassy weeds and sedges were recorded under HM-10 *fb 'HM-4;* and *'HQPM-1'*, which was due to faster growth of HM-10. Significantly lower density of weeds, higher grain yield, net returns and B: C were observed under atrazine 750 g/ha *fb* 1 HW at 30 DAS as compared to unweeded check.

CONCLUSION

Zero tillage sowing of maize with residue mulching was found a viable alternative method of crop establishment as compared to conventional raised bed sowing method. This resulted in lower weed infestation, higher productivity and economic returns. Atrazine 750 g/ha PRE *fb* 1 HW at 30 DAS was effective in controlling weeds in maize crop.

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Effect of herbicides and row spacing on weed dynamics and productivity of wheat

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A field experiment was conducted during *Rabi* season of 2011-12 at Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur. The experiment consisted of six weed control treatments (pinoxaden 40 g/ha, isoproturon 750 g/ha, metribuzin 400 g/ha, sulfosulfuron 25 g/ha, idosulfuron 25 g/ha and weedy check) and three row spacings (17.5 cm, 20.0 cm and 22.5 cm) making eighteen combinations. These treatments were evaluated in factorial randomized block design with three replications. Wheat variety Raj 4037 was used as a test crop.

Results of field experiment revealed that application of herbicides caused significant reduction in weed density and weed dry matter. The maximum reduction in weed density and weed dry matter was recorded in the plots treated with metribuzin followed by isoproturon and sulfosulfuron at 45 DAS and at harvest. Herbicidal treatments significantly increased number of tillers 45 DAS and plant height at 90 DAS and at harvest. The dry matter accumulation by crop at all the growth stages was significantly higher under isoproturon which was closely followed by sulfosulfuron. The maximum value of effective tillers, ear length, number of grains/ear and test weight were observed with isoproturon followed by sulfosulfuron. Consequently, isoproturon produced significantly higher grain (5.72 t/ha) and biological yield (12.64 t/ha) compared to other treatments. Herbicidal treatments also significantly increased RGR, CGR and NAR over weedy check, except metribuzin, it has phytotoxic effect on wheat crop.

All the herbicide significantly increased N, P and K content and uptake by wheat grain as well as straw over weedy check. The maximum N, P and K uptake by crop was recorded with the application of isoproturon which was significantly superior over all other treatments. Application of isoproturon produced maximum net returns (' 83753/ha) and BC ratio (4.07).

The effect of row spacing was significant on density and dry matter of weeds 45 DAS and at harvest. The minimum density of weeds was observed under row spacing of 17.5 cm which was closely followed by 20.0 cm and both these had significantly lower than 22.5 cm in this respect.

Row spacing did not have significant impact on plant height. The maximum number of effective tillers was recorded under 20.0 cm whereas dry matter accumulation was under 22.5 cm row spacing. Sowing at 17.5 cm row spacing produced significantly higher grain (4.94 t/ha) and biological yield (11.94 t/ha) compared to other row spacing.

Row spacing of 17.5 cm recorded maximum N, P and K uptake by wheat grain and found superior to 20.0 and 22.5 cm row spacing in this respect while, uptake by straw did not differ significantly with each other. Row spacing of 17.5 cm registered maximum net returns (' 71314/ha) and BC ratio (3.45) which was significantly superior over 20.0 and 22.5 cm spacing.

Wheat production in rice-wheat-greengram cropping system under conservation agriculture: Experience from farmers' field

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India is the second largest producer of wheat in the world with an average annual production of 80 mt (million tonnes) in recent years. It accounts for approximately 11.79 per cent of world's wheat production. Madhya Pradesh is an important wheat growing state, accounting for 8.7% of production and 14.3% of the area under cultivation. The area under wheat in the state is 3.7 million ha and the production is 6.1 tonnes, at a productivity of 1.6 tonnes/ha. In Madhya Pradesh, major constraints in wheat production are heat and drought stress and late sowing. Conservation agriculture (CA) is the promising technology to overcome the ill effects of conventional practices in many parts of the north India. Therefore, by adopting CA could avoid delay in planting and reduce the cost of production. Savings in input cost, fuel consumption and irrigation water-use have been reported due to adoption of zero tillage in wheat cultivation. Weeds are the major biotic constraint in CA. Hence, considering the above points, on- farm Demonstrations were conducted in farmers' fields to evaluate productivity, weed growth and profitability of wheat in rice-wheat-greengram cropping system under CA.

METHODOLOGY

Five on-farm demonstrations were conducted under rice-wheat-greengram cropping system to evaluate the effect of CA technology on weed growth, yield and economics of wheat crop in five villages of Seoni district of M.P. an area of 2 hectares during *Rabi* season of 2015-16. The treatments consisted of wheat sown with Farmer's practice; wheat sown under CA with recommended fertilizer dose (RFD) and without herbicide; wheat sown under CA without RFD and with herbicide; wheat sown under CA with RFD and post-emergence (POE) herbicide (clodinafop + metsulfuron 400 g/ ha). The sowing was done by using happy seeder machine without removal of previous crop residue (rice stubbles and straw).

RESULTS

The major weed floras observed in the On-Farm Research (OFR) trials were *Chenopodium album, Chenopodium ficipholium, Medicago polymorpha, Lathyrus aphaca, Vicia satvia, Vicia hirsuta, Rumex dentetus, Chichorium intybus, Avena fatua, Anagallis arvensis, Convolvulus arvensis etc*. Weed growth in terms of weed density and weed dry weight influenced by the different treatments. The highest weed growth was observed under the treatment CA with RFD and without herbicide followed by farmer's practice. The lowest weed growth was recorded in the treatment where wheat sown under CA without RFD and POE herbicide (clodinafop + metsulfuron) followed by CA with RFD and POE herbicide (clodinafop + metsulfuron). The highest plant height and spike density were noted under CA with RFD and POE herbicide (clodinafop + metsulfuron-methyl) and lowest in farmer's practice. Wheat sown under CA with RFD and POE herbicide (clodinafop + metsulfuron-methyl) produced highest grain yield followed by CA without RFD and with herbicide, CA with RFD & without herbicide and farmer's practice. B:C ratio followed the same pattern. Zero tillage advanced the sowing date and resulted in proper placement of seed, early emergence of wheat seedlings and availability of higher nutrient and moisture content due to surface retention of previous crop residue (Rathore *et al.* 2015) and effective management of weed and nutrient through the recommended practices, which might have helped the crop to compete with the crop sown under conventional tillage. Results corroborate to the findings given by Mishra and Singh (2012).

Table 1. Weed growth and productivity of wheat as influenced by various treatments in on-farm research trials

Treatment	Weed density (no./m^2)	Weed biomass (g/m^2)	Plant height (cm)	Spike density (m^2)	Grain yield (t/ha)
Wheat sown with Farmer's practice	40.5	9.6	87.22	270	2.83
Wheat sown under CA with RFD & without herbicide	53.5	10.1	88.35	271.33	2.91
Wheat sown under CA without RFD & with herbicide	10	2.2	89	287	3.48
Wheat sown under CA with RFD and POE herbicide (clodinafop + metsulfuron)	15	2.3	95.51	355.33	5.05

Values are mean of five independent locations

CONCLUSION

Conservation planting method (zero tillage with residue retention) and recommended dose of N with effective weed control appeared to be the best practice for improving wheat productivity for wheat in rice- based cropping system.

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Effect of tillage, crop residue and weed management practices on productivity and profitability of rice under rice-based cropping system

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Conservation agriculture began 20 year ago with introduction of zero-tillage (ZT) in wheat to reduce cultivation cost and reduce land preparation period for timely sowing of subsequent crops Malik *et al.* (2005). Rice and wheat are exhaustive feeders, and the double cropping system is heavily depleting the soil nutrient content. Conservation agriculture would directly improve crop yields by increasing soil nutrient availability, decreasing erosion, improving soil structure and increasing soil water holding capacity as a consequence of improving soil organic matter content. In Chhattisgarh, total area under rice is 3.7 mha with a production of 7.45 mt in 2013-14. Weeds are a problem in rice cropping system, their control is essential for successful crop production. The goal of weed control is not only to preserve plants from yield loss, but also to minimize weed seed reserve in the soil. Tillage and herbicides are used for weed control, but the degree of control achieved may vary widely depending on weed species present, soil type, climatic condition, tillage method, etc.

METHODOLOGY

A field experiment was carried out at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur during *Kharif* seasons of 2015 and 2016. The experimental soil was inceptisols, low in organic carbon, low in available nitrogen, medium in phosphorus and high in potassium with neutral soil reaction. Five treatments comprised of two conventional tillage with transplanted rice, one conventional tillage with direct seeded rice, two treatments of zero tillage with direct seeded rice, of which, one had residue cover, were placed in main plot. While in sub plots, three treatments of weed management were placed and comprised of recommended practice *i.e.* application of pyrazosulfuron 20 g/ha *fb* pinoxsulam 22.5 g/ha POE, integrated weed management *i.e.* application of oxadiargyl 80 g PRE *fb* hand weeding at 25 DAT/S and one unweeded control. The experiment was laid out in split plot design replicated thrice. The residue of previous crop was left as such in one of the ZT treatments. The gross plot size was 12 m x 12 m. Medium duration rice cultivar *'MTU 1010'* was taken as test crop.

RESULTS

Weed dry matter

Weed flora of the experimental field consisted of *Echinochloa colona* among grasses, *Cyperus iria* among sedges and *Alternanthera triadra* and *Spilanthes acmella* in broad leaf weeds dominated the weed flora. Tillage and weed management practices influenced significantly dry matter production of weeds and it was significantly low under conventional tillage (transplanted) over conventional or zero tillage (direct seeded) at all the stages. Significant variations were observed due to tillage and weed management practices at 60 DAS/T. Weed dry matter was significantly low under CT-Transplanted treatments than CT/ZT-direct seeded treatment at all the stages. Similarly, weed dry matter was significantly low under recommended herbicide *i.e.* pyrazosulfuron 20 g/ha *fb* pinoxsulam 22.5 g/ha POE treatment than unweeded check but was at par with integrated weed management treatment.

Table 1. Weed growth, grain yield and economics of rice as influenced by tillage, crop residue and weed management treatments.

Treatment	Weed dry matter (g/m^2) 60 DAS		Grain yield (t/ha)		Net income Rs/ha	B:C Ratio
	2015	2016	2015	2016	2016	2016
Tillage						
CT (transplanted)	6.11 (36.8)	4.90 (23.51)	3.39	3.68	23695	1.77
CT (transplanted)	6.50 (41.7)	5.56 (30.41)	3.31	3.62	21955	1.72
CT (direct seeded)	8.04 (64.10)	8.68 (74.84)	2.97	2.86	17924	1.76
ZT (direct seeded)	8.16 (66.1)	9.32 (86.36)	2.52	2.56	15618	1.72
ZT(direct seeded) + R	8.01 (63.6	8.82 (77.29)	2.72	2.21	10499	1.48
LSD (P=0.05)	1.39	3.12	NS	0.19	-	-
Weed management						
Pyrazosulfuron 20 g/ha *fb* pinoxsulam 22.5 g/ha POE	5.09 (25.4)	5.77 (32.79)	4.20	4.00	31610	2.20
IWM oxadiargyl 80 g PRE *fb* hand weeding at 25 DAT/S	5.24 (27.0)	7.03 (48.92)	3.51	4.26	34541	2.27
Unweeded	10.55 (110.9)	9.57 (91.08)	1.23	0.74	-12342	0.46
LSD (P=0.05)	1.11	0.86	0.57	0.15	-	-

Yield and economics of rice

Among the direct seeded rice the highest yield was obtained under CT (DSR) whereas, the lowest grain yield of rice was recorded under ZT (DSR) + R. Significantly higher seed yield was recorded under recommended practice *i.e.* pyrazosulfuron 20 g/ha *fb* pinoxsulam 22.5 g/ha POE followed by integrated weed management. The net income and B:C ratio was higher under CT (transplanted) followed by CT (DSR). However, the lowest net return and B:C ratio was obtained under ZT (DSR) + R. Weed Management either through recommended herbicides *i.e.* pyrazosulfuron 20 g/ha fb pinoxsulam 22.5 g/ha POE or IWM *i.e.* oxadiargyl 80g PRE *fb* HW at 20 DAT/S observed effective in alleviating weed dry matter and enhancing grain yield of rice as well as net income and B:C ratio (Table-1).

CONCLUSION

Weed Management either through recommended herbicides *i.e.* pyrazosulfuron 20 g/ha fb pinoxsulam 22.5 g/ha POE or IWM *i.e.* oxadiargyl 80g PRE fb HW at 20 DAT/S observed effective in alleviating weed dry matter and enhancing grain yield of rice as well as net income and B:C ratio.

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Response of maize to tillage and weed management and herbicide residue in soil

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The productivity from conventionally till maize after rice is low due to dalay in land preparation and planting and increased cost of cultivation for land preparation. The zero till system popular in rice-wheat system can be extended to rice-maize system successfully. Weed infestation is one of the major constraints pulling down the productivity of zero till maize. Hence the present experiment involving tillage and weed management in zero till maize was conducted.

METHODOLOGY

A field experiment entitled "Response of maize to tillage and weed management and herbicide residue in soil " was conducted during *Rabi* season of 2014 at Agronomy Main Research Farm, Orissa University of Agriculture and Technology, Bhubaneswar to study effect of different tillage methods and weed management practices on weed biomass and yield of maize and the herbicide residue in soil.

Three different tillage methods i.e. conventional tillage(CT), minimum tillage (MT) and glyphosate + zero tillage (ZT) and six different type of weed management practices i.e. atrazine 1.25 kg/ha pre-emergence (W_1), 2,4-D 0.5 kg/ha post-emergence (W_2), W_1 + W_2 (W_3), atrazine 1.25 kg / ha pre-emergence + one hand weeding at 30 days after sowing(W_4), two hand weeding at 15 and 30 days after sowing (W_5) and weedy check (W_6) were tried in split plot design with three replications. Three different tillage methods were allocated to main plots and six weed management practices to subplots. "*Nilesh (NHM-51)*" was taken as the test variety of maize. The soil of the experimental site was sandy loam with pH of 5.91, EC of 0.52 dS/m, OC 0.69%, available N 288 kg/ha, available P 41 kg/ha and available K_2O 290 kg/ha.

RESULTS

Twenty four species of weeds associated with the crop included 8 grasses *viz*. *Acrachne racemosa* Heyne ex Roem Ohwi, *Cynodon dactylon* (L.) Pers., *Dactyloctenium aegyptium* (L.) P. Beauv. Wild., *Digitaria ciliaris, Digitaria sanguinalis* (L.) Scop., *Echinochloa colona* (L.) Link., *Eleusine indica* (L.) Gaertn. and *Sporobolus diander* (Retz.) P. Beauv.; two sedges *viz*. *Cyperus iria* L. and *Cyperus rotundus* L. and 14 broad-leaved weeds *viz*. *Acalypha indica* L., *Ageratum conyzoides* L., *Alternanthera philoxeroides* (Mart.) Griseb., *Amaranthus spinosus* L., *Borreria articularis* (L. f) Wild., *Commelina benghalensis* L., *Cynotis cucullata* Kunth., *Eclipta alba* Hassak., *Heliotropium indicum* L., *Oldenlandia corymbosa*, *Physalis minima* L., *Synedrella nodiflora*, *Trianthema portulacastrum* L. and *Tridax procumbens* L.

Among three tillage management practices, zero tillage performed the best with the minimum weed dry weight of 25.24 g/m^2 at harvest and recorded the maximum grain yield of 6.73 t/h and stover yield of 8.78 t/ha and increased grain yield by yield by 6.1 and 12.9% and stover yield by 3.3 and 8.3% compared to minimum and conventional tillage, respectively. Yield of maize in zero tillage was higher in Himachal Pradesh by 16.7% (Chopra and Angiras 2008). Atrazine 1.25 kg/ha + one hand weeding performed the best with the minimum weed dry weight of 12.9 g/m^2 at harvest with the maximum grain yield of 7.62 t/ha and stover yield of 9.62 t/ha. This practice increased grain yield by 18, 46, 4, 9 and 76% and stover yield by 5.4, 3.0, 3.4,5.1 and 47.8% compared to atrazine alone, 2,4-D, atrazine + 2,4-D, two hand weeding and weedy check, respectively. Sunitha *et al.* (2012) observed that pre-emergence application of atrazine 0.5 to 1.0 kg/ha in combination with hand weeding at 30 DAS recorded the lowest weed dry weight.

Table 1. Weed dry weight, yield of grain and straw and harvest index as influenced by tillage methods and weed management practices

Treatment	W_1	W_2	W_3	W_4	W_5	W_6	Mean
Dry weight of weeds(g/m^2)) at harvest							
CT	6.02	5.64	4.60	4.06	4.40	9.66	5.73
	(35.29) *	(30.78)	(20.13)	(15.47)	(18.43)	(92.28)	(35.40)
MT	5.75	5.39	4.38	3.75	4.18	9.03	5.41
	(32.14)	(27.99)	(18.13)	(13.09)	(16.50)	(81.58)	(31.57)
ZT	5.26	4.92	3.98	3.32	3.84	7.99	4.89
	(26.70)	(23.30)	(14.88)	(10.01)	(13.71)	(62.85)	(25.24)
LSD(P=0.05)	T = 0.26	W = 0.17		T×W = 0.52		W×T = 0.29	
Grain yield (t/ha)							
CT	5.92	4.78	7.11	7.21	6.67	3.74	5.91
MT	6.32	5.13	7.33	7.57	7.23	4.61	6.37
ZT	7.08	5.76	7.65	8.08	7.16	4.65	6.73
Mean	6.44	5.22	7.36	7.62	7.02	4.33	6.33
LSD(P=0.05)	T = 0.59		W = 0.22	T×W = 0.96		W×T = 0.38	
Stover yield (t/ha)							
CT	8.11	6.87	9.17	9.28	8.90	6.33	8.11
MT	8.58	7.32	9.23	9.47	9.37	7.01	8.50
ZT	9.55	8.07	9.57	10.10	9.18	6.18	8.78
Mean	8.75	7.42	9.32	9.62	9.15	6.51	8.46
LSD (P=0.05)	T = 0.49		W = 0.40	T×W = 1.13		W×T = 0.70	
Harvest index							
CT	42.22	41.03	43.66	43.74	42.81	37.17	41.77
MT	42.43	41.22	44.32	44.42	43.54	39.67	42.60
ZT	42.59	41.71	44.43	44.46	43.76	42.90	43.31
Mean	42.41	41.32	44.14	44.20	43.37	39.91	42.56
LSD (P=0.05)	T = 1.02		W = 1.61		NS		NS

*Original values in parentheses and * " (x+1) transformed ones before parentheses, CT - Conventional Tillage, MT - Minimum Tillage and ZT - Zero Tillage, W_1- atrazine 1.25 kg/ha, W_2 - 2,4-D 0.5 kg/ha, W_3- W_1 + W_2, W_4 - atrazine 1.25 kg/ha + one hand weeding, W_5 - Two hand weeding at 15 and 30 DAS and W_6- Weedy check

Cucumber was taken as the sensitive plant for detecting herbicide residue in soil. In experimental plots, atrazine was applied 500 ppb or 1.25 kg/ha. The growth parameters of the sensitive plant grown in soil collected from atrazine treated plots were similar to those observed at atrazine concentration of 100 ppb indicating the presence of 16% of residue and degradation of the rest in soil through various channels of detoxification. The growth parameters of cucumber noted in soil collected from 2, 4-D treated plots were similar to those observed with 2, 4-D concentration of 50 ppb. In the experimental plots, 2, 4-D was applied 0.5 kg/ha *i.e.* equivalent to 250 ppb. After harvest of maize, approximately 50 ppb residue was left in soil after degradation of the rest indicating a loss of 80% of applied 2, 4-D through various chemicals.

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Productivity and profitability under crop establishment method in rice and weed management in *toria*

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In Odisha, many farmers raise rice crop by transplanting of seedling under puddled condition. Field preparation by puddling results in alteration of soil physical properties, which adversely affects the succeeding crops (Gangwar *et al.* 2008). Drum seeding and direct seeding in row are alternative to transplanting, due to less labour and water requirement and reduction in crop duration by 10 days and these methods provide comparable grain yield as that of transplanted rice. Under rain fed condition, a short duration *toria* is grown after rice. Zero till *toria* can solve majority of these problems. Ghosh *et al.* (2010) established *toria* crop successfully without ploughing the land. The trial was designed to find a proper crop establishment for rice and suitable weed management strategy for zero till *toria*.

METHODOLOGY

A field experiment was conducted during 2013-14 and 2014-15 at Agronomy Main Research Farm, OUAT, Bhubaneswar. During *Kharif*, the seven crop establishment methods in rice were tried in randomized block design (RBD) with three replications. During *Rabi* season zero-till *toria* crop was grown on residual soil moisture conditions. The residual effects of seven crop establishment methods imposed in rice and three weed management practices *viz.*W_1-application of glyphosate (pre-planting desiccation),W_2-application of quizalofop-ethyl (post-emergence) and W_3-application of glyphosate + quizalofop-ethyl. were tried in split plot design with three replications. Rice cv. '*Naveen (CR-749-20-2)*' and *toria* cv. '*Sushree (ORT-7-2)*' were taken as test variety of the crops. The soil of the experimental site was sandy loam with pH of 5.4, medium OC of 0.51%, available N of 251 kg/ha, available P of 10 kg/ha and available K of 111 kg/ha.

RESULTS

Among crop establishment methods, transplanted rice with post-emergence application of bispyribac sodium 0.02 kg/ha followed by mechanical weeding (E_7) recorded the maximum system rice equivalent yield of 5.66 t/ha over seasons (Table 1). Drum seeding with same management (E_6) and DSRL with pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding (E_4) gave statistically similar system rice equivalent yield. Among weed management practices, application of glyphosate as PPD followed by quizalofop-ethyl as post-emergence spray (W_3) proved the most effective with yield of 4.89 t/ha. Among treatment combinations transplanted rice with post-emergence application of bispyribac sodium 0.02 kg/ha followed by mechanical weeding gave the maximum rice equivalent yield of 5.79 t/ha. Among crop establishment

Table 1. Effects of crop establishment methods in rice and weed management practices in rice on productivity and profitability of rice-zero till *toria* cropping sequence (pooled data of two seasons *i.e.* 2013-14 and 2014-15)

Treatment	E_1	E_2	E_3	E_4	E_5	E_6	E_7	Mean
Rice equivalent yield (t/ha)								
W_1	4.33	4.51	4.69	5.14	4.25	5.16	5.77	4.84
W_2	4.09	4.31	4.33	4.82	4.06	4.80	5.42	4.55
W_3	4.37	4.53	4.79	5.23	4.31	5.22	5.79	4.89
Mean	4.27	4.45	4.61	5.06	4.22	5.06	5.66	4.76
LSD (P=0.05)	E =637		W =25		E x W =422		W x E =65	
Net return (₹/ha) rice-toriacropping system								
W1	23148	30839	31827	38909	27213	38330	40392	32951
W2	18960	27195	25989	33478	23720	32466	34587	28056
W3	21644	29178	31175	38081	26145	37112	38682	31717
Mean	21251	29071	29663	36822	25693	35969	37887	30908
LSD (P=0.05)	E =8614		W =414		E x W= 5737		W x E= 1093	
Return per rupee investment								
W1	1.66	2.05	2.03	2.31	1.92	2.24	2.09	2.04
W2	1.53	1.89	1.81	2.08	1.78	2.02	1.91	1.86
W3	1.59	1.93	1.93	2.19	1.83	2.13	1.99	1.95
Mean	1.59	1.96	1.93	2.19	1.84	2.13	2.00	1.95
LSD (P=0.05)	E =0.28		W =0.03		E x W =NS		W x E= NS	

E – Crop establishment, W – Weed management, E x W - E at same or different level of sub plot(W), W x E -W level for same level of main plot(E)

methods, transplanted rice with post-emergence application of bispyribac-sodium 0.02 kg/ha followed by mechanical weeding (E_7) gave the maximum system net return of ₹37887/- per ha. Other crop establishment methods like drum seeding with same weed management practices, DSRL with pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding (E_4) and DSRL with pre-emergence application of pendimethalin 1.0 kg/ha followed by post-emergence application of bispyribac sodium 0.02 kg/ha (E_3) remained at par over all seasons.Among weed management practices, application of glyphosate alone in *toria* proved the most remunerative with the maximum net return of Rs. 32 951/-. Other two weed management practices recorded significantly less net return as compared to it. Among crop establishment methods, DSRL with pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding (E_4) gave the maximum return/rupee investment of 2.19 over seasons. Among weed management practices, application of glyphosate alone proved the most remunerative with the maximum return/rupee investment of 2.04 over seasons.

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Weed management in conservation agriculture

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Traditional agriculture practices involve cultivation involving removal or burning of all residue which is energy intensive system. In contrast Conservation agriculture (CA) technologies involve minimum soil disturbance, soil cover through crop residues or other cover crops, and crop rotations. Changes in patterns of tillage, planting systems, and other management strategies can alter the soil environment and lead to a major change in weed flora. Conservation agriculture (CA) is being promoted as an alternative to conventional cropping practices for increasing crop yields and conserving soil resources. In spite of all these benefits the adoption of CA can't be widely popularized due to the serious threat posed by the weeds which are considered to be the major biological constraints in realizing the yield. Weed management is very crucial under CA.

Weed dynamics in CA

Minimum soil disturbance results in concentration of weed seeds accounting about 60-90% in the top 5cm of soil surface. Thus reduction in tillage frequency or intensity affects the weed infestation which in turn causes differences in composition and relative time of emergence of weed species between CA system and conventional tillage system. Further under CA system minimum soil disturbance favours the shift in weed species which was found to be dominated with perennial weed species dominating the annual weed species. Soil surface residues can interfere with the application of herbicides causing a greater likelihood of weed escapes if residue is not managed properly or herbicide application timings or rates are not adjusted. Weed control is a great challenge in adoption in CA.

OPTIONS OF WEED MANAGEMENT

Preventive measures to avoid the contamination in the field are the first and foremost important strategies to reduce weed infestation. The use of clean weed free seeds as far as possible and cleaning of irrigation canal and machinery constitutes some of the preventive measures. Crop planting dates can be adjusted to provide crop competitive advantage over weeds. Adoption of NT facilitates earlier sowing of wheat by 1–2 weeks thus helping the crop to establish before emergence of dormant *Phalaris minor* (Chauhan et al., 2012). Increasing the crop density also provides the crop competitive advantages in using resources over weeds. The use of high seeding rates may not increase crop yield in weed-free environments, but their use in weedy or partially weedy environments has been found to reduce weed biomass and increase crop yield. The use of narrow row spacing gives an advantage to the crop by allowing faster canopy closure and less light penetration through the leaves, which help reduce weed competition. Altering timing, placement, and source of fertilizer to preferentially provide the crop better accessibility to nutrients is effective in weed management. Band placement of fertilizer was found to be beneficial than broadcasting. Water management is also found to be beneficial in influencing weed density. The crops having early growth and vigorous growth habit can have the potential to suppress the weeds effectively. Breeding of competitive cultivars having allelopathic effect can be a potential technique in weed control. It was found that *'PBW-343'* was superior against *P. minor* under late sown condition. Herbicide-tolerant crops may facilitate adoption of no-till practices and can be used in conjuction with others. The residue suppresses weed germination and emergence by releasing allele chemicals as well as by reducing light availability to the weed seeds. It not only reduces weed seedling emergence, but may also delay or prolong seedling emergence. However the presence of residue was found to intercept soil active herbicides accounting about 15-80%. Rotation of crops with different management practices disturbs the growing cycle of weeds and prevents build-up of problematic weeds. The stacked rotation designs offer superior weed control compared to yearly rotations which involves rotation of crops for two consecutive years before rotating. The use of stale seedbed technique can significantly reduce weed density in a crop in CA systems and facilitates sowing of crop in a relatively weed free environment. This practice stimulates germination of weed seeds by providing light irrigation followed by killing using a nonselective herbicide. Laser land leveling by ensuring uniform crop stand can control weeds in addition to 75% saving in labour requirement. Microbial weed control can offer largely untapped resource for bio-control of weeds. Hericides which are considered to be an integral component of weed control in CA can be used in conjuction with other options. The timing of post-emergence herbicides is critical to avoid any yield loss due to weed competition. Herbicide rotation, mixture of molecules having alternate mode of action and/or integration of weed management practices is preferable as continuous use of a single herbicide over a long period of time may result in the development of resistant biotypes, shifts in weed flora, and negative effects on the succeeding crop and environment.

Table 1. Effect of tillage and weed control on weed growth and yield of winter crops after rice at Jabalpur

Winter crops	Pendimethalin 1.0 kg/ha		Weedy check	
	Zero tillage	Conventional tillage	Zero tillage	Conventional tillage
Chickpea seed yield	1.59	2.03	1.45	1.68
Net returns(x10^3/ha)	16.43	21.04	15.53	16.39
Pea seed yield	2.23	2.01	1.51	1.26
Net returns(x10^3/ha)	23.20	16.08	13.09	5.74
Linseed seed yield	1.09	0.98	0.65	0.79
Net returns (x 10^3/ha)	8.23	3.04	2.35	1.29

Source: Mishra and Singh (2011)

CONCLUSION

Since no single method of weed control can provide desired level of weed control regarding the diversity of weed problems, there is a need to integrate different weed-management strategies for widening the weed control spectrum and efficacy for sustainable crop production under CA. Approaches such as stale seedbed practice, uniform and dense crop establishment, use of cover crops and crop residues as mulch, crop rotations, and practices for enhanced crop competitiveness with a combination of pre- and post-emergence herbicides should be integrated to develop sustainable and effective weed management strategies under CA systems. Further research is needed in area of understanding dynamics of weeds, their interference potential and suitable management practices with low-cost herbicide, optimum amount of residue for effective weed control, breeding of weed competitive cultivars having allelopathic potential, estimation of weed seed predation under CA.

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Evaluation of the bioefficacy of quizalofop-p-ethyl 5% EC against weeds in summer ground nut

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Groundnut (*Arachis hypogaea* L.) is a valuable oilseed and accounts for 33% area and 45% production in India. India ranks first among groundnut growing countries in the world with 6.74 million ha area and 7.99 million tonnes production. Integrated weed management in groundnut has great importance as groundnut suffers heavily due to weed competition in the early stage because of its short structure and initial slow growth (Bhale *et al.* 2012). Unmanaged weeds from groundnut crop results in yield loss as high as 60% to 80%. In groundnut, less crop canopy during the first 6 weeks of crop growth favours strong competition with weeds causing significant reduction in yield. Therefore, timely and effective weed control during this critical period of crop weed competition become necessary for attaining maximum yield.

Manual weeding which is the age long practice for weed control in this crop is very laborious, time consuming and expensive most importantly when there is dearth of manpower. Use of chemical herbicides is the best possible alternative over the manual weeding and inter culture operations. It has also been recommended that there should be no intercultural operations applied at pegging stage of the crop (45 days after sowing). Chemical herbicide and cultural methods are effective to control the weeds in groundnut crop . Hence, the application of post emergence herbicides shall be more useful in controlling the weeds. The present study aimed to find out the effective and economic use of post emergence herbicides to control the grassy weeds in groundnut crop.

METHODOLOGY

A field experiment was conducted on sandy clay loam soils, at Instructional Farm, Maharana Pratap University of Agriculture and Technology, Udaipur during summer, 2013 with objectives to find out the suitable dose of quizalofop-p-ethyl for summer groundnut. The experiment was laid out in randomized block design comprising of 7 treatments, *i.e.* quizelofop-p-ethyl (Elegant) 600 ml/ha, quizelofop-p-ethyl 800 ml/ha, quizelofop-p-ethyl 1000 ml/ha, quizalofop-p-ethyl 5% 1200 ml/ha, pendimethalin 30% EC 3000 ml /ha, weedy check, weed free check (crop was kept weed free throughout season by hand pulling the weeds as a when appeared in the field) and replicated thrice. Groundnut variety '*TAG-24'* is taken and plot size was 6.0 x 3.0 m = 18m^2. Crop was kept dicot weed free throughout the season by hand pulling the weeds as and when these appear in the field. Herbicides were sprayed with a knapsack sprayer with flat fan nozzle.

RESULTS

The results revealed that weed control methods markedly reduced crop-weed competition. Data on monocot weed count/m^2 40 days after sowing show that all the weed control treatments significantly reduced the density of all monocot weeds except in weedy check. Application of quizalofop-p-ethyl 1000 ml and quizalofop-p-ethyl 1200 ml found at par with each other in respect of weed count /m^2 but significant over quizalofop-p-ethyl 600, quizalofop-p-ethyl 800 and pendimethalin in controlling *Echinochloa colona* and total weeds. quizalofop-p-ethyl 1000 ml was also approved superior over quizalofop-p-ethyl 600 ml in controlling *Asphodelus tenuifolius* whereas, it was at par with quizalofop-p-ethyl 800 ml, quizalofop-p-ethyl 1200 ml and pendimethalin. Data pertaining to weed density 60 days after sowing *i.e.* 35 days after application of quizalofop-p-ethyl indicate that weed control treatment significantly reduced the density of monocot weed compared to weedy check. Application of quizalofop-p-ethyl 1000 ml and quizalofop-p-ethyl 1200 ml/ha significantly reduced *Echinochloa colona* and total monocot weeds over quizalofop-p-ethyl 600, quizalofop-p-ethyl 800 ml and pendimethalin however, both treatment were found at par with each other and application of quizalofop-p-ethyl 1000 ml recorded significantly lower monocot weed count over quizalofop-p-ethyl 600, quizalofop-p-ethyl 800 ml and pendimethalin by 22.40, 18.04 and 5.14 %, respectively on the basis of transformed value.

Treatment	Weed Control efficiency (%) 40 DAS			Weed Control efficiency (%) 60 DAS			Pod yield (t/ha)	HI %
	Echinochloa colona	*Asphodelus tenuifolius*	Total monocot weeds	*Echinochloa colona*	*Asphodelus tenuifolius*	Total monocot weeds		
Quizalofop-p-ethyl 600 ml/ha	76.26	64.00	66.43	69.12	54.20	61.79	2.09	42.80
Quizalofop-p-ethyl 800 ml/ha	76.21	64.97	68.21	72.38	59.65	65.75	2.15	43.09
Quizalofop-p-ethyl 1000 ml/ha	84.59	71.80	74.58	81.81	66.58	72.23	2.46	43.17
Quizalofop-p-ethyl 1200 ml/ha	86.40	71.91	74.98	84.82	68.21	73.90	2.48	43.28
Pendimethalin 3000 ml/ha	80.91	66.26	70.39	79.70	63.50	69.09	2.21	43.14
Weedy check	0.00	0.00	0.00	0.00	0.00	0.00	1.23	35.35
Weed free	100.00	100.00	100.00	100.00	100.00	100.00	2.63	43.43
LSD (P=0.05)	-	-	-	-		-	0.37	-

All weed control treatments was found efficient in controlling monocot weeds. Among different treatments weed control efficiency in controlling *Echinochloa colona* and total monocot weeds under quizalofop-p-ethyl 1200 ml (86.40% and 74.98%) and quizalofop-p-ethyl 1000 ml were (84.59% and 74.58%) at 40 DAS, similarly at 60 DAS weed control efficiency under market sample (84.82% and 73.90%) and quizalofop-p-ethyl 1000 ml were (81.81% and 72.23%). The highest pod yield was recorded under weed free treatment (2626 kg/ha), followed by market sample (2477 kg/ha) and quizalofop-p-ethyl 1000 ml (2457 kg/ha) which were statistically at par with each other. Data showed that harvest index ranged minimum 35.35% under weedy check to maximum 43.43 % under weed free treatments. All treatment significantly increased harvest index over weedy check. quizalofop-p-ethyl 1000 ml /ha recorded harvest index of 43.28% and 43.17%, respectively.

CONCLUSION

On sandy clay loam soils amongst various herbicide formulations significant pod yield (2.15 t/ha) and harvest index (43.09%) of groundnut was realized with quizalofop-p-ethyl 800 ml/ha.

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Influence of long-term integrated nutrient management on weed floristic diversity in rice-wheat system under mid hill conditions of Himachal Pradesh

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Weeds are the serious constraints in rice-wheat cropping system. They are dynamic in nature. The crop(s), cropping systems and management practices mainly influence the weed shifts (Leeson *et al.* 2000, Liebman and Davis 2000). Studying the weed dynamics is helpful to understand the dominance or presence/absence of a particular species in a crop/cropping system, find out ways to delay or avoid the development of resistance by them against a herbicide, identify suitable crops for crop rotation/ diversification and modify agronomic practices in favour of healthy crop growth. Under the aegis of AICRP on IFS, a long - term experiment on IPNS in rice-wheat cropping system was carried out since *Kharif* 1991. An appraisal of weed flora associated in rice-wheat cropping system has been made and presented in this paper.

METHODOLOGY

A field experiment was carried out during *Kharif* and *Rabi* seasons of 2014-15 and 2015-16 at Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya Palampur (H.P.). Twelve treatments consisting of NPK at varying doses with organic manures like farmyard manure, green manure and wheat cut straw (WCS) (Table 1) were arranged in randomized block design with four replications. Fertilizers (100%) were applied uniformly through urea, single super phosphate and muriate of potash 90 kg N, 17 kg P and 33 kg K/ha, respectively for rice and 120 kg N, 26 kg P and 25 kg K/ha for wheat. Under farmers practice 40% NPK were supplied through fertilizers to each crop plus 5 t FYM/ha on dry weight basis to rice.Two situations (S_1) -No weed control/weedy without herbicide spray or hand weeding and (ii) (S_2) - Usual weed control practice were established in each plot and data on weed count and dry weight were recorded.

RESULTS

In rice, fertility treatments brought about significant variation in the count of *Monochoria vaginalis* in first year and *Ammania baccifera* in second year of cropping system. Treatments constituting farmyard manure being at par with those containing green manure had significantly higher count of *Monochoria vaginalis* over other treatments. Treatments with green manure had significantly lower count of *Cyperus difformis* than treatments constituting the inorganic use of fertilizers, wheat cut straw and farmer's practice. However, it was at par with some other treatments. *Echinocloa* spp. was highest in treatment where WCS was used. The presence of *Cyperus difformis and Echinocloa* spp. was recorded only in first year (2014-15) and *Scirpus* spp., *Fimbristylis* spp., *Eleocharis* spp. and *Brassicae* spp. were found in second year (2015-16) only. Fertility treatments brought about significant variation in the count of *Scirpus* spp. and *Fimbristylis* spp. in second year of cropping. Usual weed control decreased the overall count of the weed over no weed control (Table 1). In wheat the fertility and weed control treatments brought about significant variation in the count of *Phalaris minor* in second year. The count of *Vicia sativa* was maximum in treatments with green manure. Fertility treatments brought about significant variation in the count of *Vicia sativa* in second year. Usual weed control significantly reduced the count of *Vicia sativa* over no weed control in second year. *Polygonum hydropiper, Cynadon dactylon, Polygonum alatum* and some other species were not recorded in first year of system. The trends were not very clear as the late emerging weeds wherever find space occupying that. Weed control created vacant spaces and as a matter of the fact *Polygonum hydropiper* occupied the vacant space and resulted in significantly higher count (Table 1).

Table 1. Effect of different fertility treatments and weed control treatments on weed count of rice

Treatment	Rice				Wheat					
	Monochoria vaginalis		*Ammania baccifera*		*Phalaris minor*		*Vicia sativa*		*Lathyrusaphaca*	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Fertility										
Control	7.7(76.0)	9.8(110)	10.3(148)	12.6(206)	3.8(26)	5.6(42)	6.4(54)	9.8(102)	1.5(6)	0.7(0)
50% NPK - rice and wheat	14.2(210.0)	8.4(118)	7.9(118)	7.2(70)	8.6(108)	9.0(90)	3.8(20)	4.9(28)	3.1(20)	0.7(0)
50% NPK - rice & 100% NPK – wheat	13.6(202.0)	12.3(162)	9.8(156)	10.8(152)	8.6(98)	10.5(114)	6.0(44)	6.5(56)	5.2(62)	0.7(0)
75% NPK - rice and wheat	9.5(126.0)	8.7(104)	16.0(380)	14.1(210)	5.7(38)	6.4(46)	7.8(68)	6.2(52)	3.0(14)	0.7(0)
100% NPK - rice and wheat	13.8(212.0)	8.0(74)	13.0(240)	6.7(76)	11.2(130)	9.5(96)	4.5(32)	5.6(38)	2.4(10)	1.1(2)
50% NPK + 50% N through FYM - rice and 100% NPK - wheat	20.7(470.0)	8.6(96)	10.3(230)	6.2(62)	10.7(150)	8.9(84)	3.4(14)	6.1(44)	2.3(14)	0.7(0)
75% NPK + 25% N through FYM - rice and 75% NPK - wheat	12.7(168.0)	10.6(132)	9.1(166)	9.8(144)	10.8(124)	8.5(74)	5.6(38)	5.7(40)	1.8(6)	0.7(0)
50% NPK + 50% N through WCS - rice and 100% NPK -wheat	13.8(194.0)	11.5(164)	14.3(376)	7.9(94)	8.6(88)	10.9(122)	3.2(14)	6.3(40)	2.0(6)	0.7(0)
75% NPK + 25% N through WCS - rice and 75% NPK - wheat	14.4(220.0)	10.6(120)	12.8(256)	10.6(158)	7.5(70)	10.2(120)	5.5(50)	5.1(32)	3.8(24)	0.7(0)
50% NPK + 50% N through green manure - rice and 100% NPK – wheat	10.2(138.0)	13.5(192)	8.6(130)	3(24)	7.6(90)	9.6(106)	5.1(30)	6.7(46)	4.9(56)	0.7(0)
75% NPK + 25% N through green manure - rice and 75% NPK – wheat	15.7(258.0)	14.1(214)	13.0(242)	11(164)	9.0(100)	9.7(94)	3.8(18)	7.1(52)	3.2(34)	0.7(0)
Farmer's practice	14.3(220.0)	9.8(108)	8.8(186)	10.5(156)	9.0(100)	9.4(96)	5.6(38)	3.9(26)	2.0(10)	0.7(0)
LSD (P=0.05)	5.5	NS	NS	6.0	NS	2.7	NS	2.8	NS	NS
Weed control										
No weed control	13.7(217)	10.5(147.7)	12.0(243.0)	8.3(127)	8.6(97.3)	10.1(108.7)	5.4(40.0)	7(55)	2.7(17.0)	0.8(0.3)
Usual weed control	13.1(198.7)	10.4(118.0)	10.3(195.0)	10.1(125.7)	8.2(89.7)	7.9(72)	4.8(30.0)	5.3(37.7)	3.2(26.7)	0.7(0)
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	2.3	NS	NS	1.4

CONCLUSION

The findings of the present investigation clearly inferred that the soil and fertility management techniques and weed management practices greatly influence the weed community structures. Thus accordingly measures for their control are needed to be designed.

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Conservation system and weed control measures on yield and soil health in wheat

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Conservation agriculture practices are designed to achieve agricultural sustainability by implementation of sustainable management practices which minimize environmental degradation and conserve resources with maintaining high yields coupled with profitable systems, and also improve the biological activities of the agro-ecosystem with limited mechanical practices and judicious use of external inputs. It is characterized by three linked principles, *viz.* (i) continuous minimum mechanical soil disturbance, (ii) permanent organic soil cover and (iii) diversification of crop species grown in sequences or associations. These benefits can be achieved through employing components of conservation agriculture e.g. conservation tillage, including reduced soil erosion and water runoff, increased productivity through improved soil quality, increased water availability, increased biotic diversity and reduced labour demands. Considering the diversity of weed problems, no single method of weed control, *viz.* cultural, mechanical or chemical could provide the desired level of weed control efficiency under conventional agriculture. Therefore, a combination of different weed management strategies were evaluated for managing the wide weed spectrum with higher efficacy for sustainable crop production and improving soil health.

METHODOLOGY

The experiment was conducted at Agronomy Research Farm of the NDUAT Kumarganj, Faizabad (U.P.) with the objective to develop an appropriate establishment method in rice-wheat cropping system along with weed management practices under irrigated ecosystem. The initial soil of experimental field was silty-loam in texture with saline reaction (pH 8.2). It was low in organic carbon C (0.29%) with low fertility status *i.e.* available N (115.2 kg/ha), available P (14.2 kg/ha) available K (230 kg/ha) and microbial properties *i.e.* bacteria (14 cfu/g), fungi (5.6 cfu/g) and actinomycetes (6.2 cfu/g) respectively. The experiment was laid out in split plot design keeping crop establishment methods in main plot and weed control method in sub-plot replicated thricely. The rhizospheric soil samples were collected randomly from the top layers of the soil depth (0-15 cm) from each plot at harvest of crop for physico-chemical and microbial studies during *Rabi* season 2015-16.

Table 1. Effect of different establishment method and weed control measures on soil health and yield of wheat

Treatment	Soil health										Wheat yield	
	BD (g/cc)	pH (1.25)	EC (/dSm)	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Bacteria (cfu/g. 10^7)	Fungi (cfu/g 10^4)	Actinomycets (cfu/10 10^4)	Grain yield (t/ha	Straw yield (t/ha)
Conservation system												
TPR (CT)- wheat (CT)	1.47	8.14	0.26	0.31	127.0	16.1	235.0	14.00	6.33	9.70	4.59	5.71
TPR (CT)- wheat (ZT)	1.46	8.14	0.24	0.32	128.6	17.7	238.9	17.30	9.63	11.83	4.36	5.41
DSR (CT)- wheat (CT-sesbania (ZT))	1.46	8.15	0.25	0.32	127.0	16.7	235.7	17.37	9.50	10.90	4.48	5.54
DSR (ZT)- wheat (ZT)- sesbania (ZT)	1.16	8.14	0.23	0.35	129.7	18.2	242.5	19.67	9.80	13.40	3.95	4.92
DSR (ZT)+ R –wheat (ZT)+ R-sesbania (ZT)	1.46	8.11	0.22	0.35	133.0	18.8	248.6	22.80	12.23	14.73	4.07	5.24
LSD (P = 0.05)	NS	NS	NS	0.05	6.95	3.16	9.07	6.70	5.56	2.23	0.42	0.42
Weed control												
Recommended herbicides	1.46	8.14	0.24	0.33	129.2	17.9	239.6	17.64	8.72	12.06	4.46	5.45
IWM (herbicide + MW)	1.46	8.13	0.24	0.33	129.8	17.4	241.8	19.12	10.30	12.54	4.98	6.05
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TPR-transplanted rice, CT- conventional tillage, ZT- zero-tillage, DSR- direct seeded rice, IWM- integrated weed management, R- residues

RESULTS

Conservation systems affected significantly the various physico-chemical and microbial properties of soil. The population of bacteria, fungi and actinomycetes were highest with DSR (ZT) + R-wheat (ZT)+R- sesbania (ZT) followed by DSR(ZT)-wheat (ZT) – sesbania (ZT). Integrated weed management (herbicide + MW) recorded the highest population of bacteria, fungi and actinomycetes followed by weed control by recommended herbicide. The values of N,P,K and OC were significantly highest with DSR (ZT)+R-wheat (ZT) +R-sesbania(ZT) followed by DSR (ZT)-wheat (ZT)-sesbania (ZT). This was because of addition of organic matter by residue and sesbania. However conventional tillage in both crop (Rice-wheat) *i.e.* TPR (CT)-wheat (CT) resulted the lowest values of OC, N, P and K due to no addition of organic matter. The values of BD, PH and EC were not affected due to conservation system. Conventional tillage establishment method recorded the maximum grain and straw yield. Significantly higher grain yield of wheat (4.59 t/ha) was recorded with TPR (CT) - wheat (CT) followed by DSR (CT) - wheat (CT) along *Sesbania* (ZT).

Integrated weed management recorded the maximum value of physico-chemical and microbial population in soil. This was mainly due to incorporation of *sesbania* which improved the organic matter in soil. Application of herbicides supplemented with one hand weeding significantly recorded the highest grain yield (4.98 t/ha) and straw yield of wheat (6.05 t/ha) followed by recommended weed management practices (Table 1).

CONCLUSIONS

Soil health and yields were improved under zero tillage establishment method. Integrated weed management treatment improved soil health and produced higher grain yield.

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Effect of herbigation on weed spectrum and yield of direct-seeded rice

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In recent days, direct sowing of paddy is practiced due to water and labour scarcity. Weed is the major biotic stress which reduces the yield of direct seeded rice (DSR). Management of weeds can be done by employing suitable weed control method. One such method is herbigation. It is a method of application of herbicides through irrigation (Nalayini *et al*. 2013). Hence, a preliminary investigation was carried out to study the effect of herbigation on weed flora and yield of direct seeded rice in coastal deltaic region of Karaikal, Puducherry UT.

METHODOLOGY

A field experiment was conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA&RI), Karaikal, Puducherry UT during *Kharif* 2016 to study the effect of herbigation on weed flora and rice yield in direct seeded condition. The experiment was laid out in randomized block design with nine treatments. The rice cultivar ADT 45 was sown with the spacing of 20 cm x 10 cm and all the recommended package of practices except weed control was adopted during the period of experimentation. The irrigation in drip system was done based on the IW/CPE ratio of 1.2 from seed germination to the harvest of the crop with in-line drippers with a discharge rate of 4 lph in the interval of 50 cm spacing. The pre-emergence herbicides were applied by herbigation on 3 DAS (Table 1).

Observations on weeds were recorded with the help of quadrate 0.25 m x 0.25 m placed randomly at four spots in each plot at 60 DAS. The data on weed density and dry weight were then analyzed by using square root transformation ("x+0.5) to normalize their distribution. The data collected from the experiments was subjected to the Fisher's method of Analysis of Variance (ANOVA).

RESULTS

The predominant weeds of the experimental field were *Echinochloa colona* (L.), *Eragrostis* spp., *Ludwigia parviflora* (L), *Eclipta prostrata* (L.) and *Cyperus iria* (L.). Manual weeding twice at 20 and 40 DAS recorded significantly lower weed density (42.7 no. /m^2), weed dry weight (23.1 g/m^2), and higher rice yield (2.42 t/ha) (Table 1). It was found to be on par with the pyrazosulfuron application by herbigation integrated with a manual weeding at 40 DAS (1.97 t/ha).

Higher weed density was observed with the application of pre-emergence herbicides by herbigation devoid of manual weeding, results in low weed control efficiency. This effect is presumably due to the more rapid microbiological and chemical (hydrolysis) degradation of herbicides in the continually wetted soil associated with high-frequency drip irrigation (Fischer *et al*. 1985).

Table 1. Effect of herbigation on weed growth and yield of direct seeded rice

Treatment	Dose (g/ha)	Weed density at 60 DAS (no./m^2)	Weed dry weight at 60 DAS (g./m^2)	Weed control efficiency (%)	Rice yield (t/ha)	Weed index
Pyrazosulfuron by herbigation *fb* manual weeding	20 *fb* 40 DAS	8.2 (61.7)*	6.1 (31.8)*	88.2	1.97	18.6
Pyrazosulfuron by herbigation alone	20	10.5 (99.7)	9.7 (85.5)	68.2	1.67	30.9
Oxadiargyl by herbigation *fb* manual weeding	100 fb 40 DAS	10.7 (108.0)	8.9 (72.2)	73.1	1.79	26.0
Oxadiargyl by herbigation alone	100	12.2 (138.3)	11.4 (122.8)	54.3	1.50	38.2
Pendimethalin by herbigation *fb* manual weeding	1000 fb 40 DAS	11.1 (113.7)	10.4 (100.7)	62.6	0.92	62.1
Pendimethalin by herbigation alone	1000	12.5 (143.3)	13.0 (152.3)	43.4	0.84	65.4
Manual weeding once	20 DAS	11.9 (132.7)	13.2 (168.7)	37.3	1.13	53.2
Manual weeding twice	20 & 40 AS	7.0 (42.7)	5.3 (23.1)	91.4	2.42	-
Weedy check	-	13.6 (172.0)	16.9 (268.9)	-	0.36	85.2
LSD (P=0.05)		2.61	3.04	NA	0.21	NA

*Original figures in parenthesis were subjected to square root transformation ($\sqrt{x+0.5}$)before statistical analysis. NA- Data statistically not analyzed.

The yield loss caused by weeds was ranged from 18.6 to 62.1% in herbigated plots integrated with manual weeding. However, maximum yield loss of 85.2% was recorded with unweeded control.

CONCLUSION

Manual weeding twice and pyrazosulfuron application by herbigation integrated with a manual weeding effectively controlled the weeds and improved the yield of direct seeded rice in coastal deltaic region of Karaikal, Puducherry UT.

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Nutrient properties of soil in pearl millet under pearl millet- mustard cropping system

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The pearl millet (*Pennisetum glauctum*) is most widely grown type of millet. Because of its tolerance to difficult growing conditions such as drought, low soil fertility and high temperature, it can be grown in areas where other cereals crops, such as maize (*Zea mays*) or wheat (*Triticum aestivum*), would not survive (Basavaraj *et al.* 2010). Nutrient depletion is one of the concern with pearl millet as it removes 34.6, 5.0 and 48.8 kg/ha of N, P and K from soil compared with sorghum and maize (Mohammed *et al.* 2016).

India is the largest producer of pearl millet, both in terms of area (7.8 million ha) and production (9.25 million ton), with an average productivity of 1270 kg/ha. However, the area around 26% is declined since 80's in traditional growing state of Gujarat, Rajasthan and Haryana but production increased by 19% owing to 48% increase in productivity.

METHODOLOGY

A field experiment was conducted to review "Nutrient properties of soil in pearl millet under pearl millet- mustard cropping system" at AICRP-Weed Management farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). Anand is situated in middle of Gujarat at 22.5^o N to 72.92^o E with the 39.5 m elevation. The soil of the experimental field was sandy loam in texture with low available nitrogen, medium in phosphorus and potassium with the pH of 8.0. The experiment was laid out in Split plot design with three replications. The treatments were comprised of different tillage practices in main plots and weed management practices in sub-plot within main plot. Pearl millet cultivar GHB-558 was sown with 10 x 45 cm. spacing.

RESULTS

The data presented in Table 1 revealed that the impact of different tillage practices gave significant differences in nutrient status of soil, whereas, different weed management practices did not show any significant difference in nutrient availability except with pH and availability of phosphorus. Hence, the impact of tillage practices on nutrient availability is more pronounced than the weed management practices.

The pH and EC values among the main & sub-plot treatment were highest recorded under CT (T1) and atrazin 0.50 kg/ha PE (W1) and lowest with ZT+ residue & atrazin 0.50 kg/ha PE *fb* IC 30 DAS (W2) respectively. The values of organic carbon, total N and available P and K were highest recorded under ZT + residue (T5) followed by ZT (T4), whereas, lowest values recorded under CT (T1) system. Among the weed management practices, the presented data showed non significant difference with organic carbon, available N, P and K. The interaction of main and sub-plot treatments also showed significant differences among the treatment.

Table 1. Nutrient status of soil as influenced by different tillage and weed management practices in pearl millet under pearl millet-mustard cropping system

Treatment	Soil parameters					
	pH	EC (dS/m)	Organic carbon (%)	Total nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
Tillage Practices in Pearl millet (T)						
T_1: Conventional tillage (CT)	8.15	0.40	0.28	543	17.6	128
T_2: Conventional tillage (CT)	8.10	0.34	0.31	610	16.6	133
T_3: Zero tillage (ZT)	8.03	0.33	0.31	614	19.2	128
T_4: Zero tillage (ZT)	8.11	0.33	0.32	633	21.4	145
T_5: Zero tillage (ZT) + Residue	7.96	0.30	0.34	665	22.0	158
LSD (P=0.05)	0.096	0.03	0.031	61.6	2.15	11.4
WM Practices in Pearl millet (W)						
W_1: Atrazine 0.50 kg/ha PE	8.15	0.34	0.31	613	18.1	144
W_2: Atrazine 0.50 kg/ha PE *fb* IC 30 DAS	8.01	0.33	0.32	630	20.6	131
W_3: Unweeded	8.04	0.35	0.30	595	19.4	139
LSD (P=0.05)	0.080	NS	NS	NS	1.55	NS
Interaction TxW	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
LSD (P=0.05)	0.18	0.053	0.025	104.04	3.48	23.95

CONCLUSION

The effect of different tillage operation proved significant differences in nutrient status of soil rather weed management practices. Hence, on sandy loam textured soil the performance of zero tillage system with residue (ZT + Residue) proved to be the best tillage practices followed by zero tillage (ZT).

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Effect of differential tillage, nitrogen and weed management practices on wheat-greengram cropping sequence

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The conventional cultivation practices of wheat under rice-wheat and maize-wheat cropping systems in Indo-Gangetic Plains (IGPs) of India need to be improved with conservation agriculture (CA) practices such as zero tillage (ZT) with residue retention and crop diversification to adapt to the changing climate and to enhance system productivity, input use efficiency, and farm profitability on a sustainable basis (Ladha *et al*. 2003). Weeds appear as a challenge in CA and weed management should be of paramount importance. Weed management is herbicide-based under ZT system. The nitrogen (N) management under conservation agriculture assumes to be another important dimension of research; hence the present investigation was undertaken.

METHODOLOGY

The field experiment was carried out during 2013-14 and 2014-15 at ICAR-Indian Agricultural Research Institute, New Delhi, on a split plot design comprising: (i) conventional tillage (CT) without residue + 100% of required N (based on soil test value) (CT-R+100N), (ii) CT + 5 t/ha maize residue incorporation + 100% N (CT+R+100N), (iii) CT + 5 t/ha maize residue incorporation + 75% N + rest N based on GreenSeeker™ (CT+R+75N+GS), (iv) ZT without residue + 100% N (ZT-R+100N), (v) ZT + 5 t/ha maize residue retention + 100% N (ZT+R+100N) and (vi) ZT + 5 t/ha maize residue retention + 75% N + rest N based on GreenSeeker™ (ZT+R+75N+GS) in main plot and unweeded control (UWC), weed free check (WFC), sulfosulfuron + metsulfuron-methyl (40 g/ha) (SSF + MSM) and pendimethalin (1 kg/ha) followed by sulfosulfuron (25 g/ha) (PMT-SSF) in sub-plot. After wheat greengram was taken as residual crop to see the carry-over effect of all the treatments.

RESULTS

The treatments ZT + R + 75N + GS and PMT-SSF alone and in combination resulted in significant reductions in weed growth (population and dry weight) and caused a considerable increase in weed control efficiency and weed control index in wheat (Table 1). Their carry-over effect was also significant on the reduction of weed competition in greengram. It led to significantly higher productivity, profitability, system productivity, irrigation water- and nutrient-use efficiencies in wheat-greengram sequence. This treatment saved N to the tune of 15-20 kg/ha and caused considerable reduction in greenhouse gases emission. The treatments ZT + R + 75N + GS and PMT-SSF enhanced soil physical (bulk density, aggregation, temperature and moisture), chemical (organic carbon stock, pools and nutrient status) and biological properties (microbial population, microbial biomass carbon and enzymes) over CT-R + 100N over the years.

Table 1. Effect of tillage, nitrogen and weed management on weed growth at 40 DAS, yield and economics of wheat-greengram sequence

Treatment	Weed density (no./m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)	Wheat grain yield (t/ha)	Greengram grain yield (t/ha)	System B:C ratio
CT-R+100N	3.09 (74.1)	2.41 (57.9)	55.8	4.48	1.06	2.04
CT+R+100N	2.55 (61.1)	1.69 (40.6)	47.2	4.63	1.19	1.71
CT+R+75N+GS	2.77 (66.5)	2.11 (50.6)	50.9	4.91	1.22	1.83
ZT-R+100N	2.37 (56.7)	1.66 (39.9)	54.8	4.51	1.09	2.38
ZT+R+100N	1.52 (36.3)	1.24 (29.7)	49.9	5.00	1.23	2.07
ZT+R+75N+GS	2.04 (48.9)	1.27 (30.4)	49.3	5.11	1.38	2.29
LSD (P=0.05)	0.69	0.35	-	0.40	0.15	0.23
UWC	5.17 (186.1)	3.72 (133.9)	0.0	4.06	1.06	1.82
WFC	0.00 (0.0)	0.00 (0.00)	100.0	5.16	1.26	2.11
SSF+MSM	2.31 (83.1)	1.71 (61.4)	50.4	4.91	1.22	2.15
PMT-SSF	2.08 (74.7)	1.50 (53.9)	55.1	4.97	1.23	2.13
LSD (P=0.05)	0.46	0.26	-	0.20	0.11	0.11

CONCLUSION

A combination of ZT + maize residue retention + 75% of required N + rest N application based on GreenSeeker™ and pendimethalin fb sulfosulfuron can be recommended for higher productivity, profitability, resource-use efficiency and sustainability of the wheat-greengram sequence in the north-western IGP of India.

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Comparative performance of different crop establishment methods on weed growth and yield of rice

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Rice cultivation in the below sea level unique wet land system of Kerala, Kuttanad, reclaimed from the backwaters, is labour intensive. The area being hot spot of pests and diseases, face severe threat from weeds from the seedling stage of the crop, resulting in poor plant population. Hence, the farmers are forced to go for higher seed rate in the double cropped wet lands, leading to pests and diseases and ultimately increased cost of cultivation. Optimising the plant population by mechanised transplanting or drum seeding are viable options for uniform crop stand and less incidence of pests and diseases. Weed management also becomes more effective either by using herbicides or by mechanised options like cono weed or power weeding. Based on this hypothesis an experiment was conducted to evaluate the influence of different crop establishment methods on the weed emergence, yield and economics of crop production.

METHODOLOGY

The field experiment was conducted at Rice Research Station, Moncompu, Kerala during *Kharif* 2014. The soil was silty clay with pH 6.2, organic carbon 2.55%, available P and K 35.8 and 342 kg/ha, respectively. The experiment was laid out in RBD with four replications in plots of 40 m^2 size. The treatment details are given in Table 1. In mechanised transplanting (Mahindra walk behind transplanter), seedlings raised in mat nursery were transplanted on 15^{th} day. In drum seeding and broadcasting pre germinated seeds were used. Both planting and sowing were done in the main field on the same day with variety MO 16 (Uma). The INM plots was fertilised with 50% recommended dose of N,$P_2 0_5$,K_2O 90,45,45 kg/ha, respectively and remaining 50% using Plant Growth Promoting Rhizobacteria enriched FYM. In organic plots whole nutrient requirement was met with PGPR enriched FYM. Weed management was done by cono weeding at 20 and 35 DAS/DAT in transpanted and drum seeded plots with organic management while, in INM plots herbicide bispyribac-sodium 10 SC 0.03 kg/ha with tank mix application of metsulfuron-ethyl 10%+ chlorimuron-methyl 10% 0.004 kg/ha at 15 DAS.

RESULTS

Among the different crop establishment methods, mechanised transplanting performed better in managing weeds as evident from the reduced weed count and weed dry weight. Weed dry weight was higher in cono weeded plots, but the disturbance in the soil root zone favoured better growth and more productive tillers in cono weeded treatments. As cono weeding is the only available weed management strategy in transplanting and drum seeding, the weed population was high compared to herbicide applied plots. Broadcasted plots had higher weed dry weight and subsequent reduction in yield. Plant growth was also higher in mechanised transplanting followed by drum seeding. Yield and yield parameters also followed the same trend. Among the organically managed plots, transplanting followed by cono weeding was on par with drum seeding followed by cono weeding. In all crop establishment methods, nutrient management with integrated approach performed better than fully organic plots.

Table 1. Effect of crop eatablishment methods, weed and nutrient management on growth and yield of rice

Treatment	Weed dry wt, g	Prod. Tillers/m^2	Plant Ht, cm, 60 DAS/ DAT	Plant Ht, cm, 90 DAS/ DAT	Yield, t/ha	B:C Ratio
BOH	4.3	137	49.3	73	3.8	1.7
BIW	3.97	157	52.1	78.7	3.5	1.4
BOH	4.35	168	59.3	85.7	4.2	1.8
BIW	5.89	160	62.9	85.7	3.9	1.5
DOH	2.68	164	58.3	84.3	4.8	2
DOC	3.79	153	56.3	85.3	3.9	1.5
DIH	2.04	180	66	91.3	5.2	2.1
DIC	2.63	141	60.8	91.3	4.5	1.5
TOH	1.84	272	68.7	85	4.7	2
TOC	2.52	326	69	87.7	4.1	1.6
TIH	2.13	296	72	88.3	6.9	2.2
TIC	2.97	337	68.3	92.3	5.0	1.9
LSD (P=0.05)	1.2	132	2.88	3.5	0.30	

B- broadcasting, D-drum seeding, T- machine transplanting; I- INM, O-organic, C- cono weeding, H-herbicide

CONCLUSION

An integrated crop/weed management approach by harnessing positive interactions of soil-water-nutrients-tillage-weeds is required for achieving the highest productivity and profitability. Mechanised transplanting and drum seeding can be adopted as an alternate to DSR, where gap filling, weeding and other cultural operations become labour intensive.

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Integrated weed management in proso millet under rainfed conditions of Konkan region of Maharashtra

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In India, proso millet is cultivated over an area of 0.07 million ha with total production of 0.43 million tonnes, with a two-third share of the total recorded millet trade. During *Kharif* season, there is luxuriant growth of crop and weeds in Konkan region. Keeping in view, a field experiment was planned on integrated weed management in proso millet (*Panicum miliaceum* L.) under rainfed conditions of south Konkan coastal region of Maharashtra.

METHODOLOGY

The field experiment was conducted at the Agronomy Farm, Department of Agronomy, College of Agriculture, Dapoli, Dist. Ratnagiri during *Kharif* season of 2015 in randomized block design comprising of ten treatments with three replications. The 30 day old seedlings of cultivar *'Vari No.10'* was transplanted in the holes prepared with the help of a pointed wooden stump (dibbler or *thomba*) at a spacing of 30 x 15 cm. The recommended dose of fertilizer i.e. 80:40:00 N,P and K kg/ha was applied through urea and single super phosphate. The treatments were imposed as per the schedule of operations.

RESULTS

The predominant weed species observed were *Ischaemum globosa*, *Digitaria sanguinalis*, *Echinochloa colona* of grasses group *Cyperus iria*, *Cyperus difformis* of sedges group and *Ludwigia octovalvis*, *Mimosa pudica*, *Physalis minima*, *Alternanthera sessilis*, *Ageratum conyzoides* among the broad-leaved weeds. It is evident from the data (Table 1) that weed free check treatment recorded significantly the lowest total dry weight (2.15 g/m^2) of weeds at harvest followed by pendimethalin 1.0 kg/ha *fb* mechanical weeding (4.97 g/m^2). The highest weed control efficiency (89.9%) was recorded under weed free check treatment followed by pendimethalin 1.0 kg/ha *fb* mechanical weeding (76.7%), pendimethalin 1.0 kg/ha (71.5%) and two mechanical weeding (70.40%) in the descending order. The weed free check treatment produced the highest grain yield (1.35 t/ha) and was found significantly superior over all the treatments followed by pendimethalin 1.0 kg/ha *fb* mechanical weeding (1.28 t/ha), two mechanical weeding (1.25 t/ha) and pendimethalin 1.0 kg/ha (1.21 t/ha) which were at par with each other (Rao *et al.* 2015).

Total nitrogen uptake by the weeds was significantly less under the weed free check (8.14 kg/ha) than rest of the treatments which was followed by pendimethalin 1.0 kg/ha *fb* mechanical weeding (13.56 kg/ha). Weed free check (47.61 kg/ha) recorded significantly higher uptake of nitrogen by proso millet, followed by pendimethalin 1.0 kg/ha *fb* mechanical weeding (42.96 kg/ha) while weedy check treatment (Table 1) recorded lowest uptake of nitrogen (26.50 kg/ha).

Table 1. Total weed biomass (g/m^2), WCE (%), yield (q/ha), nutrient uptake (kg/ha) and economics of pros omillet as influenced by various treatments

Treatment	Weed dry biomass (g/m^2)	Weed control efficiency (%)	Grain yield (t/ha)	Straw yield (t/ha)	Nutrient uptake by weeds (kg/ha)		Nutrient uptake by crop (kg/ha)		Total cost (x 10^3 ?/ha)	Net returns (x 10^3 ?/ha)	B:C ratio
					N	P	N	P			
Pendimethalin 1.0 kg/ha	6.10 (29.8)*	71.5	1.21	4.70	15.30	3.59	41.45	74.42	31.44	105.99	1.34
Oxadiargyl 80 g/ha	8.14 (39.9)	61.9	1.03	4.43	18.50	4.13	37.38	59.35	31.79	48.49	1.15
Oxyfluorfen 0.5 kg/ha	8.20 (40.1)	61.6	1.17	4.66	21.13	4.17	39.80	70.03	31.37	95.57	1.30
Pendimethalin 1.0 kg/ha *fb* mechanical weeding	4.97 (24.3)	76.7	1.28	4.73	13.56	2.92	42.96	78.48	32.34	114.47	1.35
Oxadiargyl 80 g/ha *fb* mechanical weeding	7.00 (34.2)	67.2	1.13	4.52	18.09	3.87	34.79	71.28	33.05	70.24	1.21
Oxyfluorfen 0.5 kg/ha *fb* mechanical weeding	6.85 (33.5)	67.9	1.19	4.66	17.52	4.04	40.56	73.59	32.63	89.93	1.27
Two mechanical weeding (cono/rotary weeder)	6.32 (30.9)	70.4	1.25	4.73	16.04	3.38	41.15	74.22	33.28	94.60	1.28
2,4-D Na salt 0.5 kg/ha	9.09 (44.4)	57.4	0.96	4.28	22.16	4.79	30.72	53.27	31.29	32.57	1.11
Weed free check	2.15 (10.5)	89.9	1.35	4.81	8.14	2.00	47.61	85.98	34.90	112.97	1.32
Weedy check	21.37 (104.5)	-	0.83	3.91	59.43	10.27	26.50	41.81	27.77	26.39	1.08
LSD (P= 0.05)	0.23	-	0.07	0.16	0.62	0.26	1.34	3.24	-	-	-

*Values in parenthesis are original. Data transformed to square root transformation.

Data regarding the economics of the treatments indicated that the net profit as well as B:C ratio was higher under pendimethalin 1.0 kg/ha *fb* mechanical weeding (Rs.11447/- and 1.35, respectively) as compared to the other treatments, which was followed by Pendimethalin 1.0 kg/ha (Rs.10599/- and 1.34, respectively) and weed free check (Rs.11297/- and 1.32, respectively) treatment. While, lowest net return and less B:C ratio was recorded in weedy check (Rs.2639/- and 1.08, respectively) treatment.

CONCLSION

On the basis of results obtained during study, it can be concluded that the herbicides with one manual weeding gives better results as compared to pre and post-emergence combinations or use of herbicide alone. The treatment pendimethalin PE 1.0 kg/ha *fb* mechanical weeding was the most effective and economical treatment followed by pendimethalin PE 1.0 kg/ha and weed free check to control weeds effectively in proso millet during *Kharif* season and to obtain higher productivity and profit.

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Nutrient uptake studies in Indian mustard as affected by weed management and nitrogen application

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Rapeseed and mustard [*Brassica juncea* (L.) Czern and Coss.] is an important oilseed crop in India, intensively suffers from weed competition causing yield reduction to the tune of 68 % as compared to weed free condition (Degra *et al.* 2011). Weeds drain a huge amount of nutrients from soil and consequently the crop suffers from nutrient deficiency, nitrogen in particular. Adequate application of nitrogen enhances the yield by influencing a variety of growth and yield parameters with lush green colour of the crop canopy and concurrently increasing the competitive ability of the crop. Considering these facts, a field experiment was conducted to find out the most effective weed management practice and nutrient level in Indian mustard.

METHODOLOGY

A field experiment was conducted during *Rabi* 2014-2015 at Rajasthan College of Agriculture, Udaipur (Rajasthan). The clay loam soil of the experimental field was alkaline in reaction, medium in N and P and high in K. Fifteen treatment combinations consisted of 5 weed management practices (pendimethalin 0.75 kg/ha as pre emergence, oxadiargyl 0.09 kg/ha as pre emergence, quizalofop-ethyl 0.05 kg/ha 25 days after sowing (DAS), hand weeding 25 DAS and weedy check) and 3 nitrogen levels (45, 60 and 75 kg/ha) were arranged in a randomised block design with three replications. Indian mustard variety BIO-902 (*Pusa Jaikisan*) was sown in the experimental field with recommended package of practices. The required doses of N for different treatments were applied both through urea and DAP after adjusting the quantity of nitrogen supplied by DAP for supplying 35 kg/ha of phosphorus. Observations of the parameters were taken by following standard procedure.

RESULTS

All the weed management practices significantly reduced dry matter accumulation, N and P uptake by weeds at 90 DAS, whereas significantly increased biological yield as well as N and P uptake by the crop compared to weedy check. The minimum total weed dry weight (201.24 kg/ha) was observed under one hand weeding, followed by oxadiargyl 0.09 kg/ha (217.54 kg/ha) and were found significantly superior to rest of the weed management treatments in this regard. The highest reduction in N and P uptake by weeds (9.52 and 1.702 kg/ha, respectively) was recorded under one hand weeding, followed by oxadiargyl 0.09 kg/ha (9.17 and 1.654 kg/ha, respectively) compared to weedy check (Table 1). Among different herbicidal treatments, oxadiargyl 0.09 kg/ha recorded maximum biological yield with 44.82% increase as compared to weedy check and was comparable to one hand weeding in this regard (47.46%). The highest N and P uptake (120.41 and 25.69 kg/ha, respectively) by the crop was recorded with one hand weeding at 25 DAS and was statistically at par with oxadiargyl 0.09 kg/ha, which might be ascribed to higher yields with these treatments. There was a inverse relation between uptake of nutrient by weed and crop, whenever the nutrient removal was more by weed, the corresponding uptake by the crop was less and vice-versa.

Table1. Effect of weed management and nitrogen levels on weed dry matter, biological yield and N and P uptake by weed and crop

Treatment	Weed dry matter (kg/ha) at 90 DAS	Nutrient uptake (kg/ha) by weed at 90 DAS		Biological yield (t/ha)	Nutrient uptake (kg/ha) by crop at harvest	
		Nitrogen	Phosphorous		Nitrogen	Phosphorous
Weed Management						
Pendimethalin 0.75 kg/ha	317.42	6.36	1.149	6.69	99.15	21.20
Oxadiargyl 0.09 kg/ha	217.54	4.37	0.790	7.69	118.33	25.35
Quizalofop-ethyl 0.05 kg/ha	530.88	11.07	1.978	6.17	90.88	19.94
One hand weeding 25 DAS	201.24	4.02	0.742	7.83	120.41	25.69
Weedy Check	661.34	13.54	2.444	5.31	74.12	16.06
LSD (P=0.05)	33.91	0.76	0.123	0.67	10.60	2.22
Nitrogen levels (kg/ha)						
45	362.03	7.02	1.260	5.96	84.96	17.82
60	385.44	7.91	1.434	6.83	102.15	21.66
75	409.58	8.69	1.567	7.43	114.62	25.46
LSD (P=0.05)	26.26	0.59	0.095	0.52	8.21	1.72

Amongst the three N levels, 75 kg N/ha resulted in significant increase in weed dry matter compared to 45 kg N/ha. Addition of each successive levels of nitrogen increased N and P uptake by weeds compared to their preceding lower level. This might be the reason of higher dry matter accumulation by weeds with higher doses of N. Biological yield of the crop was increased significantly with increasing dose of N up to 75 kg/ha. This result can be confirmed with the findings of Dongarkar *et al.* (2005). The uptake of N and P by the crop increased by 29.66 and 7.64 kg/ha due to 75 kg/ha compared to 45 kg/ha of nitrogen.

CONCLUSION

Pre-emergence application of broad spectrum herbicide oxadiargyl 0.09 kg/ha in Indian mustard recorded the higher uptake of N and P by crop and was comparable to one hand weeding. Among the N levels, the highest uptake of these nutrients was recorded under 75 kg/ha.

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Correlation among growth attributes, yield components, yields and weeds as influenced by integrated weed and nutrient management in greengram-rice-onion cropping sequence

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The growing urgent need for sustainable agriculture has led to a renewed interest in recycling of nutrients through organic sources in restoring soil fertility and sustaining crop productivity. T Weed and nutrient management have certain influence on crop growth, yield parameters and yield of crops. Keeping this view in mind, the present research work was carried out.

METHODOLOGY

The field experiment was conducted in humid sub-tropics of West Bengal at the Kalyani C-Block (In-check) Farm (latitude: 23°59'14'' N, longitude: 88º27'16''E and altitude: 9.75 m) of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia during two consecutive years from March, 2010 to March, 2012. The experiment was conducted with three main plot treatments and six sub-plot treatments replicated thrice with split plot design. The cropping sequence was greengram (cv. *Bireswar*) - rice (cv. *Shatabdi)* - onion (cv. *Sukhsagar*). The data were subjected to statistical analysis by analysis of variance method. The correlation studies were made to reveal the association among the variables in the investigation.

RESULTS

Greengram seed yield was significantly associated with no. of plants/m (r = 0.537*), plant height (r = 0.760**), LAI (r = 0.752**), DMA (r = 0.868**), pods per plant (r = 0.933**) and seeds per pod (r=0.929**) whereas correlation with test weight was not significant (Table 1). Rice grain yield was significantly associated with DMA(r=0.620**), plant height (r=0.968**), LAI (r=0.950**), no. of effective tillers/m^2 (r=0.983**) and no. of filled grains/panicle (r=0.906**) whereas correlation with test weight was not significant. Dry weight of weeds were critical for the rice grain yield (r = -0.902**), plant height (r = -0.861**), LAI (r = -0.861**), no. of effective tillers/m^2 (r = -0.950**), no. of filled grains per panicle (r = -0.670**), test weight (r = -0.685**) as they were significantly negatively correlated (Table 2). Dry weights of total weeds were critical for the onion bulb yield (r = -0.587*), DMA (r = -0.441*), plant height (r = -0.756**), no. of leaves per plant (r = -0.640**), bulb diameter (r = -0.626**), bulb length (r = -0.641**), no. of scale per bulb (r = -0.568*) and average bulb yield (10 bulb weight g) (r = -0.570*) as they were highly negatively correlated (Table 3). This result is in agreement with the findings of Acharya and Mondal (2010).

Table 1. Correlation matrix among seed yield, no. of plants/m2, DMA, plant height, LAI, pods/plant, seeds/pod, test weight and total weed dry weight of greengram

Parameter	Seed yield	No. of plants/ m2	DMA	Plant height	LAI	Pods /plant	Seeds/pod	Test weight	Total weed dry weight
Seed yield	1.000								
No. of plants/m2	.537*	1.000							
Plant height	.760**	.341	1.000						
LAI	.752**	.224	.768**	1.000					
DMA	.868**	.279	.625**	.771**	1.000				
Pods /plant	.933**	.490*	.923**	.809**	.746**	1.000			
Seeds /pod	.929**	.442	.910**	.802**	.766**	.975**	1.000		
Test weight	.258	.379	.359	-.172	-.124	.349	.385	1.000	
Total weed dry weight	-.587*	-.376	-.913*	-.569*	-.298	-.819**	-.794**	-.587*	1.000

Table 2. Correlation matrix among grain yield, DMA, plant height, LAI, no. of effective tillers /m2, no. of filled grain/panicle, test weight and total weed dry weight of rice

Parameter	Grain yield	DMA	plant height	LAI	No. of effective tillers m^{-2}	No. of filled grains $panicle^{-1}$	Test weight	Total weed dry weight
Grain yield	1.000							
DMA	.620**	1.000						
Plant height	.968**	.756**	1.000					
LAI	.950**	.467	.888**	1.000				
No. of effective tillers/ m2	.983**	.538*	.936**	.939**	1.000			
No. of filled grains /panicle	.906**	.675**	.875**	.900**	.856**	1.000		
Test weight	.658	.396	.648	.516	.681	.489	1.000	
Total weed dry weight	-.902**	-.389	-.861**	-.861**	-.950**	-.670**	-.685**	1.000

Table 3. Correlation matrix among bulb yield, no. of plants /m2, DMA, plant height, no. of leaves /plant, bulb diameter, bulb length, no. of scale /bulb, average bulb yield (10 bulb weight in g) and total weed dry weight of onion

Parameter	Bulb yield	No of plants/m2	DMA	Plant height	No. of leaves/plant	Bulb diameter	Bulb length	No. of scale/bulb	Average bulb yield (10 bulb	Total weed dry weight
Bulb yield	1.000									
No of plants/m2	.771**	1.000								
DMA	.508*	.508*	1.000							
Plant height	.799**	.535*	.194	1.000						
No. of leaves/plant	.941**	.784**	.490*	.884**	1.000					
Bulb diameter	.735**	.611**	.452	.933**	.835**	1.000				
Bulb length	.867**	.681**	.259	.944**	.950**	.945**	1.000			
No. of scale/bulb	.995**	.734**	.499*	.792**	.931**	.715**	.852**	1.000		
Average bulb yield (10 bulb weight in g)	.994**	.748	.514*	.782**	.931**	.699**	.840**	.996**	1.000	
Total weed dry weight	-.587*	-.374	-.441*	-.756**	-.640**	-.626**	-.641**	-.568*	-.570*	1.000

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

CONCLUSION

Weed density, biomass were significantly negatively correlated with growth attributes, yield components and yield of the component crops of greengram - rice - onion cropping sequence.

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Effect of tillage on weed and energy management for rice in Vertisols of central India

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Energy is one of the most important inputs in agricultural production required from land preparation to value addition. Seedbed preparation for sowing of crops consumes considerable amount of time and energy. Conventional tillage operations are energy intensive and create the problem in timely seeding of crop, besides increasing the cost of production. The green revolution made the agriculture into an energy intensive production system and present changing scenario of escalating fuel, fertilizers, and other input costs, necessitates the effective use of energy and other vital resources in crop production. Furthermore, energy input–output analysis is useful to assess the efficiency and environmental impact of production systems. Conservation agriculture is referred to be beneficial in improving crop productivity, reducing moisture deficits, breaking-up pest and disease cycles, minimizing weeds, enhancing nutrient cycling and soil fertility, improving the biodiversity of soil biota, reducing soil erosion, reduction in emission and increasing carbon sequestration. However, changes in tillage practices influence the vertical distribution of weed seeds in the soil, which may affect their relative abundance in the field (Chauhan and Johnson 2009, Chauhan and Opena 2012a). Hence, an experiment was carried out in the rice to study the weed growth, yield performance and energy input-output analysis under different tillage systems.

METHODOLOGY

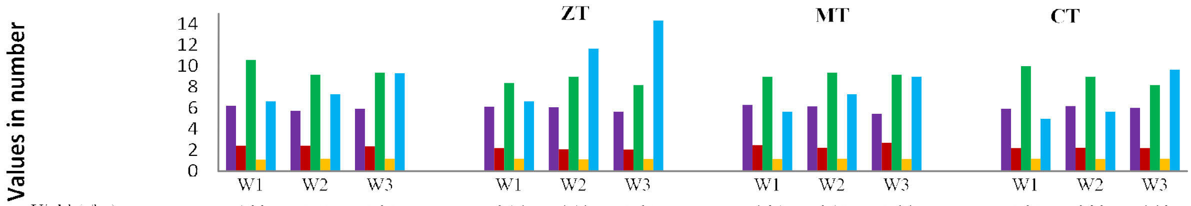
The experiment was conducted at ICAR-DWR, Jabalpur research farm during *Kharif* 2016 after the harvesting of summer greengram crop.

Tillage and weed control methods

Treatments were laid out in split plot design with the tillage, *viz.* conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and zero tillage with residue (ZT+R) as main treatments and weed control methods, *viz.* bispyribac-sodium 25 g/ha at 25 DAS + one hand weeding at 45 DAS (W1), application of bispyribac-sodium 25 g/ha as post-emergence (W2) and weedy check (W3) as sub treatments. Each main treatment was maintained a plot size of 16 x 40 m and sub-treatments with a plot size of 16 x 13 m, replicated thrice. In ZT+R treatment, threshed crop residue of greengram was applied uniformly 6 t/ha. CT involved 2 times ploughing with cultivator followed by rotavator, after which sowing was done. MT involved sowing with roto-till seed drill in a single operation. No tillage was done in ZT and ZT+R. The "*IR 6444 gold*" variety of rice was used in the treatments 8 kg/ha with DAP 60 kg/ha and Urea 120 kg/ha. Energy balance was computed using the different equivalents of agronomic practices and outputs. Energy equivalents of the machineries used for different tillage operations were calculated based on the conversion factors suggested by Kitani (1990) and Mandal *et al.* (2015).

RESULTS

Very good crop germination was observed at all the treatments unless the crop germination was affected by mustard residue in previous crop. A better crop establishment and initial growth was observed in ZT followed by ZT+R, MT and CT at initial stages. Higher number of plants per running



	W1	W2	W3	W1	W2	W3	W1	W2	W3	W1	W2	W3
Yield (t/ha)	6.23	5.75	5.95	6.16	6.10	5.67	6.31	6.17	5.46	5.95	6.20	6.03
00, no. of seeds/ panicle	2.42	2.43	2.38	2.21	2.09	2.06	2.48	2.24	2.71	2.22	2.22	2.20
No. of plant/ 1m length	10.6	9.2	9.4	8.4	9.0	8.2	9.0	9.4	9.2	10.0	9.0	8.2
Plant height (m)	1.12	1.19	1.19	1.19	1.15	1.16	1.17	1.19	1.18	1.18	1.17	1.19
No. of weeds/ m2	6.67	7.33	9.33	6.67	11.67	14.33	5.67	7.33	9.00	5.00	5.67	9.67

Fig.1. Crop establishment, growth and weed control under different tillage systems

meter length and plant height was observed in ZT+R (10.6 and 119 cm) followed by CT (10 and 119 cm), MT (9.4 and 119 cm) and ZT (9 and 119 cm). However, the number of seeds per panicle and seed yield was highest in MT (248 and 6.31 t/ha) followed closely by ZT+R (243 and 6.23 t/ha), CT (222 and 06.20 t/ha) and ZT (221 and 6.16 t/ha). Higher number of weeds was observed in ZT weedy check plot, but they were effectively controlled with herbicide application with and without manual weeding. The highest energy use efficiency was observed in ZT (9.45% and 11618.7 MJ) followed by MT (9.21% and 125583 MJ), CT (7.06% and 12472.9 MJ) and ZT+R (1.80 % and 11301.2 MJ) with respect to energy input. But the higher profit, reduction in operational time and cost, increase in soil organic carbon content and higher soil health condition was observed in ZT+R.

CONCLUSION

It was concluded that, rice cultivation as DSR under zero tillage with residue was very effective in terms of input saving, energy output and energy use efficiency with effective weed control. Crop cultivation under ZT+R also gave the benefits in terms of environmental impact.

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Weed management role in increasingcrop yield and doubling rice farmers'income in India - An analysis

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India produces 24.8% of world rice by standing first in area (43.9 million ha) and second in production (106.5 million tons) globally. Rice plays vital role in Indian food security as it is staple food for two thirds of Indians supplying 33% of food energy.Rice productivity and production are to be increased to meet the demands of increasing population. Indian rice farmers are constrained by escalating farming cost and depleting income. The rice productivity in India is low (2.4 t/ha) due to wide range of environmental conditions and ways it is grown and the biological and physical constraints that prevail. Among biological constraints weeds are major causing yield losses of 10 to 100% depending on method of rice establishment, associated weeds, cultural practices adopted, environmental and other associated factors (Rao and Nagamani 2010, Rao *et al.* 2015). Thus any effort involving improvement in food grain production to meet current and future food demands and double the farmers' income must involve rice and weed management. The objective of the present analysis is to assess weed management role in attaining higher crop production and to double the income of rice farmers in India.

METHODOLOGY

Three approaches were used for the current analysis. First is to review the published literature on economics of rice and weed management to assess the extent weed management may improve rice yield and farmers income. Second is to analyze farmer participatory demonstrations conducted in rice farmers' fields to enhance the farmers' income and improve livelihood as a part of Bhoosamrudhi program. Third is to study rice farmers' innovative experiences as case studies and disseminate them for wider usage by rice farmers for doubling their income. The experiences gained during implementation of farmers' participatory demonstrations in Bhoosamrudhi program at Raichur, Chikmagalur and Udupi districts of Karnataka are the basis for the second and third approaches analysis

RESULTS

The review of literature revealed the attainment of benefit cost ratio up to 3.4 with adoption of improved weed management technology in India, depending on the location and the method of rice establishment. The farmer participatory demonstration in Raichur district, where the farmers' rice productivity is high, the increase in crops production and doubling of income is possible by integration of integrated weed management (IWM) with improved rice varieties (IRV) (RNR 15048) use following best management practices (BMP) and crop intensification (CI). In Chikmagaluru district of Karnataka, where the rice productivity is low, increase crop production and doubling of income was observed with integration of IWM with IRV (IET 21478 and IET21479) following BMP. The observations in Udupi district revealed that crop diversification and inclusion of vegetable (brinjal, bhendi) and flower crop (Chrysanthemum) cultivation in rice paddies results in doubling of farmers' income while enabling farmer to earn at regular intervals during the period of rice crop cultivation.

CONCLUSION

It is concluded that it is possible to increase the crop production and double the income of the rice farmers. Single approach is not applicable to all the farmers. It is essential to adopt farmer specific approach that suits to farmers' available resources, economic conditions and associated environment. Integration of weed management with crops best management practices and diversification in crop rotationsis essential.Integrated rice farming systems (IRFS) approach, in which Integrated weed management (IWM) is a component, is suggested for doubling the income of the rice farmers in India.

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Weed management by different herbicide in transplanted rice

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Rice (*Oryza sativa* L.) is the staple food of more than 60% of the world population and contributing major share in the total food grain production. Generally, low rice production is due to infestation of pests, diseases, weeds management and fertility management. Weed management is one of the main factors, which affect rice yield. Controlling of different weeds cause grain yield reduction up to 76% (Yakadri *et al.* 2016). Therefore, an efficient weed management is necessary to control different types of weeds. Hand weeding though efficient is expensive, difficult and time consuming. Whereas, herbicides are very efficient weed controlling methodif applied at proper dose and stage. However, due to continuous use of single herbicide may lead to the weed resistance problem in Muktsar district of Punab. Keeping this in view, a field experiment was carriedout to evaluate the performance of different herbicides intransplanted rice.

METHODOLOGY

The experiment was conducted at the KVK, Sri Muktsar Sahib (30°.27'26" N, 74°.30'30" E) during the *Kharif* season 2016. In this experiment 6 different treatments are taken out of whichfourdifferent herbicides namely pretilachlor, butachlor, pyrazosulfuron-ethyl, oxadiargyl and one plot kept weed free and one was left unweeded. Wheat rice variety PR 121 was transplanted on 20 June. Recommended fertilizer dose of 125-31.25-30 kg NPK per hectare was applied during study period and irrigations were applied according to the requirement of the crop. The data on weed growth, yield performance were recorded.

RESULTS

All the herbicides treatments were very effective controlling the weed population. Among different grasses, the lower weed density was observed under the oxadiargyl 90 g/ha and pretilachlor 750 g/ha, butachlor 1500 g/ha, pyrazosulfuron-ethyl 15 g/ha and lower weed density among grasses was observed in weed check treatment (21.5). However, among sedges specially *cyperus rotundus*, pyrazosulfuron-ethyl recorded lower weed density (0.75) among all other herbicides and weedy check treatments. Kailkhura *et al.* (2015) also find the similar results. Similarly, total weed dry matter was lower under pretilachlor 750 g/ha (5.35/m^2) followed by oxadiargyl 90 g/ha (5.65/m^2), butachlor 1500 g/ha (7.25/m^2), pyrazosulfuron-ethyl 15 g/ha (7.58/m^2) and higher weed density was recorded with weedy check.Similarly the weed control efficiency was also higher under pretilachlor (59.0%), oxadiargyl (56.70%), butachlor (44.44%) and lower weed control efficiency under pyrazosulfuron-ethyl (41.95%). Higher grain yield was recorded with weed free treatment (7.30 t/ha) which was 18.7% higher over the control treatment (6.15 t/ha). Among different herbicides treatment the higher grain yield was recorded with application of the butachlor 1500 g/ha (7.05 t/ha) followed by pyrazosulfuron-ethyl 15 g/ha (6.95 t/ha) followed by pretilachlor 750 g/ha and oxadiargyl 90 g/ha (6.85 t/ha). Similar results were recorded by Hossain and Mondal (2014), where grain yield was higher by applying different herbicides from control treatment. As we considered about the Benefit cost ratio, herbicides pyrazosulfuron-ethyl (2.04:1) and butachlor (2.03:1) gave higher B:C ratio followed by oxadiargyl (1.97:1) and pretilachlor (1.96:1). Lower B:C was obtained with weedy check (1.72:1) and weed free (1.91:1).

Table 1. Weed growth, yield and economics of rice as influenced by different herbicides

Treatment	Weed density (no./m^2)		Weed dry matter (g/m^2)		Total weed dry matter (g/m^2)	Weed control efficiency (%)	Grain yield (t/ha)	Gross return (Rs./ha)	Net return (Rs./ha)	B:C Ratio
	Grasses	Sedge	Grasses	Sedge						
Pretilachlor 750 g/ha	9.5	5.5	3.98	1.38	5.35	59.00	6.85	103435	68515	1.96:1
Butachlor 1500 g/ha	12.25	5.5	6.28	0.98	7.25	44.44	7.05	106455	71355	2.03:1
Pyrazosulfuron-ethyl 15 g/ha	17.75	0.75	7.38	0.20	7.58	41.95	6.95	104945	70370	2.04:1
Oxadiargyl 90 g/ha	9.5	7.5	4.13	1.53	5.65	56.70	6.85	103435	68585	1.97:1
Weedy check	21.5	10	10.68	2.38	13.05	-	6.15	92865	58665	1.72:1
Weed free	-	-	-	-	-	-	7.3	110230	72405	1.91:1

CONCLUSION

It was conclude that the herbicide oxadiargyl, pretilachlor and butachlor are very effective against grasses. Whereas pyrazosulfuron-ethyl is very effective against sedges among all other herbicides treatments in Muktsar district of Punjab.

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Weed management in rice-brahmi intercropping system in *tarai* area

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Rice-wheat cropping system is one of the major dominating agricultural systems in India (Singh *et al.* 2014). Weed infestation, however continues to be a major bottleneck in direct (dry) seeded rice because of simultaneous emergence of rice and weeds either in upland or in lowland situation. Weed management in intercropping has hardly been studied to date (Hong *et al.* 2004). Intercropping with cover crop can suppress the growth of weeds more than sole cropping in early stages of crop to suppress weed growth. Thus, research has to be directed towards inclusion of medicinal and aromatic crops (MACs) in existing cropping systems such as intercrops, crop rotation, under crops, *etc*. Considering these facts, two row combinations are taken along with different weed management practices in rice-brahmi to find out the feasible and profitable intercropping system.

METHODOLOGY

A field study on direct (dry) seeded rice-brahmi intercropping system was conducted during *Kharif* 2015 and 2016 at N.E.B. Crop Research centre, Pantnagar in RBD consisting 10 treatments with 3 replications with two ratios *i.e.* 2:1 and 1:1 of rice and brahmi and sole crop of both the crop along with combination of three weed management practices *i.e.* application of pendimethalin 1 kg/ha supplemented with two hand weeding at 30 and 45 days after sowing (DAS), pendimethalin at 1 kg/ha alone and pendimethalin at 1 kg/ha *fb* cyhalofop-butyl 100 g/ha supplemented with one hand weeding at 30 DAS and weedy (Table 1).

RESULTS

The major weed flora at 60 DAS were *E. colona*, *E. cruss-galli*, *A. sessillis*, *C. axillaris*, *C. rotundus* and *C. iria* recorded in the experimental plot. At 60 DAS, the total density as well as total dry biomass of weeds was influenced significantly by the weed control treatments over the weedy situation during both the years. Amongst both ratios (1:1 and 2:1) of DSR and brahmi, the application of pendimethalin at 1000 g/ha applied as pre-emergence *fb* cyhalofop-butyl at 100 g/ha as post-emergence supplemented with 1 HW at 45 days after sowing/planting was found superior than other weed control treatments (Table 1). Highest grain and straw yield of rice in 2:1 ratio was recorded with the sequential application of pendimethalin 1000 g/ha *fb* cyhalofop-butyl at 100 g/ha along with 1 HW at 45 DAS. Brahmi herbage yield was found maximum in sole crop of brahmi. Highest net returns and benefit cost ratio was found in sole brahmi *fb* sole crop of DSR in which pendimethalin was applied as pre *fb* cyhalofop-butyl as post along with 1 HW at 45 DAS.

Table 1. Effect of weed control treatments on total weed density and dry weight, WCE (%) and yield of rice and brahmi intercropping system

Treatment	Total weed dry weight (g/m^2)		Weed control efficiency (%)		Rice grain yield (t/ha)		Brahmi herbage yield (t/ha)		Net returns (`/ha)
	2015	2016	2015	2016	2015	2016	2015	2016	
1:1Pendi (PE)	17.11 (4.25)	14.91 (3.99)	23.95	38.23	3.2	3.8	3.40	3.20	395265
1:1 Pendi (PE) + 2 HW (30 and 45 DAS)	12.00 (3.60)	9.26 (3.20)	46.66	61.64	3.61	5.1	5.10	3.56	562045
1:1 Pendi (PE) + Cyhalo (PoE) +1 HW (45 DAS)	8.80 (3.13)	6.60 (2.75)	60.90	72.65	4.19	6.2	5.42	3.80	595323
1:1 Weedy	22.50 (4.85)	24.14 (5.01)	0.00	0.00	0.00	0.00	0.74	0.14	40400
2:1Pendi (PE)	10.80 (3.43)	11.33 (3.51)	60.86	52.83	3.90	3.6	2.31	2.40	293440
2:1 Pendi (PE) + 2 HW (30 and 45 DAS)	10.95 (3.45)	7.27 (2.87)	60.32	69.75	4.30	4.8	3.81	3.00	439135
2:1 Pendi (PE) + Cyhalo (PoE) +1 HW (45 DAS)	7.35 (2.99)	3.97 (2.23)	73.36	83.45	4.81	5.7	4.22	3.20	483260
2:1 Weedy	27.60 (5.35)	24.01 (5.00)	0.00	0.00	0.30	0.00	0.80	0.20	57610
Sole rice Pendi (PE) + Cyhalo (PoE) +1 HW (45 DAS)	8.26 (3.04)	5.27 (2.50)	63.30	77.91	5.30	6.56	0.00	0.00	64860
Sole brahmi (30, 45 and 60 DAS)	10.76 (3.43)	8.20 (3.03)	52.20	65.83	0.00	0.00	4.25	3.34	717000
LSD (P=0.05)	0.082	0.042	1.84	3.25	0.24	0.78	0.18	0.024	-

PE-Pre-emergence, PoE-Post-emergence, Pendi-Pendimethalin, Cyhalo-Cyhalofop-butyl, HW-Hand weeding

CONCLUSION

It was concluded that 2:1 ratio of rice and brahmi with weed management by application of pendimethalin as pre 1000 g/ha fb cyhalofop-butyl applied as post 100 g/ha supplemented with 1HW at 45 DAS/DAP was the most effective practices for controlling weeds and gave maximum grain yield and 1:1 recorded highest brahmi herbage yield**.**

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Effect of weed management practices on yield and economics of direct-seeded rice in South-Western parts of Punjab

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Rice is the staple food crop and essential for the food security and livelihoods of the millions of South Asia people (Timsina and Connor 2001). Both Punjab and Haryana contributes about 69% into the total food procured by the Government of India (about 54% of the rice and 84% of the wheat) (Singh *et al.* 2003). Traditionally rice is grown as puddle transplanted (PTR) *i.e.* soil is puddled and kept under continuous submergence which consumes lot of water and energy. Therefore, direct seeded rice (DSR) is promoted as an alternative to PTR. DSR reported to requires less water without any significant reduction in yields. In DSR, iron and weed infestation are the main constraints. DSR fields are more species-rich with greater diversity in weed flora than PTR fields due to simultaneous germination of weeds with rice in absence of standing water to suppress weed growth (Chauhan and Johnson 2010). The yield losses due to weed interference are enormous and can go up to 90%. Keeping these factors in view, an experiment was conducted at KVK Ferozepur with an objective to study the effect of different herbicides on weed biomass, yield and economics of DSR.

METHODOLOGY

An experiment was conducted at KVK Ferozepur (Lat. 30Ú54'33 and Long. 74Ú39'50) during kharif season of 2015. The different herbicides were taken as T_1-pendamethalin *fb* hand weeding, T_2-pendamethalin 2.5 l/ha *fb* bispyribac 250ml/ha, T3-bispyribac, T4-oxadiargyl *fb* bispyribac, T5-unweeded control and replicated thrice. The short duration rice variety PR 115 was taken and after fine seedbed preparation seeding was done on 10th June 2015. For optimum plant density 20 kg/ha seed rate was used. Nutrient recommendations for DSR are identical to PTR for rice cultivars. Nutrients dose of 130 kg N/ha, 30 kg K/ha and 40 kg zinc sulphate/ha were applied as per standard procedure. The grain yield and weed biomass observations were recorded.

RESULT

Application of various herbicides significantly influenced the weed density and yield of direct seeded rice. Pendamethalin application as pre-emergence (PE) along with bispyribac as post-emergence (POE) recorded the lowest weed density followed by oxadiargyl *fb* bispyribac. Application of pendamethalin *fb* bispyribac gave the highest yield and net returns which found at par with oxadiargyl *fb* bispyribac and pendamethalin *fb* hand weeding.

Table 1. Effect of different herbicides on yield and economics of direct-seeded rice

Treatment	Weed Density at 60 DAS (no/m^2)	Weed Density at harvest (no/m^2)	Yield (t/ha)	Gross returns (Rs/ha)	Net Returns (Rs/ha)	B:C Ratio
Pendamethalin *fb* HW	5.15	5.11	5.9	83190	44315	1.14:1
Pendamethalin *fb* bispyribac	4.32	4.40	6.2	87420	51295	1.42:1
Bispyribac	6.12	6.31	4.9	69090	29340	0.74:1
oxadiargyl *fb* bispyribac	5.07	4.83	5.6	78960	43085	1.20:1
Unweeded control	22.61	21.13	3.4	47940	14400	0.43:1
LSD (P=0.05)			0.64			

CONCLUSION

It was concluded that weed biomass in DSR was low with the pre-emergence application of pendamethalin followed by post-emergence application of bispyribac. The high productivity and net return was also observed in this treatment. This could be an effective strategy to manage weed infestation in DSR.

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Effect of weed management practices on yield and economics of soybean

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Soybean [*Glycine max* (L.) Merill] popular as golden bean has become the miracle crop of 21st century. It is an excellent source of protein (40-45%) and oil (18-22%) besides it contains high level of amino acids such as lysine, leucine, lecithin and large amount of phosphorus. Successful weed control is the most important factor for fruitful soybean production, because losses due to weeds have been one of the major limiting factors in soybean production. Weeds compete with crop for light, moisture and nutrients, with early-season competition being the most critical. The grain yield reduction due to the weed infestation in soybean may be up to 35- 80% (Gupta *et al.* 2006). Weed flush come at same time in almost all the *Kharif* crops, which also restrict the availability of manpower for weeding operation in this crop. The untimely and poor weed management adversely affects proper growth and yield of soybean. Hence, the emphasis should be given to adopt chemical methods of weed control to solve the problem of minimum available labours and their high cost. In this view the present investigation was conducted to find out the best suitable combination of different herbicides to control weeds in soybean with lower cost and higher grain yield.

METHODOLOGY

A field experiment was carried out at instructional farm of Rajasthan College of Agriculture, Udaipur during *Kharif*, 2014. The experimental soil was clay loam, alkaline, medium in nitrogen and phosphorus and high in potassium. The experiment was carried out in randomized block design (RBD) with 14 treatments, *viz.* weedy check, pendimethalin 0.75 kg/ha pre-emergence and in combination with hand weeding 30 DAS, metribuzin 0.75 kg/ha pre-emergence and in combination with hand weeding 30 DAS, fenoxaprop-p-ethyl 0.075 kg/ha, imazethapyr 0.1 kg/ha, sequential application of pendimethalin and metribuzin with fenoxaprop-p-ethyl and imazethapyr, one hand weeding 20 DAS, two hand weeding 15 and 30 DAS and weed free up to 50 days stage of crop and these treatments replicated thrice. Soybean variety JS-9560 was sown at 30 cm row spacing using 80 kg seed/ha. Sowing of experiment was done on 16th July 2014 and crop was sown by using package of practices of south-east Rajasthan. Evaluation of treatments was done following standard procedures.

RESULTS

All weed control treatments significantly enhanced seed yield over weedy check. The maximum seed yield (1.42 kg/ha) was recorded under weed free check and found statistically at par with pre-emergence application of pendimethalin + hand weeding treatment (1.38 kg/ha). The per cent increse in seed yield due to weed free and pre-emergence application of pendimethalin 750 g/ha + hand weeding 30 DAS was 172.74 and 164.11 respectively, over weedy check. The increased seed yield was obviously the results of better weed control as evinced from weed dry matter recorded at 75 DAS at physiological maturity which in turn increase the availability of nutrient, moisture, light and other factor to the crop plant. The highest net returns (₹ 29508/ha) and BC ratio (2.38) were obtained under pre-emergence application of pendimethalin + hand weeding 30 DAS followed by two hand weeding 15 and 30 DAS with net return of 27244/ha and BC ratio of 2.26. The low investment coupled with good economic yield might be the reason for higher net monetary returns and BC ratio under this treatment.

Table 1. Effect of weed management practices on productivity and economics of soybean

Treatment	Seed yield (t/ha)	Weed dry matter (t/ha)	Net returns (`/ha)	B-C ratio
Pendimethalin 750 g/ha POE	0.91	0.81	15113	1.80
Metribuzin 350 g/ha POE	0.83	0.78	12518	1.68
Fenoxaprop-p-ethyl 75 g/ha POE	1.00	0.76	18078	1.94
Imazethapyr 100 g/ha POE	1.04	0.72	19265	1.98
Pendimethalin + HW 30 DAS	1.38	0.43	29508	2.38
Metribuzin 350 g/ha + HW 30 DAS	1.13	0.54	21019	2.00
Pendimethalin 750 g/ha+ fenoxaprop-p-ethyl POE	1.18	0.57	23267	2.12
Pendimethalin 750 g/ha + imazethapyr POE	1.23	0.50	24705	2.17
Metribuzin 350 g/ha + fenoxaprop-p-ethyl POE	1.13	0.56	21638	2.06
Metribuzin 350 g/ha + imazethapyr POE	1.18	0.56	23426	2.13
One hand weeding at 20 DAS	1.12	0.63	21507	2.08
Two hand weeding 15 and 30 DAS	1.32	0.47	27244	2.26
Weedy check	0.52	1.88	2344	1.13
Weed free	1.42	0.15	26749	2.04
LSD (P=0.05)	0.21	0.11	-	-

CONCLUSION

It is concluded that pre-emergence application of pendimethalin 0.750 kg/ha along with hand weeding 30 DAS recorded the seed yield of 1.38 t/ha at par with two hand weeding (1.32 t/ha) as well as weed free treatment (1.42 t/ha). This treatment also recorded the maximum net return (29508) as well as BC ratio (2.38) compared to rest of the treatments.

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Improving rainfed cotton productivity and double income through integrated weed management under high density planting system grown on broad bed furrow

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A system of high density planting (HDP) leading to more rapid canopy closure and decreased soil water evaporation. In many countries, narrow row planting have been adopted after showing improvement in cotton productivity. The adoption of high density planting (accomodation of more plants per unit area) along with better genotype with good fertilizer, early weed and boll worm management is one of the option under rainfed to break the current trend of stagnating yield of Bt cotton around 550 lint kg/ha in India and 325 lint kg/ha in Vidarbha region of Maharashtra. Cotton (*Gossypium hirsutum* L.) is a very important commercial crop of India, it sustains the cotton textile industry which is perhaps the largest segment of organized industries in the country. The critical period of weed competition in cotton was found to be 15 to 60 days (Kakade 1996). To be successful, weed management systems require advance planting and timely execution. Any delay in an application may mean reduced control, higher herbicide use rates and herbicide costs. Hence, the study was carried out to find out suitable herbicides either alone or in sequence or in combination with cultural practices for proper and timely control of weeds.

METHODOLOGY

The field trials were conducted for development of Agro techniques for high density planting system under TMC 1.4 project at Dr. PDKV Akola under medium depth soils during 2013-14 to 2015-16. Integrated weed management under HDPS was tested with eight treatments with pre- (pendimethalin 38.7 CS PE) and post-emergence herbicides (quizalofop-ethyl 5 EC, pyrithiobac sodium 10 EC and glyphosate 71 G) with combinations of cultural practices including weed free and weedy check. Pre-emergence herbicide applied as on 1st day after sowing and post- emergence herbicides applied on 20-25 DAS after sowing of cotton seed, weed number per m^2 was counted Weed control efficiency was calculated. Growth, SCY and economics were worked out.

RESULTS

Integrated weed management under HDPS was tested with pre- and post-emergence herbicides with combinations of cultural practices. Dominant weed flora was *Commelina benghalensis*, *Cynodon dactylon, Cyperus rotundus* among the monocot species and in dicots, *Euphorbia geniculata*, *Euphorbia geniculata, Parthenium hysterophorus Celosia argentea* and *Digera arvensis* during experimentation. The highest WCE was observed with weed free check (83%) and 87% under HDPS followed by weed control efficiency was maximum with PE pendimethalin (81%) and 77% at 60 DAS glyphosate was found third rank but some phytotoxic effect was noticed in HDP cotton leaves. This year there was a dry spell about 28 days in HDP cotton sown on BBF. Moisture conservation was due to cotton sown on broad bed furrows which improved the growth and SCY. Pre-emergence application of pendimethaline 38.7 CS PE 1.25 kg/ha (3.3 L in 700 L water) *fb* hoeing at 30 DAS and one hand weeding at 45 DAS was seems to be best option to reduce the early weed competition in HDP cotton. The plant height, boll numbers, boll weight and dry weight per plant was significantly higher in weed free plot over weed free check followed by spraying of PE pendimethalin *fob* Hoeing + weeding and Glyphosate treatments. The seed cotton yield was significantly highest with weed free plot followed by spraying of PE pendimethalin *fb* Hoeing at 30 DAS + weeding at 45 DAS. The significantly highest gross and net returns with weed free check, which is at par with pendimethalin 38.7 CS PE 1.25 kg/ha *fb* hoeing at 30 DAS and one hand weeding at 45 DAS.

Table 1. WCE, growth, yield and economics as influenced by various weed management practices under HDPS cotton grown on broad bed furrow

Treatment	Weed control efficiency (%) At 60 DAS	Plant height (cm)	Boll No/ plant	Boll weight (g)	Dry Weight/ plant (g)	SCY (kg/ha)	Lint Yield (kg/ha)	Gross returns (Rs/ha)	Net Returns (Rs/ha)
Pendimethalin PE 1.25 kg/ha *fb* hoeing at 30 DAS and one hand weeding at 45 DAS	81.05	68.95	5.12	2.51	50.87	1866	700	72774	38664
Quizalofop-ethyl 0.075 kg/ha POE 20-25 DAS (2-4 leaf weed stage) *fb* hoeing at 45 DAS	62.11	58.68	4.41	2.27	39.47	1415	518	55198	26441
Pyrithiobac sodium 0.075 kg/ha POE 20-25 DAS (2-4 leaf weed stage) *fb* hoeing at 45 DAS	62.52	59.50	4.45	2.22	40.29	1405	516	54808	25001
Pendimethalin PE 1.25 kg/ha *fb* quizalofop-ethyl 5 EC 0.060 kg/ha + pyrithiobac-sodium 0.062 kg/ha POE (tank mix) (2-4 leaf weed stage)	65.07	61.46	4.92	2.40	41.42	1520	561	59280	27600
Hoeing at 20-25 DAS *fb* Glyphosate 71G 1.50 kg/ha as directed spray at 45 DAS	73.97	63.11	4.70	2.46	41.58	1643	596	64064	35271
Hoeing at 20-25 DAS *fb* Glyphosate 71G 0.5 kg/ha as directed spray at 45 DAS	60.30	59.13	4.31	2.39	40.43	1523	551	59410	31513
Weed free check (2 Weeding *fb* 2 hoeing)	83.20	72.08	5.57	2.55	52.73	2011	748	78442	38305
Weedy check	0.00	44.87	1.30	2.15	25.87	455	168	17732	-3121
LSD(P=0.05)	-	8.93	0.55	0.31	7.50	253	91	9876	8610

CONCLUSIÓN

Pre-emergence application of pendimethalin 38.7 CS PE 1.25 kg/ha *fb* hoeing at 30 DAS and hand weeding at 45 DAS was found effective weed control under high density planting of cotton.

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Impact of conservation agriculture in improving the income of farmers of Madhya Pradesh

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In central India, commercialization of conservation agriculture (CA) is speeding up now a day. It aims the better use of farm resources through integrated management techniques (FAO 2001). The practices are designed to achieve the environmental conservation and sustainability of agricultural production (Sharma and Singh 2014). In the light of this situation, the study was conducted to analyse the economics of direct seeded rice crop under conservation agriculture that spur farmers to adopt CA practices.

METHODOLOGY

ICAR- Directorate of Weed Research, Jabalpur took initiative to introduce happy seeder machine to demonstrate the CA technology among farming community of Jabalpur region for sowing of direct seeded rice, wheat and green gram for the first time under on-farm research cum demonstration programme during 2012-13. Therefore, the study was conducted in Jabalpur district of Madhya Pradesh. Seventy respondents of the district were selected randomly for analysing the impact of conservation agricultural practices. The study was based on primary data and secondary data pertains to the year 2010-11 (before) and 2013-14 (after). Primary data was collected through pretested questionnaire by personal visits and secondary data was collected from Directorate of Economics and Statistics, Govt. of India.

RESULTS

The results revealed that the rice crop under conservation agriculture was less labour intensive. The labour cost was almost decreased by 70 per cent. Among material cost, the cost required for seed was decreased than earlier. Under conservation agriculture practice respondents were treated seed before the sowing time. The cost required for plant protection during CA was 23.4 percent of total operational cost, but in traditional practices it was almost 30 % of it. Specially the cost required for weed control was decreased by 53.6 per cent. The yield of direct seeded rice crop was also increased by 22.6 % under CA practices and the impact of conservation agriculture was also observed in terms of higher B:C ratio of the crop (18.34%).

Table 1. Cost of cultivation of rice crop

Sr. No.	Operation	Average Cost (Rs/ha)	
		Before	After
I	Labour cost	4087.50	1259.82
II	Material Cost		
	Seed	2547.02	2123.72
	Seed treatment	--	322.45
	Irrigation	3679.23	5057.79
	Fertilizers	2081.35	3850.09
	Plant Protection		
	i. Weed control	5090.87	2357.73
	ii. Insect control	926.25	1454.53
	iii. Disease control	487.13	811.81
	Harvesting and Threshing	2701.11	2462.49
III	Total Operational cost (I + II)	21600.46	19700.43
IV	Total Fixed Cost*	4399.77	15622.23
V	Sub Total (III+ IV) (Cost C2)	26000.23	35322.66
	Managerial cost @ 10 %	2600.02	3532.26
VI	Total cost (Cost C3)	28600.25	38854.92
	Yield (Qtl./ha)	31.42	38.55
	Price (Rs/Qtl)*	1000.00	1310.00
	Gross Income	31420.00	50500.5
	B:C Ratio	1.09 : 1	1.29 : 1

***Source: Directorate of Economics and Statistics

CONCLUSION

The study revealed that, conservation agriculture-based crop management systems are gradually undergoing a paradigm shift from intensive tillage to reduced/zero tillage (ZT) operations as a result of the success and benefit of ZT. The adoption of CA offers avenues for much needed diversification of agriculture, thus expanding the opportunity for cultivation of different crops during different seasons in a year. Previously rice cultivation was substantial for farmers but at present farmers can earn more income through rice cultivation. It is proving to be a beneficial practice and helps in earning more income to the farmers with little change in package of practices.

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Response of different fertility levels and weed management practices on weed growth, productivity and economics of *Rabi* maize

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Maize is one of the most important cereal crops of the world. The average composition of maize grain contains 70% carbohydrates, 10% protein, 4% oil, 2.3% crude fiber, 10.4% albuminoides, and 1.4% ash. It is well known fact that weeds cause severe losses to yield varies from 52 to 70% depending on the type of weed flora and their intensity. Gupta (2012) reported that the nutrient removal by weeds during the first thirty days of maize growth was 59 kg N, 10 kg P and 59 kg K per ha, which was 7-10 times more than the nutrient removal by the crop.

METHODOLOGY

The field experiment was conducted at B.A. College, Agronomy Farm, Anand Agricultural University, Anand (Gujarat) during winter season of 2012-13. Fifteen treatments consisting of three fertility levels and five weed management practices were replicated four times and laid out in Factorial Randomized Block Design. Fertilizers were applied uniformly through urea and DAP 120 kg N, 60 kg P_2O_5 and 0 kg K_2O/ha at different levels. Maize variety 'HQPM-1' was sown at spacing of 60 x 20 cm on 19th November 2012.

RESULTS

Application of 125% RDF increased grain and stover yields to the tune of 15.45% and 10.51%, respectively over 75% RDF, which was at pat with 100% RDF. Interculturing with hand weeding increased grain and stover yields by 57.25% and 27.54% over un-weeded check, which was at par with combination of atrazine and pendimethalin and both of these treatments were found significantly superior with respect to grain and stover yields over rest of the treatments.

Results of the experiment revealed that fertility levels did not exert any significant effect on weed density. Minimum total weed density was recorded with interculturing with hand weeding followed by combination of atrazine and pendimethalin. 125% RDF gave higher total weed dry matter as compared to other treatments. Amongst weed management practices, the lowest total weed dry weight was registered with interculturing with hand weedings followed by combination of atrazine and pendimethalin. These treatments gave the highest weed control efficiency 88.66% and 75.72% at harvest, respectively. Combined application of atrazine and pendimethalin gave minimum weed index 4.79%. Results corroborate with the findings Barod *et al.* (2012).

Maximum net return Rs. 57509/ ha was obtained under 125% RDF, whereas maximum B:C ratio 3.30 was obtained under 100% RDF. Interculturing with hand weeding gave highest net return of Rs. 68587/ha, however maximum B:C ratio 4.48 was obtained under combination of atrazine and pendimethalin.

Table 1. Effect of fertility levels and weed management practices on weed parameters, yield and economics of maize

Treatment	Weed density (no./m) at 25 DAS	Weed density (no./m) at 50 DAS	Weed dry weight (g/m) At harvest	Weed index (%)	Weed control efficiency (%) at harvest	Grain yield (t/ha)	Stover yield (t/ha)	Net return (Rs./ha)	B: C ratio
Fertility Levels									
75% RDF	6.30 (53.64)	7.66 (69.67)	7.93 (73.78)	-	-	4.15	7.03	49626	3.20
100% RDF	6.44 (55.77)	7.18 (63.91)	8.42 (82.18)	-	-	4.55	7.50	54810	3.30
125% RDF	6.00 (50.26)	7.75 (66.81)	9.15 (96.21)	-	-	4.79	7.77	57509	3.29
LSD (P =0.05)	NS	NS	0.80	-	-	0.26	0.41	-	-
Weed management practices									
Atrazine 1.0 kg/ha	6.03 (36.72)	6.79 (46.90)	7.78 (60.47)	8.98	67.53	4.69	7.53	61873	4.28
Pendimethalin 0.5 kg/ha	6.72 (44.84)	7.49 (56.00)	9.26 (89.24)	14.38	55.29	4.42	7.32	57507	4.03
Atrazine 0.5 kg/ha + pendimethalin 0.25 kg/ha	5.24 (27.20)	5.93 (35.33)	6.65 (44.32)	4.79	75.72	4.91	7.91	65707	4.48
IC + HW at 20 and 40 DAS	0.71 (0.00)	4.12 (16.74)	4.55 (20.59)	-	88.66	5.18	8.08	68587	4.41
Un-weeded check	12.54 (157.34)	13.34 (179.01)	14.25 (205.67)	35.95	-	3.29	6.33	40903	3.29
LSD (P = 0.05)	0.51	0.73	1.03	-	-	0.33	0.53	-	-

*Figures in the parenthesis are original values. All Figures are subjected to transformed values to square root $\sqrt{x+0.5}$

CONCLUSION

It could be concluded that for achieving higher yield and better weed control, maize should be fertilized with 100% RDF and weed management by interculturing with hand weeding or combination of atrazine and pendimethalin.

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Effect of weed and nutrient management on weeds and productivity of quality protein maize

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Maize is one of the most important cereal crops after wheat and rice in the world and a principal staple food in many countries, particularly in the tropics and sub-tropics. Weeds are the major deterrent to the development of sustainable crop production. They dictate most of the crop production practices and cause enormous losses (37%) due to their interference (Verma *et al*. 2015). It is well known that weeds are ubiquitous but their presence in cropped area particularly in rainy season crops like maize act as major limiting factor in plentiful harvest. Inadequate weed control is one of the main factors related to decrease in maize production. There is no specific recommendation for nutrient management is available for QPM therefore, it necessitated to formulated an experiment to find out the appropriate weed and nutrient management for this crop.

METHODOLOGY

A field experiment was carried out at Instructional farm of the Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur during *Kharif* 2011 and 2012. The experiment was laid out in Split Plot design with combinations of 6 weed management practices (weedy check, atrazine 0.5 kg/ha pre-emergence + hoeing and weeding 30 DAS, metribuzin 0.25 kg/ha pre-emergence + hoeing and weeding 30 DAS, oxyfluorfen 0.15 kg/ha pre-emergence + hoeing and weeding 30 DAS, two hoeing and weeding 15 and 30 DAS and weed free) and 4 fertility levels (75, 100, 125 and 150 % RDF) with 3 replications. The recommended dose of nitrogen and phosphorus was used as 120 and 40 kg/ha, respectively. The maize variety "HQPM-5" was sown at a spacing of 60 cm x 25 cm between rows and plants.

RSEULTS

The weed density and dry matter at 50 DAS tended to reduce significantly with all weed management treatments compared to weedy check. Weed free recorded minimum weed density and dry matter which was significantly superior over rest of the treatments. After weed free treatment the minimum weed dry matter of broad and narrow leaved weeds at 50 DAS was recorded under oxyfluorfen and this treatment reduced the parameter by 89.79 and 78.33%, respectively compared to weedy check (85.65 g/m^2 and 353.27 g/m^2). This might be due to the fact that pre-emergence application of oxyfluorfen controlled early flushes of weeds, while hoeing and weeding at 30 DAS destroyed late flushes of weeds. Hence, crop remained free of weeds for comparatively longer duration in general and during critical period of crop-weed competition in particular. Amongst nutrient management maximum weed dry matter was recorded fewer than 150% RDF but it was found statistically at par with 125% RDF during both the years and on pooled basis. On pooled basis the % increase in total weed dry matter owing to 125% RDF was 17.32 compared to 75% RDF. Though, application of fertilizers do not interfere in germinability of weed seeds but increasing rate of fertility levels certainly provides greater amount of nutrients to weeds which might have resulted in higher dry matter accumulation by them. Application of oxyfluorfen *fb* HW 30 DAS was found significantly superior in enhancing grain yield of maize compared to weedy check, atrazine *fb* HW 30 as well as HW 15 and 30 DAS. The pooled results showed 174.55 and 163.58% increase in grain yield owing to weed free, oxyfluorfen *fb* HW 30 DAS, respectively compared to weedy check. The better expression of yield in herbicide in combination with manually weeded plots might be due to poor resurgence frequency and growth of weeds. Hence, weeds were unable to compete with the crop plants for different growth factors. During two years of experimentation, the grain yield of maize increased with increasing fertility levels up to 125% RDF and further increase in fertility levels failed to enhance the yield significantly. On pooled basis, the per cent increase in grain yield under the influence of 150, 125 and 100% RDF was 3.60, 16.13 and 18.99 compared to their preceding counter parts. It was well emphasized that N and P fertilization plays vital role in different metabolic activities and in improving nutritional status of plant in both vegetative and reproductive parts. These improvements suggest greater availability of metabolites and nutrients synchronized with demand for growth and development of each reproductive structure.

Table 1. Effect of weed and nutrient management on weeds and productivity of quality protein maize

Treatment	Weed count/m^2*			Weed dry matter (g/m^2) at 50 DAS			Grain yield (t/ha)
	Total broad-leaved weeds	Total narrow leaved weeds	Total weeds	Total broad leaved weeds	Total narrow leaved weeds	Total weeds	
Weed management							
Weedy check	11.58 (133.52)	13.14 (172.24)	17.49 (305.46)	9.28 (85.65)	18.81 (353.27)	20.96 (438.91)	1.40
Atrazine *fb* HW 30 DAS	6.76 (45.21)	8.95 (79.64)	11.19 (124.78)	4.69 (21.50)	11.20 (124.97)	12.13 (146.53)	3.09
Metribuzin *fb* HW 30 DAS	4.71 (21.69)	5.94 (34.80)	7.55(56.48)	3.57 (12.21)	9.83 (96.16)	10.44 (108.41)	3.55
Oxyfluorfen *fb* HW 30 DAS	3.08 (8.96)	3.88 (14.56)	4.92(23.75)	3.04 (8.74)	8.78 (76.54)	9.26 (85.28)	3.7
HW15 and 30 DAS	6.90 (47.12)	9.03 (80.99)	11.34 (128.05)	6.10 (36.72)	11.06 (121.85)	12.61 (158.52)	2.94
Weed free	0.71 (0.00)	0.71 (0.00)	0.71(0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	3.85
LSD (P=0.05)	0.60	0.69	0.93	0.45	0.85	0.87	0.19
Nutrient management							
75% RDF	5.38 (28.44)	6.69 (44.19)	8.45 (70.90)	4.15 (16.68)	9.41 (87.95)	9.91 (97.61)	2.47
100% RDF	5.62 (31.03)	6.94 (47.59)	8.81 (77.12)	4.54 (20.11)	10.04 (100.30)	10.82 (116.57)	2.94
125% RDF	5.72 (32.22)	7.06 (49.27)	8.99 (80.32)	4.74 (21.97)	10.33 (106.21)	11.61 (134.18)	3.41
150% RDF	5.78 (32.85)	7.10 (49.84)	9.22 (84.51)	4.84 (22.88)	10.49 (109.44)	11.74 (137.33)	3.54
LSD (P=0.05)	NS	NS	NS	0.44	0.65	0.57	0.13

*Data subjected to $\sqrt{X+0.5}$ transformation and figures in parenthesis are original values m^{-2}

CONCLUSION

It may be concluded that in medium fertility clay loam soils, pre-emergence application of 0.15 kg/ha oxyfluorfen along with hoeing and weeding at 30 days stage of crop should be followed in maize for broad spectrum control of weeds along with harnessing the maximum maize grain yield. As far as nutrient management in maize is concerned 125% RDF through fertilizer should be applied for maximization of maize grain yield.

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Effect of different weed management practices on yield and economics of aerobic rice

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Rice is the staple food crop of India, where it is grown in an area of 43.95 million ha with a total production of 106.54 million tonnes and with an average productivity of 2.42 t/ha. Uttar Pradesh ranks 2nd in total rice production is 14.41 million tonnes (Anonymous 2013).

Aerobic rice systems are subject to greater weed pressure than conventional production systems. In traditional irrigated lowland rice systems, rice has a 2-3 week 'head start' over weeds, which favours rice in competition against weeds that have not emerged yet at transplanting, and the water layer after transplanting effectively suppresses the emergence and growth of most weed flora, including upland and semi-aquatic weeds. The lack of 'head start' and the absence of floodwater make aerobic and upland rice more weed-infested than irrigated lowland rice (De Datta and Llagas 1984). A number of herbicides has been developed for weed control in aerobic rice. Though none of the herbicide can be used alone for definite and economic control of wide spectrum of weeds in rice.

METHODOLOGY

A field experiment was carried out during *Kharif* season of 2014 at the Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India). The experiment was laid out in Randomized Block Design with eleven treatment combination and replicated three times. Rice variety: HUR-3022 was line sown at the row spacing of 20 cm with 35 kg seeds per ha on 19th July 2014.

RESULTS

The data clearly indicated that the maximum gross return was obtained from need based hand weeding (T$_{10}$) (₹ 69090), followed by pendimethalin 1.00 kg/ha at 3-4 DAS *fb* bispyribac-Na 35 g/ha at 15-20 DAS (T$_1$) (₹ 68706). The data showed that the maximum net return was obtained from pendimethalin 1.00 kg/ha at 3-4 DAS *fb* bispyribac-Na 35 g/ha at 15-20 DAS (T$_1$) (₹ 42050.7). The highest B: C ratio was obtained from pendimethalin 1.00 kg/ha at 3-4 DAS *fb* bispyribac-Na 35 g/ha at 15-20 DAS (T$_1$) (1.57). The better response of pendimethalin 1.00 kg/ha at 3-4 DAS *fb* bispyribac-Na 35 g/ha at 15-20 DAS (T$_1$) may be attributed mainly due to more yield and comparatively less cost of treatment in comparison to mechanical weeding at 20 and 45 DAS (T$_9$), need based hand weeding (T$_{10}$) and butachlor 1.5 kg/ha at 3-4 DAS *fb* bispyribac-Na 35 g/ha at 15-20 DAS (T$_5$) treatments. These results are in accordance with those of Singh and Kumar (1999).

Among herbicidal treatments the maximum grain yield (3.68 t/ha) was obtained with application of pendimethalin 1.00 kg/ha at 3-4 DAS *fb* bispyribac-Na 35 g/ha at 15-20 DAS (T$_1$). This was mainly due to lesser crop weed competition for growth resources during entire crop growth period and promoted the growth components, *viz.* plant height, dry matter production and total number of tillers/m^2 and yield components, *viz.* effective tillers/m^2 with more number of filled grains/panicle and test weight. The cumulative effect of all these growth and yield components resulted in increased grain and straw yields. The results are in conformity with those of Yadav *et al.* (2009).

Table 1. Effect of different weed management practices on yield and economics in aerobic rice

Treatment	Cost of cultivation (?/ha)	Gross return (?/ha)	Net return (?/ha)	B:C ratio	Grain yield (t/ha)
Pendimethalin 1.00 kg/ha at 3-4 DAS *fb* Bispyribac Na 35g/ha at 15-20 DAS	26655.3	68706	42050.7	1.57	3.68
Pendimethalin 1.00 kg/ha at 3-4 DAS *fb* 2, 4-D Na Salt 0.06 kg/ha at 20-25 DAS	24511.55	52500	27988.45	1.14	2.80
Pendimethalin 1.00 kg/ha at 3-4 DAS *fb* straw mulch 4 t/ha	36885.3	48660	11744.7	0.31	2.60
Pendimethalin 1.00 kg/ha at 3-4 DAS *fb* almix 40 g/ha at 25-30 DAS	25385.3	63600	38214.7	1.50	3.40
Butachlor 1.5 kg/ha at 3-4 DAS *fb* Bispyribac Na 35 g/ha at 15-20 DAS	29705.3	66114	36408.7	1.22	3.52
Butachlor 1.5 kg/ha at 3-4 DAS *fb* 2, 4 -D Na Salt 0.06 kg/ha at 20-25 DAS	24577.55	49545	24967.45	1.01	2.65
Butachlor 1.5 kg/ha at 3-4 DAS *fb* straw mulch 4 t/ha	36951.3	45270	8318.7	0.20	2.40
Butachlor 1.5 kg/ha at 3-4 DAS *fb* almix 40 g/ha at 25-30 DAS	25451.3	46740	21288.7	0.83	2.50
Mechanical weeding at 20 and 45 DAS	32671.3	67995	35323.7	1.18	3.65
Need based hand weeding	43671.3	69090	25418.7	0.58	3.70
Unweeded check	23671.3	24330	658.7	0.027	1.30
LSD (P=0.05)	-	-	-	-	0.36

CONCLUSION

On the basis of this investigation and net return it may be concluded that application of pendimethalin 1.00 kg/ha at 3-4 DAS *fb* bispyribac-Na 35 g/ha at 15-20 DAS can effectively manage weeds and produced higher yield of aerobic rice.

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Evaluation of herbicide combinations for control of mixed weed flora in black gram

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Weeds compete for water, nutrients and space and cause 43.2 to 90% yield loss in black gram (Rao *et al.* 2010). The continuous rainfall during the season makes the manual weeding impracticable (Shweta and Singh 2005). Chemical weed management in black gram has been found effective and economical. However, continuous use of single/narrow-spectrum herbicide for years together may results in weed shift, weed resistance and a number of other serious upheavals. Identification of alternate strategies such as new herbicides and herbicide mixtures may be the need of the hour to tackle this problem. Therefore, new herbicides with different modes of action to tackle the ever increasing problem of complex weed flora vis-à-vis shift in weed flora were evaluated.

METHODOLOGY

The field experiment was conducted at the research farm of Regional Research Sub-station Berthin, Bilaspur during *Kharif* 2015. Soil of the test site was sandy loam in texture, slightly alkaline in reaction and medium in available nitrogen, phosphorus and potassium. Twelve weed control treatments, *viz.* imazethapyr at 70 and 80 g/ha (pre-emergence and at 3-4 leaf stage of the weeds), ready mix combination of imazethapyr + imazamox 70 and 80 g/ha (pre-emergence and at 3-4 leaf stage), pendimethalin at 1000 g/ha, ready mix combination of imazethapyr + pendimethalin 1000 g/ha (pre-emergence), hand weeding twice (25 and 45 DAS) and unweeded check (Table 1) were tested on black gram variety UG-218 in Randomized Block Design with three replications. Nitrogen, phosphorus and potassium were applied as per the recommendation *i.e.* 20, 40 and 20 kg/ha, respectively. The herbicide treatments were applied with knapsack power sprayer using 600 L water/ha.

RESULTS

Echinochloa colona, Dactyloctenium aegyptium and *Cyperus iria* were the major weeds constituting 51, 34 and 17%, respectively, of total weed flora at 60 DAS. Pre-emergence ready mix combination of imazethapyr + imazamox at 70-80 g/ha effectively controlled grasses and sedges. Ready mix combination of imazethapyr + imazamox at 80 g/ha (pre) resulted in significantly higher seed yield. Uncontrolled growth of weeds reduced black gram seed yield by 68.1%. Gross and net returns due to weed control were highest under pre-emergence ready mix combination of imazethapyr + imazamox at 80 g/ha followed by a pre-emergence ready mix combination of imazethapyr + imazamox at 70 g/ha. Marginal benefit cost ratio was highest under pre-emergence imazethapyr at 80 g/ha followed by pre-emergence imazethapyr at 70 g/ha, pre-emergence ready mix combination of imazethapyr + imazamox at 70 g/ha and pre-emergence ready mix combination of imazethapyr + imazamox at 80 g/ha.

Table 1. Effect of treatments on total weed count (no./m^2, 60 DAS), seed yield (kg/ha) and economics in blackgram

Treatment	Dose (g/ha)	Time of application	Total weed count*	Seed yield	Gross return due to weed control (` /ha)	Net returns due to weed control (` /ha)	MBCR
Imazethapyr	70	Pre-emergence	14.2 (202.7)	1175	93947	92268	55.0
Imazethapyr	80	Pre-emergence	12.8 (165.3)	1270	106929	105060	56.2
Imazethapyr	70	3-4 leaf stage	17.3 (298.7)	762	37914	36235	21.6
Imazethapyr	80	3-4 leaf stage	16 (256)	952	64077	62208	33.3
Imazethapyr + imazamox	70	Pre-emergence	10.3 (106.7)	1397	124736	122478	54.2
Imazethapyr + imazamox	80	Pre-emergence	7.6 (58.7)	1492	137519	134975	53.1
Imazethapyr + imazamox	70	3-4 leaf stage	14.6 (213.3)	984	68682	66424	29.4
Imazethapyr + imazamox	80	3-4 leaf stage	13.7 (186.7)	1048	77514	74970	29.5
Pendimethalin	1000	Pre-emergence	14.9 (224)	1143	90274	88429	47.9
Imazethapyr + pendimethalin	1000	Pre-emergence	11.3 (128)	1302	112054	109546	43.7
Hand weeding	-	25 & 45 DAS	2.9 (10.7)	1333	116071	107571	12.7
Unweeded check	-	-	25.7 (661.3)	476	-	-	-
LSD (P=0.05)		-	1.8	125	-	-	-

* Data transformed to square root transformation ($\sqrt{x+0.5}$). Figures in parentheses are the means of original values.

CONCLUSION

In conclusion, it may be inferred that pre-emergence application of ready mix combination of imazethapyr + imazamox at 80 g/ha is an effective alternative to pendimethalin or manual weeding or imazethapyr alone or even its post-emergence application in providing satisfactory control of mixed weed flora and giving higher productivity and profitability in black gram.

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Integrated weed management studies in cabbage

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Weeds form a serious negative factor in crop production and are responsible for marked losses in crop yield (Mani *et al.* 1968). Among the different problems encountered in the cabbage production, the control of weeds is of utmost importance, as the weeds have been found to reduce the yield to 45-80% (Chadha 2001). Although considerable research work has been carried out in India on various aspects of cabbage cultivation, but the problem of weeds in this crop needs special attention, as weeds when present in the field reduce the yield and impair the quality of the produce. The major portion of the cost of cultivation accounts for the expenditure involving cost, time and labour required in weeding operations. To overcome this, manual weeding or application of black polythene mulch is the only option left with the farmers. Therefore, in order to find a better solution using integrated treatments, the present investigation was undertaken:

METHODOLOGY

A field experiment was conducted at Experimental Farm of Krishi Vigyaan Kendra, Una during *Rabi* 2014. Soil of experimental area was sandy loam in texture, moderately acidic in reaction and medium in available nitrogen, low in phosphorus and in potassium status. The experiment was laid in Randomized Block Design with three replications using cabbage variety Golden Acre. All the recommended package of practices were followed during the growing season of the crop. Twelve weed control treatments, *viz.* pendimethalin at 0.75 kg/ha (PPI) followed by propaquizafop at 0.075 kg/ha (30 DAT), pendimethalin at 0.75 kg/ha (PPI) followed by black polythene mulch (after transplanting), pendimethalin at 0.75 kg/ha (PPI) followed by one hand weeding (30 DAT), oxyfluorfen at 0.25 kg/ha (PPI) followed by black polythene mulch (after transplanting), oxyfluorfen at 0.25 kg/ha (PPI) followed by one hand weeding (30 DAT), oxyfluorfen at 0.25 kg/ha (PPI) followed by propaquizafop (30 DAT), alachlor at 1.0 kg/ha (PPI) followed by propaquizafop (30 DAT), alachlor at 1.0 kg/ha (PPI) followed by black polythene mulch (after transplanting), alachlor at 1.0 kg/ha (PPI) followed by one hand weeding (30 DAT), black polythene mulch (after transplanting), two hand weeding (30 and 60 DAT) and weedy check.

RESULTS

Results of the study revealed that oxyfluorfen at 0.25 kg/ha (PPI) followed by black polythene mulch (after transplanting) with weed control efficiency (WCE) of 83.93% and pendimethalin at 0.75 kg/ha (PPI) followed by black polythene mulch (after transplanting) with weed control efficiency (WCE) of 81.23% were comparable and resulted in significantly lower population and dry weight of *Commelina benghalensis*, *Chenopodium album*, *Melilotus indica* and *Cyperus rotundus*. Therefore, study concluded that net benefits can be obtained with integrated application of oxyfluorfen at 0.25 kg/ha (PPI) followed by black polythene mulch (after transplanting) over other treatments with highest gross returns of Rs. 165800 and benefit cost ratio of 3.17.

Table 1. Effect of treatments on economic returns

Treatment	Rate (kg/ha)	Cost of production Rs/ha	Gross returns Rs/ha	Net returns Rs/ha	B:C ratio
Pendimethalin (PPI) *fb* propaquizafop (30 DAT)	0.75 and 0.075	39305.44	115448.2	76142.7	1.94
Pendimethalin (PPI) *fb* black polythene mulch (after transplanting)	0.75	40360.19	155831.8	115471.6	2.86
Pendimethalin (PPI) *fb* one hand weeding (30 DAT)	0.75	38943.19	122249.2	83306.0	2.14
Oxyflourfen (PPI) *fb* propaquizafop (30 DAT)	0.25	38748.52	119292.2	80543.7	2.08
Oxyflourfen (PPI) *fb* black polythene mulch (after transplanting)	0.25	39803.27	165800.9	125997.7	3.17
Oxyflourfen (PPI) *fb* one hand weeding (30 DAT)	0.25 and 0.075	38386.27	121235.3	82849.1	2.16
Alachlor (PPI) *fb* propaquizafop (30 DAT)	1.0 and 0.075	39365.44	121362.1	81996.6	2.08
Alachlor (PPI) *fb* black polythene mulch (after transplanting)	1.0	40420.19	153930.9	113510.7	2.81
Alachlor (PPI) *fb* one hand weeding (30 DAT)	1.0	39003.19	121150.9	82147.7	2.11
Black polythene mulch (after transplanting)	-	38510.19	85118.19	46608.0	1.21
Two hand weeding (30 and 60 DAT)	-	37943.19	81781.05	43837.9	1.16
Weedy check	-	36243.19	45748.39	9505.2	0.26

CONCLUSION

It can be concluded that the use of herbicides in cabbage is highly profitable for getting higher returns due to effective weed control. Oxyfluorfen at 0.25 kg/ha *fb* black polythene mulch was the most effective treatment in controlling the weeds with highest weed control efficiency and increased plant growth, yield and benefit cost ratio.

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Molecular variations in *Physalis peruviana* collected from different locations in India

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Physalis (Physalis peruviana L.), also known as cape gooseberry or ground-cherry, a small herbaceous annual/ perennial weed plant is a member of Solanaceae family plays an important role in nutrition as an excellent base for dietetic products. Only recently, the plant has become an important crop and widely introduced in cultivation in tropical, subtropical and even temperate areas. *Physalis* has a short shelf-life cycle. The species is capable of adapting to any warm climate and expresses tolerance to cold. However, it does not like excess moisture or frost. The flowers are hermaphrodite, solitary, and bell-shaped. Its most distinctive feature is the fruiting calyx which enlarges to cover the fruit and hangs downwards similar to a lantern. Some of the health benefits of *Physalis* include: blood purification, reduction of the albumin in the kidneys, reconstruction and strengthening of the optic nerve, alleviation of throat infections, elimination of intestinal parasites, and treatment of prostate problems (Fischer *et al.* 2012). Highly valued for its unique flavour, texture and colour, recent research has shown that *physalis* fruit is rich in many beneficial compounds (Ramadan 2011). *Physalis* fruit is rich in pro-vitamin A, ascorbic acid, and in some vitamins of the B complex (thiamine, niacin, and vitamin B12) and may be recommended as an alternative source for vitamin A to malnourished children. Additionally, the fruit is rich in crude protein, phosphorous and iron, although calcium content is low. Therefore, by considering weedy characteristics as well as potential of holding high nutritional contents in its fruit, a study was carried out to see the variation in different useful traits at Directorate of Weed Research, Jabalpur. The main objective of the study was to highlight the nutritional potential of *Physalis peruviana* which can be utilized potentially against malnutrition problems in India or elsewhere.

METHODOLOGY

A total of 18 *P. peruviana* genotypes were collected in the year 2013-14 from geographically different locations of India (Table 1). 20 days young leaves were used for DNA extraction from each plant of every population.

PCR amplifications were performed in a programmable thermocycler. Each sample was amplified in a reaction mixture containing 50 ng genomic DNA, *Taq* polymerase 1 unit, 10x PCR buffer with 2.5 mM $MgCl_2$ and 200 ìM of each dNTP, 10 pmol of 10-mer RAPD primers. Cycling parameters for RAPD were adjusted to 5 min at 94 °C for pre-denaturation, 45 cycles each of 1 min at 94 °C for denaturation, 1 min for annealing at 37 °C, 2 min at 72 °C for extension and a final extension at 72 °C for 5 min. After cooling to 4 °C, amplified products were separated on 1.5 % agarose gel in 1x TAE buffer with 1 Kb plus ladder to determine the size of amplified DNA fragments. The final RAPD data generated was used to calculate pairwise similarity co-efficient values using the similarity for qualitative data (SIMQUAL) format of NTSYS-pc version 2.1 (numerical taxonomy and multivariate analysis system) software package.

RESULTS

Vast variation in morphological and physiological traits as well as yield attributes was noticed in different accessions of Physalis peruviana. In addition, molecular diversity analysis revealed variations in different accessions within and across the species.

During the present investigation initially 60 RAPD primers were screened with biotypes of *P. peruviana.* Forty two RAPD primers that produced consistently strong amplification products and polymorphic banding patterns were selected for further analysis. The polymerase chain reaction was carried out using a single decamer primer at a time. The sequences of these primers are presented in Table 2. Selected 42 RAPD primers amplified a total of 224 loci. The band size of amplified fragments ranged from 100-2200 bp. Out of 224 bands amplified 52 were found to be monomorphic (23.2%) and remaining 172 were polymorphic (78.8%). Average numbers of bands per primer was 3.73 while average number of polymorphic band per primer was 2.9. Maximum numbers of bands (8) were scored by primer OPN-04 while minimum numbers of bands (3) were scored by primers OPE-10.

Table1. *Physalis peruviana* collection sites

Code	Collection sites	Latitude	Longitude	Type	Fruit size	Fruit shape
PP1	Nagpur (MH)	21.1458° N	79.0882° E	Cultivated	Large	Long
PP2	Modinagar (UP)	28.8316° N	77.5780° E	Cultivated	Medium	Round
PP3	Pune (MH)	18.5204° N	73.8567° E	Cultivated	Medium	Long
PP4	Nashik (MH)	19.9975° N	73.7898° E	Cultivated	Small	Round
PP5	Lucknow (UP)	26.8467° N	80.9462° E	Cultivated	Medium	Round
PP6	Jabalpur (MP)	23.1815° N	79.9864° E	Cultivated	Large	long
PP7	Varanasi (UP)	25.3176° N	82.9739° E	Cultivated	Medium	Round
PP8	Jaipur (RJ)	26.9124° N	75.7873° E	Cultivated	Medium	Round
PP9	Jodhpur (RJ)	26.2389° N	73.0243° E	Cultivated	Medium	Round
PP10	Nashik (MH)	21.1458° N	79.0882° E	Cultivated	Large	Round
PP11	Goa	15.2993° N	74.1240° E	Cultivated	Medium	Round
PP12	Kolkata (PB)	22.5726° N	88.3639° E	Cultivated	Medium	Round
PP13	Nagpur (MH)	21.1458° N	79.0882° E	Cultivated	Small	Round
PP14	Pune (MH)	18.5204° N	73.8567° E	Cultivated	Medium	Round
PP15	Agra (UP)	27.1767° N	78.0081° E	Cultivated	Large	Round
PP16	Surajpur (C.G.)	23.5027° N	82.8210° E	Cultivated	Medium	Round
PP17	Saoner, Nagpur (MH)	23.5027° N	82.8210° E	Cultivated	Medium	Round
PP18	New delhi	28.6139° N	77.2090° E	Cultivated	Medium	Round

CONCLUSIONS

This is the first diversity assessment of *Physalis peruviana* based on morpho-physiological parameters in Indian subcontinent. Understanding their variability patterns and interactions with environments to determine morphological variation in flower and fruits are key scientific questions in evolutionary developmental biology. These results will help to establish novel strategies to improve/ incorporate useful traits related to the productivity and fruit quality of *Physalis peruviana.* To conclude, RAPD variations were more among the *P. peruviana* genotypes. The genetic diversity analysis among the genotypes shows the genetic distance and similarity on the whole genome basis that is, difference in their genetic makeup throughout the genome.

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Assessment of economic viability of post-emergence herbicides in pigeonpea

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Pigeon pea [*Cajanus cajan* (L.) Millsp] is an important pulse crops of India after chickpea, accounting 90% of world's total production. But, severe infestation of weeds is observed in pigeon pea resulting into approximately 80% reduction in grain and seed yield (Talnikar *et al.* 2008). Therefore, weeds must be controlled during the critical period of 7-8weeks for obtaining high seed yields. As, hand weeding is costly and time consuming, thus, it becomes essential to use the economically viable post emergence herbicides, hence present investigation was under taken.

METHODOLOGY

The present experiment was conducted during *Kharif* season of 2014 at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) to assess the economic viability of post emergence herbicides against weeds. Sowing of pigeon pea cultivar ICPL-87119 15 kg/ha, was done in randomized complete block design with three replications comprising 10 treatments including propaquizafop 50, 62.5, 100 and 125 g/ha, fenaxaprop-P-ethyl 100 g/ha, imazethapyr 100 g/ha, propaquizafop 62.5 g/ha + imazethapyr 75 g/ha, propaquizafop 100 g/ha + imazethapyr 100 g/ha, hand weeding (20 and 40 DAS) and weedy check. The herbicides were applied at 20 days after sowing. Further, economics of different treatments were worked out in terms of cost of cultivation, gross monetary returns (GMR), net monetary returns (NMR) and benefit-cost ratio (B:C) (profitability per rupee of investment) on per hectare area basis to ascertain the economic viability of the treatments, using following formula's

a) The cost of cultivation for each treatment was determined on the basis of prevailing cost of different inputs.

b) Gross monetary returns = Value of seed + Value of stover

c) Net monetary returns = Gross monetary returns - Cost of cultivation

d) B:C ratio = Gross monetary returns/ Cost of cultivation

RESULTS

It was found that, weed free treatment receiving two hand weeding, required maximum cost (Rs. 28418 g/ha), in comparison to all the other treatments, where cost required was less (Rs 18493 to 20218/ha). Thus, use of herbicide for control of weeds seems to be more cost effective. Also, gross monetary returns (GMR) was minimum (Rs 53114 /ha) under weedy check, but was maximum (Rs. 98741 /ha) under hand weeding twice followed by combined application of propaquizafop 62.5 g/ha + imazethapyr 75 g/ha and propaquizafop 100 g/ha + imazethapyr 100 g/ha (Rs. 90392 and 93382/ha respectively). All the plots receiving either hand weeding or herbicidal treatments fetched higher GMR than weedy check because of enhanced seed and stick yields.

Table 1. Cost of cultivation, GMR, NMR and B:C ratio as influenced by weed control treatments

Treatment	Cost of cultivation (Rs/ha)	GMR (Rs/ha)	NMR (Rs/ha)	B:C ratio
Propaquizafop 50 g/ha POE	18493	62445	43952	3.38
Propaquizafop 62.5 g/ha POE	18587	63323	44736	3.41
Propaquizafop 100 g/ha POE	18868	71095	52227	3.77
Propaquizafop 125 g/ha POE	19056	72568	53512	3.81
Fenoxaprop-p-ethyl 100 g/ha POE	19768	68881	49043	3.48
Imazethapyr 100 g/ha POE	19368	78851	59483	4.07
Propaquizafop 62.5 g/ha + imazethapyr 75 g/ha POE	19524	90392	70868	4.60
Propaquizafop 100 g/ha + imazethapyr 100g/ha POE	20218	93382	73164	4.62
Hand weeding twice (20 and 40 DAS)	28418	98741	70323	3.47
Weedy check	17918	53114	35196	2.96

The net monetary returns (NMR) was only Rs. 35196/ha under weedy check, while, it was maximum (Rs. 73164/ha) when weeds were controlled by application of propaquizafop 100 g/ha + imazethapyr 100 g/ha. The low investment under combined application of propaquizafop 62.5 g/ha + imazethapyr 75 g/ha for controlling weeds resulted in good economic yield in comparison the former treatment. The advantage of higher GMR under hand weeding was nullified due to higher variable cost for control of weeds (Rs. 28418/ ha). These results are in close conformity to the findings of Sukhadia *et al.* (2000). The benefit – cost ratio was highest for propaquizafop 62.5 g/ha + imazethapyr 75 g/ha or propaquizafop 100g/ha + imazethapyr 100 g/ha (4.60 and 4.62) and was least for weedy check. These results are in close conformity with the findings of Srivastava *et al.* (2004).

CONCLUSION

It was concluded that Combined application of propaquizafop 100 g/ha + imazethapyr 100 g/ha and propaquizafop 62.5 g/ha + imazethapyr 75 g/ha was found economically viable for effective control of weeds.While, cost of cultivation was found maximum in case of hand weeding.

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Impact of weed management in turmeric under mid hill conditions of Himachal Pradesh

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India is the largest turmeric producer, consumer and exporter. It is a long duration slow growing crop. Turmeric took a long time to emerge and develop a canopy structure sufficient to compete with weeds. Keeping these points in view, an investigation was initiated (Sachdeva *et al.* 2015) with continuous refinement to evolve effective weed management strategy in turmeric for the mid hill conditions of Himachal Pradesh.

METHODOLOGY

The field experiment was conducted for three consecutive years of 2014, 2015 and 2016 at Palampur to evolve herbicide based integrated weed management schedule in turmeric. The experimental soil was silty clay loam in texture, acidic in reaction, medium in available nitrogen, phosphorus and high in available potassium. The treatments consisted of different combinations of chemicals and mechanical methods (Table 1). Turmeric variety 'Palampur Pitamber' was planted on July 1, 2014, May 15, 2015 and May 31, 2016 with recommended package of practices except treatments. The crop was harvested on January 2015, 25 December 2015 and 19 December 2016. Herbicides were applied with knapsack power sprayer using 600 L water per hectare. Data on density and dry weight of weeds were recorded one month after the treatments imposed.

RESULTS

The economic threshold levels (g/m^2) with the weed management practices studied varied between 4.8 to 11.2 g/m^2 (Table 1). It is clearly indicated that any increase in the cost of treatment would lead to higher value of economic threshold whereas an increase in price of crop produce would result in lowering the economic threshold. Hand weeding thrice had higher cost tending to increase the economic threshold more than the integrated weed management treatments. The linear relationship between weed dry weight (x) and fresh rhizome yield (Y) of turmeric is given below:

$$Y= 14132 – 64.2x \text{ ....} (R^2= 0.602)$$

The equation explains that 60.2% variation in fresh rhizome yield due to weed dry weight could be explained by the regression equation. With every one gram per m^2 increase in weed weight, the fresh rhizome yield was expected to fall by 64.2 kg/ha.

Due to higher rhizome yield net returns and B:C were highest following the application of atrazine *fb* mulch *fb* hand weeding. Weed index, a measure of the efficiency of a particular treatment as percentage of yield potential under weed free (hand weeding thrice in the present investigation) was maximum under atrazine *fb* mulch *fb* hand weeding (-46.9). The rest of the treatments had plus value of weed index indicating that much percent loss in yield under them relative to the weed free. Due to phytotoxicity, atrazine/metribuzin/ pendimethalin *fb* fenoxaprop + metsulfuron-methyl, glyphosate *fb* hand weeding and oxyflourfen *fb* hand weeding had higher weed index than untreated check. Weed persistence index was lowest under hand weeding thrice followed by atrazine *fb* mulch *fb* hand weeding and pendimethalin *fb* mulch *fb* hand weeding. Weed management index, agronomic management index and integrated weed management index were highest under atrazine *fb* mulch *fb* hand weeding. Efficiency index indicating the weed killing potential of a herbicide/treatment and its phytotoxicity on the crop, was highest under hand weeding thrice.

Since the treatments were not consistent or differed in performance with respect to the parameters studied, an overall impact index (OIi) considering efficiency of weed control, yield and economics was drawn to have a valid inference. The overall impact index was highest for metribuzin *fb* mulch *fb* hand weeding, followed by atrazine *fb* mulch *fb* hand weeding, pendimethalin *fb* mulch *fb* hand weeding, hand weeding thrice and oxadiargyl *fb* hand weeding. Oxyflourfen *fb* hand weeding, pendimethalin *fb* hand weeding, metribuzin *fb* hand weeding and atrazine *fb* hand weeding also had higher overall impact index than the threshold value of one. The other treatments had lower overall impact index than the threshold value.

Table 1. Effect of treatments on fresh and cured rhizome yield (t/ha) and impact assessment indices

Treatment	Dose* (g/ha, t/ha)	Time (DAT)	Weed control efficiency (%)	Rhizome yield		NR	B:C	WI	WPI	WMI	AMI	IWMI	TEI	OIi	Gt	Et
				Fresh	Cured											
Metribuzin *fb* hand weeding	700	0-2, 45, 75	86.2	12.1	7.4	254847	2.59	3.1	0.38	1.82	0.45	1.14	4.13	1.04	311	7.1
Metribuzin *fb* fenoxaprop + metsulfuron	700, 67 + 4	0-2, 45	38.0	3.6	2.5	26777	0.29	87.8	0.41	1.41	0.29	0.85	-0.75	0.41	230	5.2
Metribuzin *fb* straw mulch *fb* HW	700, 5	0-2, 0-5, 75	95.2	16.9	11.5	447663	4.54	-28.6	0.46	2.55	0.61	1.58	29.89	1.55	317	7.2
Pendimethalin *fb* HW	1000	0-2, 45, 75	86.5	11.4	7.8	269855	2.72	8.2	0.36	1.90	0.47	1.19	4.74	1.06	326	7.4
Pendimethalin *fb* fenoxaprop + metsulfuron	1000, 67 + 4	0-2, 45	37.7	3.8	2.6	30318	0.33	86.7	0.38	1.46	0.31	0.89	-0.72	0.43	223	5.1
Pendimethalin *fb* straw mulch *fb* HW	1000, 5	0-2, 0-5, 75	90.9	16.8	11.2	429805	4.27	-25.5	0.31	2.59	0.61	1.60	15.01	1.50	353	8.0
Atrazine *fb* HW	750	0-2, 45, 75	86.8	11.1	7.4	253623	2.59	-11.2	0.32	1.80	0.44	1.12	4.26	1.01	305	6.9
Atrazine *fb* fenoxaprop + metsulfuron	750, 67 + 4	0-2, 45	38.4	3.2	1.9	-3730	-0.04	90.8	0.41	1.03	0.03	0.53	-0.98	0.34	210	4.8
Atrazine *fb* straw mulch *fb* HW	750, 5	0-2, 0-5, 75	89.0	16.6	11.7	455540	4.62	-46.9	0.30	2.77	0.64	1.70	13.33	1.50	318	7.2
Oxyfluorfen *fb* HW	300	0-2, 45, 75	86.6	11.1	8.2	289588	2.90	25.5	0.32	2.00	0.50	1.25	5.47	1.10	340	7.7
Oxadiargyl *fb* HW	250	0-2, 45, 75	88.4	13.8	9.6	357700	3.64	-3.1	0.32	2.29	0.56	1.43	8.89	1.29	312	7.1
Glyphosate *fb* HW	1230	25, 45, 75	88.7	10.8	5.7	172259	1.78	32.7	0.32	1.35	0.26	0.80	1.74	0.91	288	6.6
Glyphosate *fb* HW	1845	25, 45, 75	94.2	10.7	5.8	176223	1.80	36.7	0.42	1.29	0.23	0.76	3.74	0.94	302	6.9
Hand weeding		25, 45, 75	96.0	14.3	10.6	396347	3.65	0.0	0.29	2.34	0.57	1.46	31.26	1.41	494	11.2
Weedy check			0.0	7.6	4.7	144497	1.80	23.5	1.00	-	-	-	0.00	0.51	311	-
LSD (P=0.05)				4.1	2.7	-	-	-	-	-	-	-	-	-	-	-

*Herbicide, g/ha; mulch, t/ha; NR, net return; WI, weed index; WPI, weed persistence index; WMI, weed management index; AMI, Agronomic management index; IWMI, integrated weed management index; TEI, treatment efficiency index; OIi, overall impact index; Gt, gain threshold; Et, economic threshold

CONCLUSION

Thus in order of preference metribuzin 0.7 kg/ha *fb* mulch *fb* hand weeding (45&75 DAP), followed by atrazine 0.75 kg/ ha *fb* mulch *fb* hand weeding (45 and 75 DAP), pendimethalin 1.0 kg/ha *fb* mulch *fb* hand weeding, hand weeding thrice (45 and 75 DAP) and oxadiargyl 0.25 kg/ha *fb* hand weeding (45 and 75 DAP) are recommended for effective weed management in turmeric under mid hill conditions of Himachal Pradesh.

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Economic benefit analysis of Assert™ herbicide in paddy

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Weeds in rice are one of the most important biological hindrances to maximizing crop yield. Weed emergence in relation to crop emergence is an important factor in crop-weed competition. Crop losses due to weed competition varies with the duration (days) and intensity (plants/m^2) of weed infestation in the crop. The crop is likely to experience yield reduction, unless it is kept weed free during an early part of its growing period (Azmi *et al*. 2007). In general, controlling weeds to provide a period of minimal weed competition is one of the important weed management strategies in order to minimize the labour requirement for weeding operations, enhance the efficiency of herbicide use, maximize crop yields and thus maximize economic returns to rice farmers.

Therefore, present studies were initiated to evaluate the yield advantage and economic benefit of Assert™ herbicide application in comparison to the current weed control options used by rice farmers.

METHODOLOGY

Field studies were conducted in transplanted rice during the 2015 crop season in the state of West Bengal and Uttar Pradesh in India. Assert™ 2.5% OD (at 25 g/ha) was compared with farmer practice of bispyribac-sodium 10% SC (at 25 g/ha). Application time for Assert varied from 15-20 days after transplanting (DAT) across locations while bispyribac was applied between 20-25 DAT as per farmers' practice in that area. Need based hand weeding (one time) was also performed in the Assert and bispyribac treatments at 25-30 days after application. At two field sites, a pre-emergence herbicide was applied before treatment of Assert and bispyribac, while at the other two sites, no pre-emergence herbicide was applied. These were large plot (200 m^2) non-replicated trials. All other cultural practices and plant protection measures were kept the same for all treatments. Total weed control cost (herbicide cost + labour cost for hand weeding) was calculated for each treatment and crop yield was recorded, using the complete large plot. Yield of trial plots was converted into yield per acre and multiplied by prevailing market price of rice to arrive at the farmer value of rice harvest.

RESULTS

Dominant weed flora in experimental fields consisted of grasses *(Echinochloa colona, Echinochloa crus-galli)*, sedges *(Cyperus difformis)* and broad-leaf weeds (*Monochoria vaginalis*, *Ludwigia* sp.). Weed control treatments were applied as per dose rate and application time described in methodology. Based on the cost of the herbicide treatment, number of labours required to hand weed each plot and final yield, Assert followed by (*fb*) 1 hand weeding (HW) recorded a saving of 0-2 labours/acre over current farmers' practice of bispyribac *fb* 1 HW and 23.5 to 25.5 labours per acre over non-herbicide treated plots. The use of a herbicide treatment followed by hand weeding to clean out the weeds occurring later, after initial herbicide treatment, showed a yield increase of 60 to 65 kg per acre over farmer practice by reducing the crop weed competition. Finally, a net value increase (economic benefit addition) of Rs 1070 to 3774 per acre over Bispyribac program and Rs. 9394 to 22,989 per acre over the hand weeded untreated was recorded.

Table 1. Economic value of Assert™ compared to current weed control practices

Location/ Crop culture	Treatment	No of Field Sites	Cost of herbicide treatment (Rs./acre)	Cost of Hand weeding (Rs./acre)	Total weed control input (Rs./acre)	Grain yield (kg/acre)	Value of Rice Harvest (Rs./acre)	Net value per acre** (Rs.)	Economic value addition over Untreated(Rs.)
West Bengal- TPR	Assert 25 g/ha at 15-20 DAS *fb* one HW	2	850	1375 (5.5X250)*	2225	2897	34764	32539	9394
	Bispyribac 25 g/ha at 20-25 DAS *fb* one HW	2	700	1875 (7.5X250)	2575	2837	34044	31469	8324
	Untreated- no herbicide application	2	0	6375 (25.5X250)	6375	2460	29520	23145	0
Uttar Pradesh- TPR	Pretilachlor *fb* assert 25 g/ha *fb* 1 HW	2	1050	150 (1X150)	1200	3255	39060	37860	22989
	Pretilachlor *fb* bispyribac 25 g/ha at 20-25 DAS *fb* HW	2	900	150(1X150)	1050	2928	35136	34086	19215
	Untreated- no herbicide application	2	0	3525 (23.5X150)	3525	1533	18396	14871	0

*Figure in parenthesis are number of labour X cost per labour. One labour is equal to 8 hrs.

** Net value per acre calculated by multiplying the yield per acre with prevailing price of rice in that area.

CONCLUSION

Economically better productivity with reduced labour costs and higher yields was obtained with application of Assert ™ at 25 g/ha over the current farmer practice of either bispyribac or hand weeding in transplanted rice. assert ™ application at 15-20 days after transplanting resulted in significant labour savings from hand weeding, reducing the dependence on labour under present conditions of labour scarcity.

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Effect of chemical and cultural practices in controlling weeds of mesta (roselle)

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Weed control in mesta and jute involves all available methods, combining of which an integrated weed management system has been developed. But considering the present day labour scarcity and their higher wages for cultural and mechanical weed control practices and disturbed economics of mesta cultivation, an emphasis should be given to adopt the intercropping and chemical weed control using herbicides like pretilachlor. The application of pretilachlor is helpful to control weeds and increases net returns per rupees invested in mesta (Choudhury *et al.* 2009). For this purpose study was undertaken to find out the effect of chemical and cultural practices in controlling weeds of mesta (roselle).

METHODOLOGY

A Field experiment was carried out for *Kharif* season of 2016 at Jute and Allied Fibre Crops, MPKV, Rahuri (MS), with seven treatments combinations, *viz.* T_1: Pretilachlor 50% EC 900 ml /ha (pre-emergence) + one hand weeding (15 DAE), T_2: Nail weeder -1st at 5-6 DAE (at field capacity) and 2nd at 10 DAE + one hand weeding with in row at 15DAE, T_3: Mesta+ groundnut (1:1),T_4: Mesta+ clusterbean (1:1),T_5: Mesta+ blackgram(1:1),T_6: Hand weeding Twice (15 & 21 DAE) and T_7: Unweeded control with randomized block design and replicated thrice. The experimental soil was vertisol in nature with low in available nitrogen (170.23 kg ha^{-1}), medium in available phosphorus (14.02 kg/ha) and high in available potassium (3866.01 kg/ha). The soil was moderately alkaline in reaction (pH 8.1). Gross and net plot size was 5 m x 4 m and 2.70 m x 4.20 m. Component crops in between mesta rows and mesta spacing at 45 cm row-row. The cultivar of mesta (AMV-5) and intercrops like groundnut (Phule unnati), clusterbean (Phule gawar) and black gram (TAU-1) were sown. Fertilizer doses of 40, 20 and 20 kg/ha N, P_2O_5 and K_2O, respectively were applied. N was applied in three equal split doses one as basal dose and another top dressed at 21 and 35 DAS. Application of three irrigations, usual weed and pest control measures as per recommendations.

RESULTS

The results indicated that, among the chemical and cultural practices of weed control, the application of pretilachlor 50% EC 900 ml /ha, at 45-48 hours of sowing with irrigation + one hand weeding (15 DAE) recorded the lowest weed count (5.91), dry matter (4.13 g) and maximum weed contol efficency (56.96 %) at 30 DAS than rest of the treatments of mesta and it's intercrops (Table 1). As a results of restricted cell division, growth of the emerging weed seedling is prevented and death due to lack of food resrves. On the contrary, sole mesta with vacant inter row space at initial stage might have invited more number of weeds. These findings are in harmony with those of Choudhury *et al.* (2009) and Prachand *et al.* (2014).

Table 1. Weed count, weed dry weight and weed control efficiency as influenced by different treatments

Treatment	Weed count (no./m^2)	Weed dry weight (g/m^2)	Weed control Efficiency (%)	Fibre yield (t/ha)	Intercrop yield (t/ha)	Fibre equivalent yield (t/ha)	Cost of cultivation (x 10^3 `/ha)	B:C ratio
T_1-Pretilachlor + 1 HW (15 DAE)	5.91 * (34.66)	4.13 (16.69)	56.96	1.61	-	1.61	44.80	1.79
T_2-Nail weeder (5,10 DAE) + 1 HW 15 DAE	6.82 (46.38)	4.76 (22.34)	50.41	1.38	-	1.38	45.77	1.51
T_3-Mesta + gr.nut(1:1)	7.70 (58.92)	5.37 (28.34)	44.13	1.98	0.93	2.53	61.16	2.07
T_4-Mesta + clusterbean(1:1)	8.68 (75.26)	6.04 (36.18)	37.23	1.15	0.83	1.74	64.62	1.34
T_5-Mesta + black gram 1:1)	8.27 (68.19)	5.76 (32.82)	40.01	1.54	0.43	2.06	55.28	1.86
T_6-Hand weeding twice (15&21DAE)	6.90 (47.56)	4.81 (22.86)	49.90	1.17	-	1.17	47.50	1.23
T_7- Unweeded control	13.34 (177.11)	9.62 (92.18)	-	0.83	-	0.83	41.07	1.01
LSD(P=0.5)	16.47	0.79	7.76	0.22	-	0.24	-	0.27

*Actual values are given in parenthesis which was transformed by root square transformation Price rate (Rs/q): Mesta Rs.5000/q; Groundnut pod-Rs.3300/q; Clusterbean-Rs-3500/q; Black gram Rs.6000/q (2016).

The growing of mesta + groundnut intercrop recorded significantly higher fibre equivalent yield (2.53 t/ha) than rest of the treatments. The application of pretilachlor 50% EC 900 mL/ha, at 45-48 hours of sowing with irrigation + one hand weeding (15 DAE) also recorded higher fibre yield (1.61 t/ha) than rest of all treatments except intercrops like mesta + gr.nut., mesta + cluster bean and mesta + black gram. The lowest fibre yield (0.83 t/ha) was recorded in unweeded control treatment due to higher weed count (13.34/m^2) and weed dry weight (9.62 g) at 30 DAS. The maximum yield and yield attributes of mesta + groundnut recorded maximum B:C ratio (2.07) than rest of the treatments (Table 1) due to additional benefits of intercrop like groundnut and black gram which has smothering effect of weeds and also increases more nitrate reductase activities in root which is beneficial for base crop and legume having peg formation and pod development stage. These findings are analogous to those of Prachand *et al.* (2014) and Mathukia *et al.* (2015).

CONCLUSION

Intercropping of mesta + groundnut (1:1) recorded higher fibre yield and economic returns under irrigated condition. The application of herbicide pretilachlor 50% EC is exhibited lower weed count, weed dry weight and higher weed control efficiency at 30 DAS in mesta.

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Skill development of spray professionals for enhancing the bio-efficacy of herbicides

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Management of weeds in wheat in Indo-Gangetic Plains (particularly in north-western parts including Punjab and Haryana) remained the important issue since the resistance occurred in *Phalaris minor*. A poor control of weeds with alternate herbicides (clodinafop, fenoxaprop, sulfosulfuron, and some others) has been noticed during last 2-3 years in wheat crop. The extension agencies like Krishi Vigyan Kendra conducted surveys on adoption pattern of herbicides and their spray techniques. The feedback revealed that improper spray techniques found to be one of the major reasons of decreased efficiency of herbicides in wheat. The need was felt to impart proper training to the spray professionals.

METHODOLOGY

In Punjab and Haryana, majority of the farmers get the spray of herbicides done by the spray professionals, easily available in villages. These personals are either illiterate or poorly educated (hardly primary or middle passed), thus they have little know-how of pesticide application. In order to educate them and to enhance their technical skill, Krishi Vigyan Kendra, Ambala organized three small courses/ trainings of five days each (a total of 90 participants) during the year 2015 for such rural youths (belonging to scheduled caste families as per the scheme) engaged in spraying of pesticides including herbicides.

RESULTS

The trainees got acquainted with all the technical knowledge including various types of pesticides including herbicide formulations, optimum dose per unit area, quantity of water for application, right growth stage of weeds for control, time of application of herbicides, consideration of weather parameters (sunlight, fog, wind speed *etc*). Special emphasis was laid on study of spray equipments, their parts particularly type of various nozzles for different types of pesticides. Demonstrations were given on use of herbicides starting from pouring of chemicals in spray pumps, adding of water, stirring, selection of nozzle for spray, height of spray boom and finally the speed of sprayer. The trainees were made aware on health hazards of different type of pesticides for their safe use. It was very satisfying experience that the skill imparted to trainees raised their level of professional confidence, application of their knowledge in the field while spraying and reported satisfactory results of applied pesticides, particularly of herbicides. Thus such human resource development programs for spray professionals improved their technical skill which proved effective in enhancing the efficacy of applied pesticides and of herbicides in particular.

Tillage and weed management effects on physico-chemical properties in soybean-wheat-green gram cropping system

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Tillage systems or cropping sequences can affect soil health. Deep soil ploughing had significant negative impact on soil health and quality parameters. Some studies showed that increasing soil organic matter, soil structure due to maintenance of reduced oxidation of soil organic matter with minimum disturbance of soil compared to conventional tillage. Similarly, diversification in crop rotations can also affects soil health by affecting carbon contents, due to the difference in chemical composition of different crop residues that are added to soil. Weeds are one of the major biological constraints in conservation agriculture system. However, precise information on the long term effects of different tillage practices and intensified soybean based crop rotations on soil health in the central India region is lacking. The objectives of present study were to determine the effects of different tillage-residue and weed management practices on physico-chemical properties of soil in soybean-wheat-greengram cropping system.

METHODOLOGY

The field experiment was conducted for three cropping cycles at research farm of ICAR - Directorate of Weed Research, Jabalpur, M.P., India on Vertisol. The experiment were laid out in a thrice replicated split plot design included five tillage-residue management practices as main plot treatments, *viz.* conventional tillage (CT) in soybean – CT in wheat, CT in soybean - zero tillage (ZT) in wheat – ZT + residue (R) in greengram, ZT + R in soybean – ZT in wheat - ZT + R in greengram, ZT in soybean - ZT + R in wheat - ZT + R in greengram, ZT + R in soybean - ZT + R in wheat - ZT + R in greengram, and three weed management practices as sub-plot treatments, *viz.* W_1: control in all three crops; W_2: pendimethalin 750 g/ ha as pre-emergence *fb* imazethapyr 100 g/ha as post-emergence in soybean during rainy, mesosulfuron 12 g/ha + iodosulfuron 2.4 g/ha as post-emergence in wheat during winter season, imazethypry 100 g/ ha as post-emergence in greengram during summer season; W_3: metribuzin 500 g/ha as pre-emergence + 1 HW at 45 DAS in soybean during rainy, clodinofop 60 g/ha + metsulfuron 4 g/ ha as post-emergence in wheat during winter season, and quizalafop 50 g/ha as post-emergence in greengram during summer season. Soil samples were taken from 0-15 cm depth using core samples from the each plot for the analysis of different soil properties after harvest of soybean.

RESULTS

The soil pH varied within a range of 6.87-6.99 and electrical conductivity was in a range of 0.12-0.17 dS/m. There was no significant change in both soil pH and electrical conductivity under tillage-residue management practices as well as weed management practices.

Tillage-residue management practices had significant impact on organic C after three cropping cycle but there was no change in organic C due to different weed management practices. Among tillage-residue management practices, higher organic carbon percent was recorded under ZT-ZT+R-ZT+R which was significantly higher than CT alone treatment. The available phosphorus and potassium were not significantly affected by the tillage-residue and weed management system. However, compared with the initial values, higher available P and K was recorded in the treatment of ZT-ZT+R-ZT+R than other treatments (Table 1). Thus, residue retention in soybean- wheat- greengram system had an impact on improvement of physic-chemical properties of soil. This may have effect on the productivity of subsequent crop due to many favorable factors, *viz.* improved soil water regimes, improved soil physical properties, aeration and better C and nutrient accumulation (Bhattacharyya *et al.* 2015).

Table 1. Physic-chemical properties as influenced by different tillage-residue recycling and weed management practices

Treatment	pH	EC (dS/m)	OC (%)	P (kg/ha)	K (kg/ha)
Tillage-residue management					
CT-CT	6.99	0.12	0.55	6.88	257.67
CT-ZT-ZT	6.87	0.17	0.61	6.61	278.26
ZT + R-ZT-ZT + R	6.93	0.13	0.74	6.76	256.64
ZT – ZT + R-ZT + R	6.89	0.15	0.79	8.49	281.68
ZT + R-ZT + R-ZT + R	6.92	0.16	0.75	6.66	229.50
LSD (P=0.05)	NS	NS	0.10	NS	NS
Weed management					
W1	6.92	0.15	0.75	7.08	268.78
W2	6.94	0.14	0.67	7.11	264.98
W3	6.96	0.14	0.65	7.11	245.06
LSD (P=0.05)	NS	NS	NS	NS	NS
Initial value	6.94	-	0.65	6.21	246.20

CONCLUSION

The results suggest that ZT with residue retention and crop diversification are useful strategies for improvement of physic-chemical properties of soil. Future research will evaluate the impact of ZT on application of fertilizer dose in presence of crop residue mulch on the productivity and sustainability of soybean-wheat-green gram cropping systems in the region.

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Nitrogen and weed management effects on weed growth and rice productivity under conservation agriculture in rice-wheat-greengram cropping system

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In India, rice is the stable food for three-fourths of the population. Long term experiments indicate that rice yield has stagnated in major rice-based cropping systems (Ladha *et al.* 2003). The yield is stagnating and total factor productivity is declining due to fatigued natural resource base. Potential solution includes a shift from conventional to conservation agriculture (CA) system. The CA system is based on three linked principles of minimum soil disturbance, soil surface cover at all times with crop residues retention, and diversified crop rotation. CA practice may affect N dynamics and thus N management in comparison with conventional practice. Changes in agronomic management practices influence the density and diversity of weeds. Therefore, the present study was carried out to study the performance of rice with weed and nitrogen management in rice-wheat-greengram cropping system under conservation agriculture.

METHODOLOGY

An experiment was conducted during rainy seasons of 2014 and 2015 at research farm of ICAR-Directorate of Weed Research, Jabalpur. The treatments included four tillage-residue management practices, *viz.* zero tillage + rice residue (ZT + RR), zero tillage + residue burnt (ZT + RB), conventional tillage + residue incorporation (CT + RI) and conventional tillage + residue burnt (CT + RB); two N-levels, *viz.* 100% recommended dose of nitrogen (RDN) and 125% RDN,; and three weed management options, *viz.* control (unweeded check), pendimethalin 1000 g/ha (pre-emergence) followed by bispyribac-Na 25 g/ha at 25 days after sowing (DAS) (Chemical approach), and *Sesbania* co-culture + pendimethalin 1000 g/ha (pre-emergence) followed by 2,4-D 500 g/ha at 25-30 DAS followed by hand weeding at 45 DAS (Integrated weed management). Thus, 24 treatment combinations were laid out in a thrice replicated split-split plot design, keeping tillage and residue management in main plots, N-levels in sub-plots and weed management options in sub-sub-plots.

RESULTS

Zero tillage + residue retention significantly reduced weed density compared with other tillage-residue management practices during both years. During both years, integrated weed management significantly reduced weed density and biomass over the chemical weed management and unweeded practices. There was no significant impact on the weed density due to both N-levels. Tillage-residue management practices did not exert significant influence on plant height and panicle length, whereas number of tillers and panicle, and 1000-grain weight significantly varied. Higher number of tillers and panicles were recorded under ZT+RR, which was at par with CT+RI during 2014, while in 2015, ZT+RR was significantly superior to other tillage-residue management practices. The highest 1000-grain weight was noted under ZT+RR and CT+RI in year 2014, whereas ZT+RR was significantly superior in year 2015. Application of 125% N showed significant improvement in number of tillers but other yield components did not varied due to N-levels. Panicle length was at par among different weed management practices, but other yield components differed significantly. All the yield components were the highest with IWM and the lowest with unweeded check. Chemical weed management also recorded significantly superior yield components as compared to unweeded check. The grain yield was the highest under ZT+RR, which was on par with CT+RI in 2014 but significantly superior to all other practices in 2015. Grain yield did not affect significantly due to both the N-levels. IWM practice produced the significantly higher grain yield over the other two practices. Chemical approach for weed management had also a significant improvement in grain yield in comparison with unweeded check.

Table 1. Weed density, yield components and yield as influenced by tillage-residue management, N-levels and weed management

Treatment	Weed density (m^2) at 50 DAS		Plant height (cm)		Panicle density (m^2)		Panicle length (cm)		1000 grains weight (g)		Grain yield (t/ha)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Tillage-residue management												
ZT+RR	6.31(50.94)	8.07(72.14)	103.3	87.5	271.7	236.8	23.4	22.4	24.4	23.5	4.22	3.32
ZT+RB	7.15(62.39)	8.51(80.59)	101.2	84.2	248.7	217.3	23.1	22.3	23.9	21.7	3.44	2.92
CT+RI	6.74(56.11)	8.31(76.31)	102.7	86.1	266.8	225.9	23.2	22.3	24.3	22.5	4.21	3.12
CT+RB	7.20(63.67)	8.62(82.87)	102.5	83.8	255.4	212.4	23.3	22.1	23.8	21.5	3.74	2.88
LSD (P=0.05)	0.16	0.13	NS	NS	8.0	5.0	NS	NS	0.4	0.5	0.31	0.13
N levels												
100% RDN	1.58(58.47)	8.38(78.17)	102.0	84.7	257.8	222.4	23.2	22.3	24.0	22.3	3.85	3.02
125% RDN	1.79(58.08)	8.37(77.78)	102.0	85.1	263.5	223.9	23.3	22.3	24.2	22.4	3.95	3.10
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management												
Unweeded Check	11.48(131.5)	12.31(151.2)	97.4	80.7	230.2	182.5	22.9	22.0	22.6	21.4	3.08	2.23
Chemical approach	5.70(32.25)	7.23(51.95)	102.3	84.7	268.7	236.9	23.3	22.3	24.0	22.4	4.19	3.40
Integrated weed management	3.37(11.08)	5.59(30.78)	107.7	90.7	283.0	250.0	23.6	22.6	25.7	23.1	4.44	3.55
LSD (P=0.05)	0.19	0.15	2.8	1.9	7.6	9.8	NS	NS	0.5	0.5	0.19	0.10

Figures in parentheses indicate original values

CONCLUSION

Zero tillage + residue retention and recommended dose of N with effective weed control by integrated or chemical approach appeared to be the best practice for improving rice productivity in rice-based cropping system.

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Theme 3

Herbicide residues and their mitigation

Bacterial community profiling and soil enzymatic potential assessment in herbicide applied transplanted lowland rice-rice cropping system

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Alterations to soil microbial community composition and subsequent changes in microbial diversity could potentially have pronounced long-term effects on soil quality as well as impact plant health and therefore crop production (Bending *et al*. 2007). Bacteria are the most abundant and diverse group of soil microorganisms playing a vital role in recycling soil nutrients, maintaining soil structure and promoting plant growth (Nannipieri *et al.* 2003). The 16S rRNA gene sequence is used for bacterial identification or assignment of close relationships at the genus and species level. Hence the present study is taken to understand the bacterial community and soil enzymes in response to herbicide application and this will help us in selecting an appropriate management practice for more stable and sustainable agroecosystem for food production.

METHODOLOGY

The soil samples were collected from the field experiment on long term rice-rice cropping conducted during *Kharif* 2015 and 2016 in wetland, TNAU, Coimbatore at a depth of 0-3 cm on 0, 5, 15 and 30 days after application of PE pyrazosulfuron-ethyl (10% WP) as well as POE bispyribac-sodium (10% EC). Nutrient agar (NA), Burk's N-free medium and soil extract medium were used for the enumeration of total bacteria, diazotrophs and phosphobacteria, respectively. The serial dilution and pour plate technique were used for enumeration of microbial population. The soil enzymes, dehydrogenase and alkaline phosphatase activity were assayed by Nannipieri et al. (1990 and Tabatabai and Bremner (1969), respectively. The results of the both *Kharif* 2015 and *Kharif* 2016 were pooled and analysed by standard error. The 16srDNA gene fragments were amplified from selected bacterial isolates by PCR using primers, 27F and 1492R. The sequence data were generated by automated sequencing and subjected to homology search through Basic Local Alignment Search Tool (BLAST).

RESULTS

In general, total bacteria, phosphobacteria, diazotrophs and soil enzymes were decreased upto 5 days after application of herbicides, then the mciroflora were slowly increased from 15th day and reached 10 times higher at 30 day compared with hand weeding. Among the treatments, the maximum number of bacterial population (68.7 x 10^7 cfu/g of soil) and soil enzymes, alkaline phosphatase (251.5 µg p-nitrophenol/gsoil/h) and dehydrogenase (144.5 µg TPF/g soil/24h) were recorded in PE pyrazosulfuron-ethyl fb hand weeding followed by PE pyrazosulfuron ethyl fb POE bispyribac-sodium (Table 1).

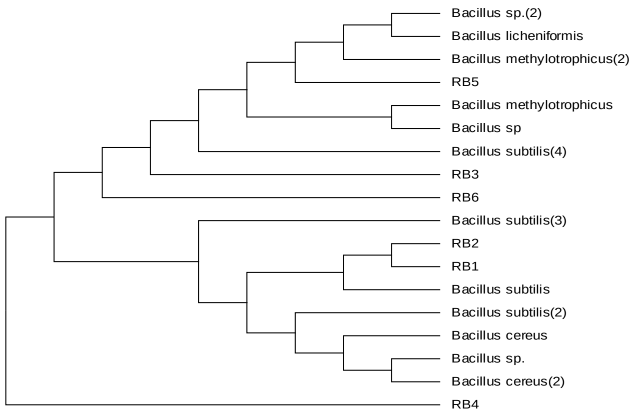

Fig. 1. Phylogenetic analysis of bacterial isolates in rice-rice cropping system by 16srDNA

Table 1. Impact of herbicides on soil enzyme activities in rice-rice cropping system (*Kharif* 2015-16)

Treatment	Alkaline phosphatase µg p-nitrophenol /g soil/h				Dehydrogenase µg TPF/gsoil/24h			
	Days after herbicide application							
	0	5	30	60	0	5	30	60
PE pyrazosulfuron-ethyl *fb* hand weeding		176.5	225.9	251.5		84.8	97.0	114.6
PE pyrazosulfuron-ethyl *fb* POE bispyribac-sodium		176.1	225.6	250.6		83.0	97.0	113.2
Hand weeding twice		205.7	221.5	236.4		90.4	96.8	108.6
Unweeded check	202.4	205.8	204.2	185.8	88.2	90.0	84.5	77.3

The 16srDNA fragments were amplified from six bacterial isolates which was predominately present during *Kharif* 2016and sequenced by automated sequencing. The result showed that the *Bacillus sp.* were predominantly present during *Kharif*, 2016 and which coming under the different species of *Bacillus subtilis*, *Bacillus cereus*, *Bacillus licheniformis* and *Bacillus methylotrophicus* (Fig. 1).

CONCLUSION

There was no detrimental change in microbial community and soil enzymes due to PE pyrazosulfuron-ethyl and POE bispyribac-sodium even though they affected the microflora and sol enzymes upto 5 days after application. Because of more substrates from all compound types (carbohydrates, carboxylic acids, amines, amino acids, polymers) of herbicides were utilized by bacteria at the high concentration compared to untreated soil. Moreover, the *Bacillus* sp. was predominately present during the cropping system which might be useful to degrade the herbicide compounds.

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Dissipation kinetics of fenoxaprop-P-ethyl in soil and residue analysis in wheat crop

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Wheat is one the most important food-grain of India and is the staple food of millions of Indians, particularly in the northern and north-western parts of the country. India is the fourth largest producer of wheat in the world and accounts for 8.7% of the world's total production of wheat. Wheat is grown on 13% of the cropped area in India. Losses due to weeds in wheat yield production range from 10-60% depending upon weed infestation. Fenoxaprop-P-ethyl {ethyl (2R)-2-[4-[(6-chloro-2-benzoxazolyl) oxy] phenoxy] propanoate} is selective post emergence herbicide of group2-(4-aryloxyphenoxy) propionic acids for controlling *Phalaris minor* in wheat crop. It inhibits acetyl CoA carboxylase (ACCase) enzyme in fatty acid and acyl lipid formations thus affecting fatty acid biosynthesis.

METHODOLOGY

Fenoxaprop-P-ethyl was applied in *Rabi* season under field condition. Two treatments consisting of fenoxaprop-P-ethyl at recommended (90 g/ha) and double recommended (180 g/ha) doses along with control were arranged in a randomized block design with three replications. Soil samples (0-15 cm depth) were collected from all plots at different time intervals to harvest time while wheat crop were taken at harvest. Samples were extracted with a mixed solvent containing ethyl acetate and methanol thrice, concentrated under pressure on rotary evaporator and subjected for cleanup with alumina solid phase extraction. Fenoxaprop-P-ethyl residues were analysed by RP-HPLC at 236 nm using C-18 ODS-II column, and mobile phase methanol:water:*o*-phosphoric acid (80:20:0.01%v/v).

RESULTS

The recovery of fenoxaprop-P-ethyl from soil, wheat grain and straw were in the range 85.10-91.25%, 72.50-84.66% and 77.64-82.24%, respectively. Fenoxaprop-P-ethyl persistence in soil was 10 and 15 days at lower and higher application dose, respectively after which it was below detectable. Dissipation of fenoxaprop-P-ethyl followed first order kinetics. The half life values calculated for fenoxaprop-P-ethyl was 1.45 days for lower application rate and 2.30 days for higher rate. At harvest fenoxaprop-P-ethyl residues were below detectable limit in soil, wheat grain and wheat straw/ plant. The limit of quantification of fenoxaprop-P-ethyl was 0.005, 0.008 and .01µg/g for soil, grain and straw.

CONCLUSION

It was concluded from the study that post-emergence application of fenoxaprop-P-ethyl is safe even at higher dose for humans and environment as residues were below MRL in soil, grain and straw of wheat.

A novel approach for estimation of imazethapyr and imazamox using gas chromatography/tandem mass spectrometry

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A new quantification method was developed using gas chromatography/tandem mass spectrometry for estimation of two imidazolinone herbicides imazethapyr and imazamox. The samples were processed by applying three methods involving ultrasonic assisted extraction, matrix solid-phase dispersion and solid-phase extraction in order to achieve an extraction procedure which can be fast, reliable, inexpensive with acceptable accuracy and precision. Percent recoveries obtained in MSPD was > 80 with good precision values expressed in term of relative standard deviation (RSD %) which was found less than 10. Linearity was good within the range of 0.001–1.000ìg/mL. The limit of detection andquantification for both herbicides were 0.001 and 0.003 ìg/g, respectively. In this study, MSPD was found superior than other methods in term of better recoveries with negligible matrix and considerable saving because of simultaneous extraction and clean-up steps.

METHODOLOGY

The samples were processed by applying three methods namely extraction based on ultrasonic assisted extraction (UAE), matrix solid-phase dispersion (MSPD) and solid-phase extraction (SPE). UAE was carried out in an ultrasonic bath of 40 KHz constant frequency at 30-35°C for 10 min by taking 10 g soil in 50 mL glass vial having 10 mL of 10 ìM ammonium acetate solution. For MSPD, a representative10 g of soil sample was mixed with 5 g of activated florisil (at 250°C for 6 hours) and 0.01 mg activated charcoal. The mixture was packed in glass column and eluted with 50 ml of methanol and 10 ìM ammonium acetate solution (7:3 v/v). In SPE, 10 g soil was taken in centrifuge tube and added 10 mL of 10 ìM ammonium acetate solution. The mixture was roto-spinned for one hour and then centrifuged at 3500 rpm for 10 min. The supernatant thus collected was concentrated to dryness over rotary vacuum evaporator (HeidolphHei-Vap) and reconstituted with 10 mL methanol. Further clean-up was achieved through C-18 extraction cartridge using 50 ml methanol. The ammonium acetate fraction collected in UAE and MSPD were also evaporated to dryness over rotary vacuum evaporator and the process was repeated thrice by adding 5 mL methanol to ensure complete removal of aqueous layer. The residues were re-dissolved in 2 mL methanol for analysis over gas chromatography/tandem mass spectrometry.

In literature, most of the instrumental methods reported for imazethapyr and imazamox detections were based on either HPLC or LCMS (Rojano *et al.* 2013 and Assalin *et al.* 2014). In present study, a MRM programme was developed for both herbicides after developing a method in SCAN and product ion.

RESULTS

Three new methods UAE, MSPD and SPE were evaluated for extraction of imazethapyr and imazamox residues from soil with slight modifications. UAE was used with the aim that such mechanical effect can provide better penetration of the solvent into the soil and therefore improve the recovery. In UAE, recovery ranged between 66.44 to 76.21%, but matrix was not clear as it was not followed by any clean–up step. Based on above observations, two more methods MSPD and SPE were used. Both the methods were quite efficient with recoveries lying between 80.1 to 88.6%. The recoveries obtained demonstrated that the accuracy and precision of the proposed methods were acceptable for residue analysis of both herbicides and the LOQ achieved (3 ng/g in this study) by these methods are in good agreement with detection limit in cereals (2 ng/g) established by European Union (EU) legislation and are lower than the concentration (5 ng/g) known to be harmful to highly sensitive crops like sugar beet. The methods were also shown to be reliable in routine analysis for determination of herbicide residues in soil. However, MSPD was found superior to SPE as the method is cheap and offered considerable saving due to simultaneous extraction and clean-up steps without using any cartridges along with good recoveries with negligible matrix even at low fortification levels.

CONCLUSION

MSPD is an efficient method for samples preparation and residues estimation of imazethapyr and imazamox in soil. GCMS/MS is highly sensitivity with high accuracy and robustness for such trace level estimations.

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Soil microbial population as affected by common herbicides in transplanted rice

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The effect of herbicides on soil physical, chemical and biological properties are quite pertinent. The growth of different microbial activities has been reduced due to applications of different herbicides (Shukla and Mishra 1999). Butachlor and Pretilachlor are the widely used herbicides in transplanted rice in the state. The herbicide application in combination *i.e.* butachlor + 2,4-D is also being applied in rice. The addition of organic matter, provides beneficial effect on biological properties of soil (Mishra *et al*. 2001). In this situation, the information in respect to the impact of herbicides in combination on the specific group of soil organisms is very limited. Therefore, the present investigation was carried out to evaluate the effect of different herbicides in combination on the soil microbial population in sandy loam soil of Bhubaneswar.

METHODOLOGY

Field experiment were conducted at Central Farm OUAT, Bhubaneswar during the *Kharif* of 2011 in the transplanted rice to evaluate the effect of different herbicides in combination with or without organic matter on the soil microbial population. Six different treatments consisting of two sole applications of pretilachlor 0.75 kg/ha with and without organic matter, two herbicide combinations *i.e* butachlor 0.75 kg/ha + 2, 4- DEE 0.4 kg/ha with or without organic matter along with two hand weedings with or without organic matter. The rice crop variety '*Khandagiri*' was sown on 21.06.2011 after following all standard packages of practices. Organic matter (OM) in the form of green manure crop *Sesbania aculeata* (of 35 days old) was incorporated at the rate of 6 t/ha in the required treatments. After harvest the surface soil (0-15cm) was collected from the trial plots, air dried and ground to pass through 5 mm sieve. The soil is of sandy loam textural class with Ph 7.1 and organic carbon 0.52 %. Microbial population in the soil sample was analysied by following serial dilution technique by taking nutrient agar medium and martins rose Bengal medium for estimation of total bacteria and total fungi populations.

RESULTS

The bacterial population of the soils varied from 20.0 to 25.0 x 10^9 / g soil. The weed control measures followed in *Kharif* rice significantly changed the bacterial population in soils. Application of butachlor with 2,4-D EE and its rotation with pretilachlor reduced the bacterial population by 9.0 % and 7.0 % over hand weeded treatments. Application of organic matter did help in stabilizing the bacterial population (24.2 x 10^9) and recorded an increase of 9.0 % over the treatments without organic matter. The population of fungi varied from 69.0 to 84.2 x 10^5/g soil. Similarly, application of herbicides decreased the fungal population by 6.4 to 9.5% over hand weeded treatments and addition of organic matter enhanced the fungal population (79.2 x 10^5 / g soil) by 8.4%. The variations in fungal population due to herbicide application in *Ksharif* were not significant (Table 1).

Table 1. Soil microbial population as influenced by different weed control measures

Treatment	Bacterial population (CFU/g soil) x 10^9	Fungal population (CFU/g soil) x 10^5
Hand weeding (Twice) - OM + inorg. Fert.	20.15	74.41
Hand weeding (Twice) + OM + inorg. Fert. (N adjusted for OM)	25.12	84.33
Butachlor 0.75 kg/ha + 2,4-DEE 0.4 kg/ha - OM + inorg. fert.	18.70	68.34
Butachlor 0.75 kg/ha + 2,4-DEE 0.4 kg/ha + OM + inorg. fert.(N adj.)	18.74	72.57
Pretilachlor 0.75 kg/ha - OM + inorg. fert.	17.88	69.04
Pretilachlor 0.75 kg/ha + OM + inorg. fert. (N adj.)	19.21	72.40
LSD(P=0.05)	1.01	5.46

CONCLUSION

The microbial population with respect to treatments were in the order: Hand weeding (twice) > butachlor 0.75 kg/ha + 2,4-D EE 0.4 kg/ha > butachlor + 2,4-D EE in rotation with pretilachlor 0.75 kg/ha

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Persistence of imazethapyr in on soybean and soil

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Imazethapyr, a systemic herbicide of imidazolinone group, is recommended for a pre-plant incorporation, pre-emergence and post emergence application. Imazethapyr is mainly used in soybean, however, its use has been extended to many other crops like corn, groundnut, oilseed rape and vegetables for major annual and perennial grasses and broad-leaved weeds (Sondhia and Varshney 2010). It inhibits acetolactate synthatase (ALS), a key enzyme in the biosynthesis of the branched chain amino acids isoleucine, leucine and valine, leading to disruption of protein and DNA synthesis. Different half-lives have been reported for different rates of application of imazethapyr. Patel et al. 2009 reported that herbicide incorporated in the soil persisted longer than imazethapyr applied to the soil surface. Similarly, soil type also affects its persistence. At the recommended dose of herbicide application, generally the problem does not arise and its selectively kills the weeds. But when the dose is more than recommended rates due to some reason or method of application, possibility of residues in soil and crop cannot be ruled out. Therefore, an experiment was conducted to study the persistence of imazethapyr residues in soil and soybean when applied to soybean crop at recommended and higher dose.

METHODOLOGY

A field experiment was conducted in *Kharif* 2010-11 at research farm of Indian Agricultural Research Institute, New Delhi in randomized block design with two rates of application of imazethapyr consisting of recommended (100 g/ha) and double the recommended (200 g/ha) doses. The soil of IARI was sandy loam with 0.4% organic carbon and 7.1 pH. The soil samples (0-15 cm) were collected at 0, 10, 20, 30, 40, 75 and 100 days while grain samples were analysed at harvest. The samples were extracted with 0.5 N NaOH solution for 1 h on a horizontal shaker followed by addition of methanol. The pH was adjusted to 2 with 6 N HCl and mixture partitioned with dichloromethane. Organic layer was collected, dried (anhydrous Na_2SO_4) and evaporated to dryness at rotavapour. Residues were analyzed on a HP-1100 series high-performance liquid chromatography equipped with diode array detector at 250 nm using C-18 column with mobile phase acetonitrile and water (70:30) at a flow rate of 1mL/min.

RESULTS

Imazethapyr gave a sharp peak at 4.5 min with instrumental detection limit of 0.05 µg/mL. LOQ of the method was 0.1 µg/g. The residues of imazethapyr were present in soil till 100 days. However, in harvest soil they were below detectable limit. Half-life was calculated using log residues. Residues dissipated with a half-life values of 19 and 20.3 days when fitted to first order kinetics. However, the residues after 45 days degraded very slow indicating biphasic dissipation. The residues in soybean grains were BDL at both the rates of application.

CONCLUSION

In spite of higher rate of application of imazethapyr the herbicide is safe for soybean in sandy laom soil as to detectable residue were found in soil at harvest time. MRL of imazethapyr in soybean is 0.1 µg/g. The residues in grains were also below detectable limit. With method LOQ of 0.1 µg/g the residues in soybean grains were also safe at both the rates of application.

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Field persistence of pinoxaden in a rice-wheat-green manure cropping system under conservation agriculture

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Wheat is the most imperative cereal crop contributing more than one-third of the total food grain production in India. In this crop, weed infestation is one of the major biological constraints necessitating the use of herbicides to avoid crop yield losses. The fate of such chemicals in soil continues to be a cause of great concern as their presence in soil may not only damage the sensitive succeeding crops but also adversely affect human and animal health. Pinoxaden, belonging to phenylpyrazolin chemical family, is widely used as post-emergence herbicide for controlling grassy weeds in wheat in northern India (Ohkawa *et al.* 2007). The tillage and residue management practices influence the behaviour and persistence of herbicides in the soil. The published information on the effect of conservation agriculture practices on dissipation rate of pinoxaden in soil and its terminal residue in wheat is scarce.

METHODOLOGY

A field study in rice-wheat-green manure cropping system was conducted in strip plot design at Ludhiana, India during 2014-15. Five tillage and residue management treatments consisted of puddled transplanted rice (PTR) with conventional tillage (CT)- wheat (CT); PTR (CT)- wheat (zero till-ZT)- green manure (GM); direct seeded rice (DSR) (CT)-wheat (CT)- GM; DSR (ZT)-wheat (ZT+ rice residue)- GM; DSR (ZT + wheat residue)-wheat (ZT+ rice residue)- GM. Three weed management treatments consisted of recommended herbicides (RH), integrated weed management (IWM) and unsprayed control. The RH and IWM plots were sprayed with pinoxaden 50 g/ha at 30 days after sowing; one late hand hoeing was done in IWM plots. The soil samples were collected from 0-20 cm depth at 0 (3 h), 3, 5, 7, 10, 21, 30, 45 days after herbicide application and at harvest. The wheat grain and straw samples were collected at harvest. Pinoxaden from soil/wheat grain was extracted by the matrix solid phase dispersion (MSPD) method (Kaur et al. 2014).

RESULTS

The mean percent recoveries of pinoxaden at the fortification level of 0.01 to 1.0 µg/g ranged from 84 to 98.1% with relative standard deviation less than 10%. Limit of detection (LOD) and limit of quantification (LOQ) was 0.003 and 0.01 µg/g, respectively.

Pinoxaden residues in soil ranging from 0.059 to 0.079 µg/g were detected at 0 day after the application. The residues decreased with time and less than 0.01 µg/g residues were detected in zero tillage treatments, PTR (CT)-wheat (ZT)-GM (ZT), DSR (ZT)-wheat (ZT + residue)-GM (ZT) and DSR (ZT + residue)-wheat (ZT+residue)-GM (ZT), 30 days after herbicide application. Under conventional tillage treatments, PTR (CT)-wheat (CT) and DSR (CT)-wheat (CT)-GM (ZT), pinoxaden residues in soil were below detection limit in 45 days after application.

Dissipation in soil followed first order kinetics (Table 1). DT_{50} ranged from 8.8 to 11.8 days in different treatments under IWM whereas under RH DT_{50} ranged from 10.1 to 17.5 days. Retaining residues of rice in ZT has effect on DT_{50} as it was comparatively greater in CT than in ZT in both IWM and RH. This could be probably due to the accumulation of crop residues in soil of ZT treatments that enhanced the organic matter content and microbial abundance.

The residues in soil and wheat grain and straw at harvest under different tillage and residue management treatment were below the limit of quantification and MRL (maximum residue limits) set by EPA.

Table 1. Regression equation, k, R^2 and DT_{50} of pinoxaden, applied to wheat, in soil in a rice-wheat green manure cropping system under conservation agriculture

Treatment	Integrated weed management				Recommended herbicide			
	Regression equation	R^2	K (/days)	DT_{50} (days)	Regression equation	R^2	K (/days)	DT_{50} (days)
PTR (CT) - wheat (CT)	y= -0.0256x + 0.937	0.962	0.059	11.8	y= -0.0172 + 0.735	0.961	0.039	17.5
DSR (CT) - wheat (CT) - GM (ZT)	y= -0.0272x + 0.906	0.997	0.063	11.1	y= -0.0178 + 0.669	0.973	0.041	17.0
PTR (CT) - wheat (ZT) - GM (ZT)	y= -0.0330x + 0.777	0.978	0.076	9.1	y= -0.0228 + 0.67	0.997	0.053	13.1
DSR (ZT) - wheat (ZT + Residue) - GM (ZT)	y= -0.0333x + 0.782	0.992	0.078	9.0	y= -0.0235 + 0.821	0.993	0.054	12.7
DSR (ZT + Residue) - wheat (ZT + Residue) - GM (ZT)	y= -0.034x + 0.853	0.998	0.079	8.8	y= -0.0298 + 0.621	0.997	0.068	10.1

PTR- Puddle transplanted rice; CT- conventional till; ZT- zero till; GM- green manure; DSR-direct seeded rice

CONCLUSION

Pinoxaden dissipation in soil followed first-order degradation kinetics. Its half-life under different tillage and residue management practices ranged from 8.8-17.5 days under IWM and RH herbicide treatments. Its harvest time residues in soil and wheat grain were below MRL. Therefore, pinoxaden could be considered as low toxicity herbicide for environment and human health.

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Degradation of imazethapyr and imazethapyr + imazamox (RM) in sandy loam soil of Hisar

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ALS inhibiting herbicides used mainly in soybean (imazethapyr) and other edible legumes for broad spectrum weed control. This herbicide has a great potential of carryover effect to next crop, which can result in weed control throughout the growing season. Though it has a half-life of 60 to 90 days under field conditions Persistence controlled by soil, climate, temperature and herbicide properties.

METHODOLOGY

The present study was conducted during *Rabi* season of 2014 in Screen house of Department of Agronomy, CCS Haryana Agricultural University, Hisar. The soil taken for experiment was sandy loam in texture, collected from Agronomy Research Farm having pH 8.1, low in organic carbon (0.3%). The treatments consisting of imazethapyr and imazethapyr + imazamox (RM) 0, 17.5, 35, 70 and 140 g/ha at different Incubation period (25ºC), viz.0, 7, 15, 30, 60 and 120 days were tried in complete randomized design (CRD) replicated four times. Mustard (RH-749) used as indicator plant. Dried and sieved soil treated 280 g/ha with solution of herbicides in 2 kg of soil lot for each incubation period. Treated soil incubated at 25^0C at given periods after completion of incubation period sample taken out from incubator and placed in Deep freezer at temperature range of -5^0C to 10^0C to arrest all reactions responsible for herbicide degradation in soil. At start of *Rabi* season, treated soil samples kept in deep freezer were taken out and serially diluted with soil having soil: sand: vermicompost in 3:1:1 to get desired concentration of herbicides. Diluted soil then filled in pot and seeding of mustard was done in filled pots

RESULTS

Imazethapyr, imazethapyr + imazamox (RM) and incubation periods had significant effect on emergence of mustard. At 15 DAS highest mean emergence 87.1% and 92.5% was recorded in imazethapyr and imazethapyr + imazamox (RM) at 17.5 g/ha, whereas significant reduction in emergence at higher rate of (140 g/ha) in both the herbicides. Reduction in emergence significantly higher in imazethapyr as compared to imazethapyr + imazamox (RM) (Table 1), results was similar with Vencill 2002.

Similarly, averaged data over herbicides and different incubation periods showed significant effect on emergence. Emergence increased with increasing incubation periods of both the herbicides at 25^0C with decreasing rate of herbicides, increasing days of incubation decreased persistence of different herbicides rate (Table 1), Singh et al. 2010 also reported increase in imazethapyr temperature incubations germination of mustard increased.

Periodical residues of herbicides remaining in soil are expressed as percentage of the initial concentration. There was 22, 56, 61, 83 and 78% loss of imazethapyr after 7, 15, 30, 60 and 120 days of incubation, whereas imazethapyr + imazamox (RM), corresponding losses were 40, 80, 87, 95 and 97% at respective incubation periods (Fig. 1).

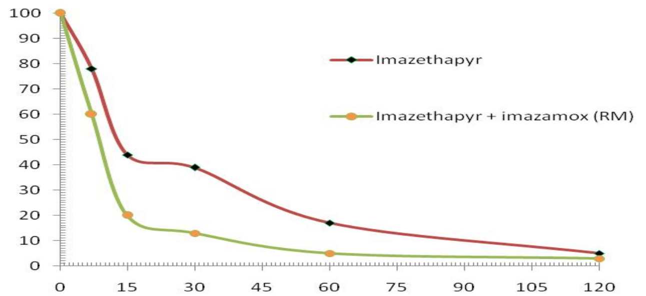

Fig. 1. DT_{50} of imazethapyr and imazethapyr + imazamox in sandy loam soil at different incubation periods.

Table 1. Residual effect of different concentrations of imazethapyr and imazethapyr + imazamox incubated for different periods in sandy loam soil on emergence of mustard.

Herbicide rate (g/ha)	Incubation period (days)						Herbicide		Mean
	0	7	15	30	60	120	Imazethapyr	Imazethapyr + imazamox	
	Emergence (%)								
140	36.9	40.0	50.0	59.4	70.0	78.8	51	60.6	55.8
70	46.3	51.9	61.3	71.3	78.8	90.0	62.3	70.8	66.6
35	52.5	60.6	71.9	79.4	87.5	100.0	72.7	77.9	75.3
17.5	73.8	80.0	88.8	96.3	100.0	100.0	87.1	92.5	89.8
0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mean	61.9	66.5	74.4	81.3	87.3	93.8	74.6	80.4	
LSD(P=0.05)	Conc.		Period		Conc. x Period		Herbicide	Herbicide x Conc.	
	1.67		1.83		4.10		1.06	2.36	

About 50% (DT_{50}) of imazethapyr and imazethapyr + imazamox (RM) was lost in 19 days and 12 days (Fig.1), dissipation time (DT_{50}) of the herbicides in the soil was found greater in clay than sandy-loam, for both imazapic and imazapyr (Ulbrich et al. 2005).

CONCLUSION

It was concluded that the imazethapyr and imazethapyr + imazamox (RM) degradation increasing with increasing incubation periods. DT_{50} of imazethapyr was higher than imazethapyr + imazamox (RM).

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Response of terrestrial weed species to pretilachlor decontamination in contaminated medium

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Nonpoint source of runoff from agricultural fields may contain high levels of nutrients, particularly nitrogen (N) and phosphorus (P), and can be a major contributor to eutrophication of adjacent surface water bodies like ponds, lakes and rivers. In addition to nutrients, a certain proportion of herbicides also reaches natural systems, via surface runoff during strong rainfall events (Schulz, 2004). Edge-of-field losses can range from less than 1% of the amount applied to as much as 10% which has impact on surface water quality viz-a-viz on non-target organisms. In this respect, development of plant consortia as buffer strip may check entry of such contaminants in adjacent water bodies. The investigation was therefore carried out to test terrestrial weeds for pretilachlor tolerance across a different range of nutrient levels.

METHODOLOGY

A pot experiment was carried out to evaluate three plant species, viz. *Vetiveria zizinoides, Typha latifolia,* and *Acorus calamus* exposed to three pretilachlor levels (0, 750 and 1500 g/ha) with and without NPK levels (120-60-60 kg/ha) at the Directorate of Weed Research, Jabalpur. The observations of plant height was taken at different stages whereas weed dry weight, root biomass, leaf area, pretilachlor residues, chlorophyll and N uptake were taken at harvest.

RESULTS

The experimental results suggested that all the plant species tolerated with optimum pretilachlor levels (750 g/ha). Among weedy plants, *Vetiveria zizinoides* showed more tolerance at higher dose of pretilachlor (1500 g/ha) than *Acorus calamus* which reflected less tolerance resulting stunted growth (Table 1). Compared to these plant species, *Vetiveria zizinoides* had strong tolerance to pretilachlor in every aspect. The order of pretilachlor uptake in plant was *Vetiveria zizinoides* > *Typha latifolia* > *Acorus calamus* whereas the order for pretilachlor residue in soil was *Acorus calamus* > *Vetiveria zizinoides* > *Typha latifolia.* Pretilachlor residue in *Acorus* rhizosphere soil remained relatively higher than *Vetiveria.* Although pretilachlor residue was lower in *Typha* soil but resulted in toxicity to its plant growth. It appears that higher concentration of pretilachlor was absorbed and translocated to shoot whereas the *Acorus* followed by *Typha* absorbed and accumulated pretilachlor in their root part. The plant height & root length, number of tillers and leaf area of *Typha latifiloa* was affected at higher dose of pretilachlor. Among three plant, *Vetiveria zizinoides* removed higher nitrogen which has implication for N remediation at contaminated sites.

Table 1. Effect of different levels of pretilachlor on fresh and dry weight of weed specie

Treatment	*Acorus calamus*		*Typha latifolia*		*Vetiveria zizinoides*	
	Fresh weight (g/pot)	Dry weight (g/pot)	Fresh weight (g/pot)	Dry weight (g/pot)	Fresh weight (g/pot)	Dry weight (g/pot)
Pretilachlor (g/ha)						
0	3.96	2.31	2.72	1.62	7.57	4.10
750	3.91	2.30	3.03	1.70	7.20	4.51
1500	3.87	1.87	2.74	1.79	8.05	4.78
SEm±	0.31	0.23	0.22	0.05	0.47	0.24
LSD (P=0.05)	NS	0.50	NS	0.12	1.05	0.53

CONCLUSION

Having ability to tolerate higher levels of pretilachor and nutrient uptake, *Vetiveria* zizinoides is a phytoremediating agent which can be incorporate into a phytoremediation scheme for removal of nutrients and decontamination of pretilachlor in soil near to surface water bodies.

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Optimization of MSPD, LLE, SPE and QuEChERS for quantification of ethoxysulfuron in soil

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Ethoxysulfuron, 3-(4, 6-dimethoxypyrimidin-2-yl)-1-(2-ethoxyphenoxysulfonyl urea) is a systemic post-emergence herbicide and widely used for post-emergence control of grassy weeds in many cereal crops and vegetables including management of *Orobanchae* in solanaceae crops. Ethoxysulfuron has the unique characteristic of exhibiting herbicidal activity against weeds that show resistance to other commercialized sulfonylurea herbicides (Rao et al. 2015). These herbicides are applied at very low dose but are persistent in environment and therefore result in environmental contaminations including various health hazards. Determining fate of sulfonylurea herbicide in soil is a challenging task because of very low analyte concentration and their acidic nature which make them difficult to extract from sample. In this study, samples were processed by applying three methods involving matrix solid phase dispersion (MSPD), liquid-liquid extraction (LLE), solid phase extraction (SPE) and modified QuEChERS in order to achieve an extraction procedure which can be fast, reliable, inexpensive with acceptable accuracy and precision. QuEChERS with slight modifications was found superior in term of better recovery, high precision with lower LOQ.

METHODOLOGY

The samples were processed by applying four methods namely extraction based on MSPD, LLE, SPE and modified QuEChERS. For MSPD, a representative 10 g of soil sample was mixed with 10 g of silica gel and 0.05 mg activated charcoal. The mixture was packed in glass column and eluted with 50 mL of acetonitrile acidified with 1% acetic acid. In LLE, the samples were extracted with 100 mL acetonitrile acidified with 1% acidic acid followed by sample clean-up using liquid-liquid portioning with 100 mL ethyl acetate. In SPE, 10 g soil was taken in centrifuge tube and added 25 mL of acetonitrile acidified with 1% acidic acid. In all processes, pH was maintained between 2.5 to 3. The mixture was vortex for 20 min and centrifuged at 3500 rpm for 10 min. The supernatant thus collected was concentrated to dryness over rotary vacuum evaporator (Heidolph Hei-Vap) and reconstituted with 10 mL methanol. QuEChERS method was applied in three ways. In first method, routine QuEChERS method was adopted using $MgSO_4$ and PSA for clean-up. In second and third methods, modified QuEChERS was applied by adding sodium acetate in place of PSA and without $MgSO_4$ clean-up, respectively. The fractions collected in all of the above processes were evaporated to dryness over rotary vacuum evaporator and the process was repeated thrice by adding 5 mL acetonitrile to ensure complete removal of aqueous layer present if any. The residues were re-dissolved in 2 mL acetonitrile for analysis over HPLC-PDA at 241 nm.

RESULTS

Four new methods MSPD, LLE, SPE and modified QuEChERS were evaluated for efficient extraction of ethoxysulfuron from soil. Recoveries experiments were performed at two fortification levels of 0.01 and 0.05 µg/g. All methods have their own advantages in term of cheapness and easy operations. But recoveries in MSPD, LLE and SPE were ranging between 40 to 65% with lot of matrix interference during analysis. Routine QuEChERS involved $MgSO_4$ and PSA clean-up was having recoveries between 60-78%. Based on above observations, two more QuEChERS methods with slight modifications provided good recoveries ranging between 80-96%. But QuEChERS involving PSA clean-up without using $MgSO_4$ was having recoveries between 89-96% with least matrix effect, good peak shape and linearity within dynamic range of 0.01-1ìg/ mL^1. The precision values expressed as relative standard deviation (RSD) were <10%. The recoveries obtained in later method demonstrated that the accuracy, precision and repeatability were acceptable for residue analysis of ethoxysulfuron and the LOQ achieved (0.03 µg/g in this study) by these methods are in good agreement with detection limits established by various regulatory agencies.

CONCLUSION

Modified QuEChERS without using $MgSO_4$ is an efficient method for sample preparation and residues estimation of low dose herbicide ethoxysulfuron in soil.

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Effect of day time application of mesosulfuron-methyl on fungal population of wheat rhizosphere

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Mesosulfuron-methyl is a broad spectrum herbicide which mostly applied as post-emergence to get rid of weed notoriety in wheat. At recommended rates, herbicides have no short- or long-term effect on microbial populations. But indiscriminate and over-application of herbicides to achieve higher weed control efficacy may have ill effects on public health and environment. They not only control target organisms, but also leave potential residual effect in soil and cause various negative impacts, such as the killing of beneficial non-target organisms. Microorganisms are of importance as they play a vital role in herbicide dissipation because they consume the herbicide molecules and utilize them as a source of energy and nutrients for growth and reproduction (Sondhia *et al.* 2013, 2016). Since the information on day time effect of mesosulfuron-methyl on soil microorganisms is not available in literature. Therefore a comprehensive study has done to see effect of day time application of mesosulfuron-methyl on fungal population of wheat rhizosphere.

METHODOLOGY

A field experiment was conducted during *Rabi* seasons of 2014-15 and 2015-16 at Product Testing Unit, Department of Agronomy, JNKVV, Jabalpur (M.P.). Fifteen treatments comprising of three doses of mesosulfuron-methyl (10, 11.5 and 12 g/ha) including one hand weeding (30 DAS) and unweeded check as a main plots treatments and were superimposed with three day times of herbicide application (8 am, 12 noon and 6 pm) as a sub plot treatments and laid out in a split plot design with four replications. Wheat variety GW 273 was sown in the experimental field with recommended package of practices. Major plant nutrients (120 kg N, 60 kg P_2O_5, 40 kg K_2O/ha) were applied through urea, single super phosphate and muriate of potash. The herbicides was sprayed as post emergence at 40 days after sowing (DAS) using a spray volume of 500 L/ha with a knapsack sprayer fitted with flat fan nozzle.

Enumeration of microorganisms

Soil samples were collected from 0-15 cm surface soil in all the plots at the time of 0, 10, and 30 days after herbicide application and at harvest during both years. The soil samples were soaked into 90 mL deionized water at the rate of 10 g, later this mixture was shaken for 10 min and kept for 5 min. Thereafter, 1 mL of the supernatant was diluted twice and inocubated in the diluted water at hte constant temperature of 30^0C. The viable microbial counts were analyzed by the standard technique of serial dilution and pour plating. Enumeration of fungi was carried out in soil extract by Rose Bengal Agar medium. After allowing for development of discrete microbial colonies during incubations under suitable conditions, the colonies were counted and the number of viable fungi [expressed as colony forming units (cfu)] per gram dry weight of soil was estimated by taking into account the soil dilutions.

RESULTS

Fungi population was influenced by doses of mesosulfuron-methyl at 5 DAA and harvest stage only but at other stages significant difference among the weed control treatments did not exist. In general, the fungal population was less at 5 DAA but it was increased with time being higher at harvest, irrespective of doses of mesosulfuron and day time effects (Table 1). The fungi population was numerically higher under mesosulfuron-methyl when applied at the lowest dose (10 g/ha), but it was declined with the increase in doses of mesosulfuron-methyl being the minimum when it was applied at the highest dose (12 g/ha). Whereas it was maximum under weedy check closely followed by hand weeding at 5 and 10 days after application but reverse was true in case of mesosulfuron-methyl applied at 12 g/ha and lower doses at 30 DAA and harvest. This is attributed to moderately toxic effect on fungi during earlier period but colonies recovered from toxic effect at 30 DAA. After 10 DAA, degree of change in fungal counts was increased as the concentration/dose of herbicide increased. In case of day time, fungal population was significantly higher when mesosulfuron applied during noon time rather than evening time of the day at 5 DAA. However, day time application of mesosulfuron-methyl did not cause significant variation on the population of fungi at 10, 30 DAA and at harvest stage.

Table 1. Effect of day time application of mesosulfuron-methyl on fungal population (two seasons pooled data)

Treatment	Fungus (10^4 cfu/g dry weight of soil)			
	5 DAA	10 DAA	30 DAA	Harvest
Main plot (herbicide dose)				
Mesosulfuron-methyl 10 g/ha	19.84	19.83	23.75	27.42
Mesosulfuron-methyl 11.5 g/ha	19.25	19.25	24.33	29.84
Mesosulfuron-methyl 12 g/ha	19.00	19.42	25.00	32.17
Hand weeding (30 DAS)	20.87	21.17	21.00	25.50
Unweeded check	21.13	21.67	21.17	26.25
LSD (P=0.05)	0.98	NS	NS	2.08
Sub-plot (day time of spray)				
Morning (8 am)	20.10	20.45	23.80	28.35
Noon (12 pm)	20.60	20.90	22.65	27.55
Evening (6 pm)	19.35	19.40	22.70	28.80
LSD (P=0.05)	0.67	NS	NS	NS

DAA- Days after application

CONCLUSION

Post-emergence application mesosulfuron-methyl is safe because it did not affected adversely the fungal population to that of non herbicidal treatments (hand weeding and weedy check plots) as the toxic effect of mesosulfuron-methyl at all day time application on total fungal population disappeared by 30 days after its application.

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Optimisation of LC-MS/MS method for the analysis of 65 herbicides in pulses

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India, even though the largest producer of pulses is not able to bridge the demand supply gap due to myriads of reasons and the Government has initiated a number of programmes and price support policies for increasing the production of pulses to ensure food security and nutritional security (Chaubey 2014, Tamang *et al.* 2015). Weed infestation in pulses is one of the constraints limiting the production of pulses. It is reported that about 17-20% losses in pulses is caused by weeds (http://farmer.gov.in/imagedefault/pestanddiseasescrops /pulses.pdf). Many developing countries like us are facing shortage of workers to hand weed fields as millions of people move from rural to urban areas. In those situations herbicides use offer much cheaper and effective alternative to manual hand weeding. Use of herbicides besides increasing crop yield and replacing tillage, also helps in reducing soil erosion, fuel use, greenhouse gas emission, nutrient runoff and conserving water (Ewald and Aebischer 2000). Increasing use of herbicides, however, is a cause of concern as sometimes overuse or misuse of these herbicides leave harmful residues in the edible portion. The food commodities are required to be monitored for the presence of these toxic residues to ensure human safety. In this context, present investigations aims at developing sensitive and selective multiresidue protocol for trace level analysis of 65 herbicides in various pulses using LC-MS/MS.

METHODOLOGY

A method involving sample processing using QuEChERS and analysis using LC-MS/MS for simultaneous identification and quantification of 65 herbicides (viz. acetochlor, alachlor, anilophos, atrazine, atrazine, bensulfuron-methyl, bentazon, bispyribac-sodium, bromacil, butachlor, butylate, chlorimuron-ethyl, chlormequat chloride, chlorpropham, clodinafop-propargyl, clomazone, cycloate, cyclopentadiene, diclofop-methyl, diclosulam, dinoseb, dithipyre, diuron, ethoxysulfuron, fenoxaprop-P-ethyl, fluazifop-P-butyl, flufenacet, fluometoron, forchlofenuron, halosulfuron-methyl, hexachloro, hexazinone, imazamox, imazethapyr, isopropalin, isoproturon, lactofen, linuron, methabenzthiazuron, metobromuron, metolachlor, metribuzin, metsulfuron-methyl, molinate, pebulate, pendimethalin, penoxsulam, pentachlorophenol, picloram, propachlor, propanil, propaquizafop, propazine, pyrazosulfuron-ethyl, quizalofop-ethyl, quizalofop-P-tefuryl, simazine, tembotrione, terbacil, trifluralin, trisulfuron and vernam) in 23 minutes run was developed after optimization of different LC and MS instrumental parameters using Shimadzu LCMS/MS-8030 instrument equipped with Zorbax Eclipse Plus C-18 column. (Agilent make). The mobile phase was mixture of A: 80:20 water (5mM ammonium formate):methanol; and B: 10:90 water (5 mM ammonium formate):methanol. In 23 minute run, under electrospray ionization mode (ESI) in positive and negative mode, MRM optimization were done for selection of best product ion for identification and quantification. A modified QuEChERS based method was used for extraction and cleanup of the herbicides in pulse matrices. Validation of method for estimation of the herbicies in different pulse matrix was done as per single laboratory validation approach.

RESULTS

The performance of the method was evaluated considering the various validation parameters, viz. Linearity, Specificity, Sensitivity, Recovery and Repeatability. A mixture 65 herbicides of 9 different concentrations were injected in the optimized method and the 9 point linear calibration curves for each herbicides were obtained in a range of 0.01 µg/g to 10 µg/g with correlation coefficient (r) of e"0.98. The ILOD for all the pesticides were achieved at 0.01 µg/g whereas method LOD (MLOD) and method LOQ (MLOQ) were found in the range of 0.01 µg/g and 0.1 µg/g, respectively. Evaluation of performance for extraction and cleanup of the herbicides in pulse matrices of the modified QuEChERS method was done by preliminary recovery experiment in 11 pulses (Soya beans, kidney bean, cow pea, kabli chana, pea, gram, blackgram, greengram, lentil, arhar and chick pea) at 1 µg/g level where all the pulses, except cow pea, have shown recovery of the herbicides in the range of 65-120%. Further recovery studies were conducted in 4 representative pulses (gram, lentil, blackgram, pea) at 0.1 µg/g level of fortification using modified buffered QuEChERS method standardised for low moisture foods. It was observed that due to pulse matrix interference around 80% of the herbicides were recovered in acceptable range of 70-120% with accepable repeatability (RSD d"20%) when compared agaist solvent standard. The matrix interferences were nullified by the use matrix match standard. In each case matrix match calibration curves were prepared for each herbicides and corrected recoveries of all the herbicides were obtained within acceptable range.

CONCLUSION

The developed method with mass confirmation technique is effective in detecting and quantifying the residues of 65 herbicides and can be used routinely for monitoring of these herbicides in pulses meant for export as well as domestic consumption.

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Adsorption efficiency of chitosan-bentonite biocomposite for removal of imazethapyr from water

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Imazethapyr (2-[4,5-oxo-1-H- imidazol-2-yl]-5ethyl-3-pyridine carboxylic acid) belonging to imidazolinones family, is extensively used as pre-plant incorporated, pre-emergence and post-emergence herbicide for weed management in various crops. The mode of action involves the inhibition of acetolactate synthase, the first enzyme in the biosynthesis of branched chain amino acids (leucine, isoleucine and valine), leading to the disruption of protein and DNA synthesis. Imazethapyr is a highly water soluble, persistent and mobile herbicide which act as a potential groundwater contaminant and shows toxicity to aquatic organisms such as fish, freshwater alga and aquatic vascular plants (Magdaleno *et al.* 2015). Thus, an attempt was made to develop effective adsorbent for remediation of imazethapyr from water.

METHODOLOGY

Chitosan-bentonite (CB) biocomposite was synthesised using ultrasonic assisted extraction and confirmed using spectral techniques. Adsorption experiments were carried out using batch technique according to OECD procedure (OECD 2000). Adsorbent was added into 10 mL aqueous solution of imazethapyr (pH= 5) for concentration ranging between 0.1-100 µg/mL and shaken on a mechanical shaker at 150 rpm for 24 hrs. After equilibration, the suspension was centrifuged at 3,000 rpm for 10 min and herbicide residues were quantified using liquid chromatography tandem mass spectrometry (LC-MS/MS). The adsorption efficiency of CB biocomposite for imazethapyr was calculated from the equation:

$$Adsorption\,\% = \frac{C_i - C_e}{C_i} \times 100$$

where C_i (ìg/mL) and C_e (ìg/mL) is the initial and equilibrium concentration of herbicide, respectively. To study the regeneration of the adsorbent, desorption was conducted twice with distilled water and suspension was equilibrated. All experiments in this study were performed in trip-licate.

RESULTS

The adsorption equilibrium was attained within 24 hrs and beyond this no significant adsorption was observed. Adsorption kinetics of imazethapyr onto the biocomposite followed pseudo-second order kinetics with coefficient of correlation (R^2)>0.99. The adsorption efficiency of CB biocomposite under optimized conditions ranged between 90.67 to 96.90%. Adsorption data fitted well to the Freundlich isotherm (R^2 > 0.97) as compared to Langmuir isotherm. The adsorption capacity of imazethapyr was found to be 184.93 ìg/g. The adsorption at different concentrations was found to favourable as supported by adsorption intensity (1/n) and separation factor (R_L). Desorption studies suggested that adsorbed imazethapyr could be recovered, but the extent of percent desorption was found to decrease with an increase in cycle number.

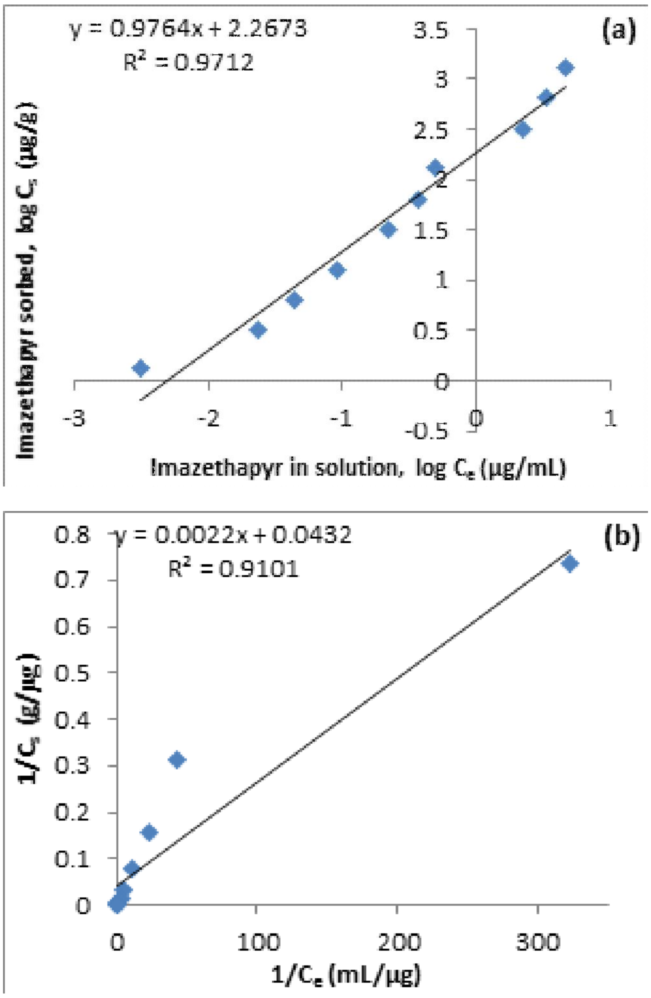

Fig. 1. (a) Freundlich isotherm (b) Langmuir isotherm for imazethapyr adsorption on CB biocomposite

CONCLUSION

Adsorption study showed that about 96.9% of imazethapyr could be removed using chitosan-bentonite biocomposite as adsorbent which could be efficiently desorbed. However, chemical modifications on adsorbent need to be explored in order to further improve the removal efficiency of imazethapyr from water.

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Evaluation of leaching potential of bispyribac-sodium in sandy loam soil of Punjab

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Behaviour of herbicides in soil is determined by a number of physical, chemical and biological processes including degradation, adsorption–desorption, volatilisation and leaching. Among these processes, leaching of herbicide in soil is an important process that determines their fate in soil and aquatic environment. The leaching process is influenced by several physico-chemical and environmental factors such as soil texture, solubility, adsorption and amount of herbicide in the soil, and climatic conditions. Bispyribac-sodium [sodium 2,6-bis(4,6-dimethoxypyrimidin-2-yloxy)benzoate] is a selective herbicide of the group pyrimidine benzoates employed for post-emergence control of grasses, sedges and broad-leaved weeds in rice fields (Fischer *et al.* 2000). It is faintly acidic compound and has high water solubility (73300 mg/L). Based on its physical and chemical properties, it has the potential of diffusing easily in the soil, resulting in possible contamination of groundwater and surface water in surrounding areas through runoff and leaching and adversely affecting terrestrial and aquatic life (USEPA 2001). Keeping in view the scanty information available on the leaching behaviour of bispyribac-sodium in Punjab soil, the study was conducted to evaluate leaching potential of bispyribac-sodium in sandy loam soil.

METHODOLOGY

Sandy loam soil (0-20 cm depth) was collected from the field of the Punjab Agricultural University, Ludhiana, with no herbicide application. Leaching studies were carried out in a randomized design with three replicates in polyvinyl chloride (PVC) columns uniformly packed with soil. Columns were saturated with distilled water prior to herbicide application. Bispyribac sodium (10% SC) was applied at 2 µg/mL and 4 µg/mL to soil columns. The columns were leached with 210 mL of water daily for 10 days (equivalent to 300 mm rainfall). The leachate fractions from the columns were collected and were analyzed for herbicide concentration. At the end of experiment, columns were cut into two equal halves and the soil was sampled from 10 cm segments for residue analysis. Bispyribac sodium from water and soil was extracted using salting out assisted liquid-liquid extraction (SALLE) and matrix solid phase dispersion (MSPD), respectively and quantified using HPLC.

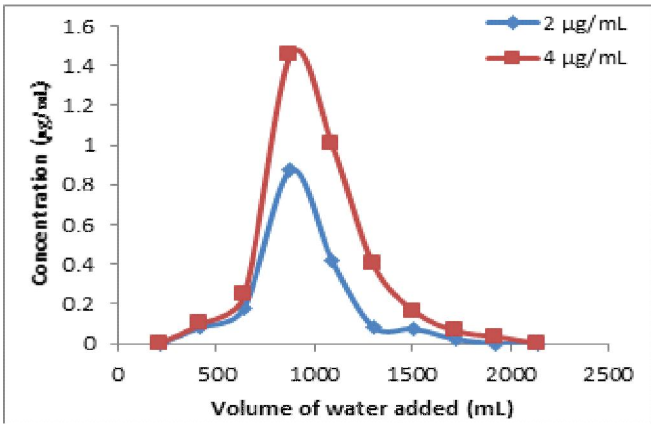

Fig. 1. Breakthrough curve for bispyribac-sodium at 2 µg/mL and 4 µg/mL dose rate

RESULTS

The mean percent recoveries for triplicate soil and water samples at fortification level of 0.01-1.00 µg/mL varied from 92.5-98.7. The limit of detection and limit of quantification were 0.003 and 0.01 µg/g, respectively. The concentration of bispyribac-sodium was found to vary with the applied dose rate. The results revealed that maximum concentration of 86.7% bispyribac-sodium was detected in leachate whereas 8.1% was recovered from the soil. Comparatively higher residues were detected in leachate fractions at 4 µg/mL dose rate as compared to 2 µg/mL. This could be probably due to high water solubility of bispyribac sodium which might have resulted in its less adsorption in soil.

CONCLUSION

Maximum concentration of bispyribac sodium present in the leachate was indicative of its high probability of penetrating into the deeper layers of the soil and consequently may contaminate the ground water.

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Dissipation kinetics of penoxsulam in sandy loam soil

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Use of herbicides to control weeds, primarily with the intention to increase yield, has been a common practice in global agricultural production technology. However, their excessive, repeated and indiscriminate use may also result in unintentional exposure of the ecosystem causing phytotoxicity to crops, residual effect on susceptible succeeding crops, aquatic life and other non-target organisms and ultimately hazards to human health. Thus, it is imperative to monitor herbicide residues in various commodities to assess their buildup, bio-magnification and bioaccumulation. Penoxsulam [3-(2,2-difluoroethoxy)-N-(5,8-dimethoxy[1,2,4] triazolo[1,5-c] pyrimidin-2-yl)-á,á,á-trifluorotoluene-2-sulfonamide], a new acetolactate synthase (ALS) inhibiting triazolopyrimidinesulfonamide (TSA) herbicide is used for post-emergence control of annual grasses, sedges and numerous broadleaf weeds in rice cultivation (Roberts *et al.* 2003). It is absorbed via leaves, shoots and roots and is translocated in plants to meristematic tissues. Penoxsulam is water soluble, hydrolytically stable, non-volatile and highly mobile herbicide that gets weakly adsorbed to non-acidic soils but is moderately adsorbed to acidic soils and has unacceptable risk for aquatic plants. Scanty information is available on the dissipation of Penoxsulam in Punjab soil hence the present study is undertaken to study dissipation behaviour of Penoxsulam in sandy loam soil under laboratory conditions.

METHODOLOGY

Air dried and sieved soil samples were added into plastic plots and saturated using distilled water. Soil was fortified using penoxsulam (240 SC) at two doses, *viz*. 22.5 g/ha and 45 g/ha and the contents were thoroughly mixed and incubated. Control samples were also incubated under identical conditions. Soil samples from treated and control pots were collected at 0, 1, 5, 10, 15, 30, 45, 60 and 90 days after treatment for estimation of penoxsulam residues. Penoxsulam from soil samples was extracted using matrix solid phase dispersion method (Kaur *et al.* 2014) and quantified using HPLC with UV detector.

RESULTS

The LOQ and LOD were found to be 0.01 and 0.003 ìg/g, respectively. No penoxsulam residues were detected in soil before treatment as well as in control pots. After the application of penoxsulam, the residues were found to vary with the applied concentration under field capacity. More than 75% of penoxsulam in soil dissipated within 45 days after application in both treatments (Fig. 1). Dissipation parameters of penoxsulam were calculated using first order kinetics. Penoxsulam in soil at 22.5 and 45 g a.i/ha dissipated according to equation as y = -0.018x + 2.498 and y = -0.013x + 2.618, respectively. Half-lives and other statistical parameters of dissipation of penoxsulam calculated from experimental data are summarized in table 1.

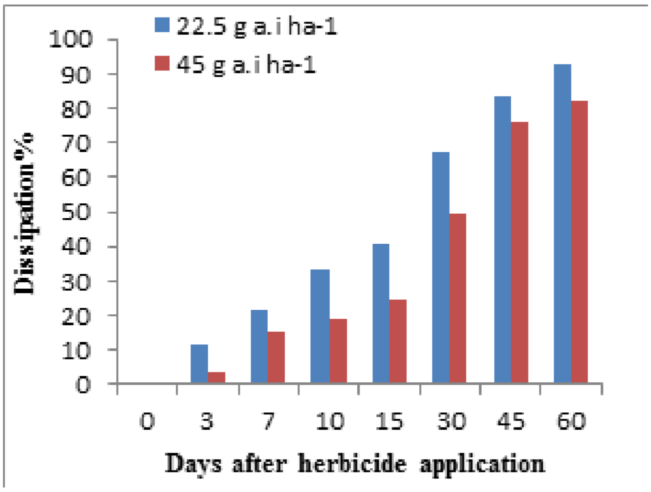

Fig. 1. Dissipation percentage of penoxsulam in soil after application

Table 1. Half-lives and statistical parameters of penoxsulam in soil

Dose (g/ha)	equation	k (/day)	DT_{50} (days)	Coefficient of determination (R^2)
22.5	y= -0.0173x +2.498	0.0397	17.44	0.993
45	y= -0.0132x +2.618	0.0132	22.71	0.980

CONCLUSION

The dissipation of penoxsulam in soil varied with the applied dose rate. It follows first order kinetics and half life ranged from 17.44 days to 22.71 days.

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Variations in soil microbial load with time due to applied herbicides in greengram

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Application of herbicides leads to unseen fluctuations in the microbial population present in the soil which can disturb their ecological balance. It is expected that its consumption will rapidly increase in future than any other pesticide. This has led to many unwanted problems (weed resistance development, residual effect, *etc*.). At the same time, we cannot draw any universal pattern of the herbicidal effect on soil (Radivojevic *et al.* 2004). This paper focuses on the fluctuation of different types of microbial population with time due to application of pre- and post-emergence herbicides in greengram. This includes total heterotrophic bacteria, fungi, actinomycetes, symbiotic nitrogen fixing bacteria and free living nitrogen fixing bacteria.

METHODOLOGY

The experiment was conducted in the Agronomy Main Research Farm, OUAT, Bhubaneswar during summer season of 2016 (March-May). The experimental design followed was RBD with seven treatments and three replications imposed on greengram variety PDM 139. The crop was grown with all the recommended packages of practices. The herbicidal treatments were oxyfluorfen 0.03 kg/ha (T1), pendimethalin 0.75 kg/ha (T2), pretilachlor0.5 kg/ha (T3), propaquizafop 10 EC 100 g/ha (T4), Na acifluorfen 16.5EC + clodinafop-propargyl 8 EC 2.5 kg/ha (T5), Na acifluorfen 16.5 EC + clodinafop propargyl 8 EC 1 kg/ha (T6) and control where no herbicide was applied (C0). The treatment T1, T2 and T3 were applied as pre-emergence 1 DAS (days after sowing) while T3, T4, T5 and T6 as post-emergence 10 DAS. Soil samples were collected from 0-15 cm depth at 0 DAS, 16 DAS and 60 DAS for microbial analysis. The analysis was done for total heterotrophic bacteria, fungi, actinomycetes, symbiotic nitrogen fixers and free living nitrogen fixers by growing them in media like nutrient agar (NA), rose bengal (RB), actinomycetes isolation agar (AIA), yeast mannitol agar (YMA) and Burk's media (BUR), respectively through the serial dilution and spread plate method.

RESULTS

It was found that the microbial population or load (ML) was significantly different among the treatments due to different modes of action of the herbicides and their doses taken. In the NA media (Fig.1) application of oxyfluorfen had significantly highest ML than others. Similar results were reported by Trimurtulu *et al*. (2015) in blackgram. But in pendimethalin, the ML rose by 84.6% from 16 DAS to 60 DAS unlike control (7.1%) although its final ML remained lower than that of control. This might be due to initial death of bacteria. Similarly the ML of propaquizafop was at par with control. This might be due to presence of more number of dicot weeds compensating for the carbon source of microbes as it kills grasses only by inhibition of acetyl Co-A carboxylase. In case of Na acifluorfen 16.5 EC + clodinafop-propargyl 8 EC 2.5 kg/ha, there was a significantly sharp downfall in ML after 16 DAS as compared to its dose1kg/ha, indicating the negative impact if higher doses. Pendimethalin showed a gradual rise in ML till the end of the season but its ML remained significantly lower than oxyfluorfen**.** The lowest ML was reported in the treatment of pretilachlor.

In RB media (Fig. 2), the total fungal count of oxyfluorfen was significantly highest than rest of the treatments. The fungal population remained lower than control in T2, T3 and T5. In case of YMA media (Fig. 3), the ML of symbiotic nitrogen fixers of Na acifluorfen 16.5EC + clodinafop-propargyl 8 EC 2.5 kg/ha and propaquizafop was significantly higher than the rest. But the ML drastically reduced to the lowest of 0.019 x10^6 cfu/g soil in the former followed by propaquizafop**.** In this case control (C0) was the best one dictating the susceptibility of these groups of microbes to herbicides. On the other hand, in AIA media (Fig.4), the actinomycetes' population increased significantly in pendimethalin treated plots while the ML was 10 times lower than its initial load at 0 DAS in oxyfluorfen treated plots. In case of BUR media (Fig. 5), oxyfluorfen and C0 had the significantly highest ML and were at par. Pendimethalin and C0 seemed to increase the ML even after 16 DAS unlike others indicating the harmlessness of the former to these microbes. Rest of the treatments negatively affected the ML of free living nitrogen fixers.

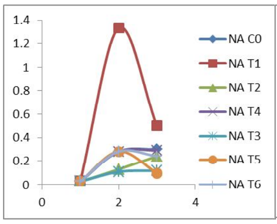

Fig. 1. Microbial load of heterotrophic bacteria*

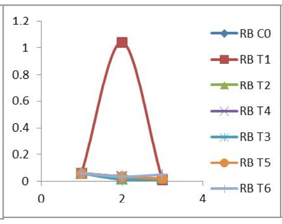

Fig. 2. Microbial load of fungi*

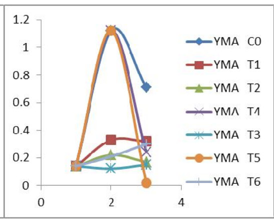

Fig.3. Microbial load of symbiotic nitrogen fixers*

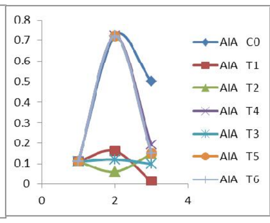

Fig.4. Microbial load of actinomycetes*

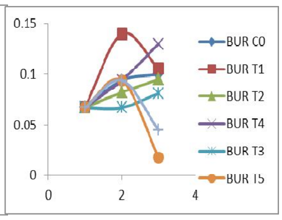

Fig. 5. Microbial load of free living nitrogen fixers*

* The x-axis shows 0 DAS, 16 DAS and 60 DAS while the y-axis shows the microbial population in 10^6cfu/g soil.

CONCLUSION

Application of herbicides negatively affects the microbial population of soil challenging the maintenance of ecological balance and soil health except for some molecules like Oxyfluorfen have positive effects to some extent. In case of pulses like greengram the death of nitrogen fixing bacteria can lead to drastic yield reductions. Thus, new ways to manage weeds must be carved out.

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Evaluation of harvest residues of sulfosulfuron in wheat

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Sulfosulfuron[1-(4,6-dimethoxypyrimidine-2-yl)-3-(2-ethylsulfonylimadazo[1,2-á]pyridin-3-yl)sulfonylurea] belongs to group B herbicides of sulfonylurea class. Sulfosulfuron is a selective, systemic, post-emergence herbicide having broad action spectra and high degree of selectivity. It effectively controls growth of both grassy and broad leaved weeds in wheat. The fate and environmental behaviour of sulfosulfuron is of concern as few studies have shown that sulfosulfuron residues caused phytotoxicity to sensitive crops in crop rotation systems (Montanya *et al.* 2006, Walia *et al.* 2006). Studies have also revealed that the next crop in rotation can be affected by the residual activity of sulfonylureas even at very low dosages (Brar *et al.* 2007). Therefore, it is of importance to study the terminal residues of sulfosulfuron in soil.

METHODOLOGY

At the Research Farm of Department of Agronomy, CSKHPKV, Palampur during *Rabi* season a field experiment consisting of four treatments replicated five times was laid out in randomized block design. Herbicide treatments applied were sulfosulfuron as Post-emergence 10 g/ha, 20 g/ha and 40 g/ha along with control. Soil, wheat straw and grain samples were collected at the harvest of crop. HPLC method was standarised for the analysis of sulfosulfuron using C_{18} column and acetonitrile: water (70:30) as mobile phase at 220 nm wavelength when it was eluted at 2.27 min. Samples after application were drawn, extracted , cleaned up and analysed for herbicide residue by HPLC.

RESULTS

Residue data in soil, wheat straw and grain are extremely important as they permit the prediction of the levels likely to remain in soil and consumable commodities and allow the assessment of risk associated with exposure. Terminal residues of sulfosulfuron in soil, wheat straw and wheat grain were determined by estimating sulfosulfuron concentration at the maturity of the crop. The data (table-1) on terminal residues of sulfosulfuron in soil, wheat straw and wheat grain indicate that residues of sulfosulfuron were below detectable levels (d" 0.001 µg/g) in soil, straw and grain samples at harvest.

Table 1. Terminal residues of sulfosulfuron in soil, wheat straw and grain

Rates of herbicide application	Residues* (µg/g)		
	Soil	Wheat straw	Wheat grains
Sulfosulfuron 10 g/ha	BDL	BDL	BDL
Sulfosulfuron 20 g/ha	BDL	BDL	BDL
Sulfosulfuron 40 g/ha	BDL	BDL	BDL

*Values are mean of five determinations; BDL means Below detectable limit

CONCLUSION

The residues of sulfosulfuron were completely lost from harvest soil, wheat straw and grain as they were below detectable levels.

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Effect of herbicides on soil fungal diversity of wheat field

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Soils are highly complex systems, with many components playing diverse functions mainly due to the activity of soil organism. Soilmicro flora plays a pivotal role in evaluation of soil conditions and stimulating plant growth. Fungi are an important component of the soil micro biota (Sondhia *et al*. 2013, 2016). Herbicide application on agricultural field can affect the micro flora of soil. Therefore, the objective of this study was to study the effect of herbicides on fungal diversity on soil treated with herbicides combination to manage weeds in wheat field during *Rabi* 2016-17.

METHODOLOGY

Sampling site of this study was wheat field that was treated with total (sulfosulfuron + metsulfuron) and vesta (clodinofop + metsulfuran) at ICAR-Directorate of Weed Research, Jabalpur in *Rabi* 2016-17. Soil samples were collected from five different spots at different time intervals as 0, 5, 10, 20 and 30 days. Soil samples from each treated plotwere mixed to obtain a representative sample. Soil fungiwere enumerated by soil dilution method (Waksman 1922). Dilution of 10^{-5} was used to isolate fungi. Potato dextrose agar with rose Bengal medium was used for isolation of fungi from soil. Microbial population was recorded on 5^{th} day. Fungal colonies morphology was studied macroscopically by observing colony features and microscopically.

RESULTS

The soil micro flora in wheat field treated with herbicide was affected at different time intervals by the application of herbicides. On the basis of identification the most common fungi such as *Aspergillus niger, Aspergillus flavus, Aspergillus nidulans, Aspergillus nigricans, Fusarium* sp., *Penicillium* sps., *Clodosporium* sps., *Rizopous* sps. were found as dominant species. Fungal growth as on fifth day is shown in fig. 1. Fungal populationas affected by the application of total and vesta was found to be in the range of 24 to 38 cfu/g and 18 to 36 cfu/g, respectively.

Fig 1. Effect of herbicides on fungal population at different time intervals

CONCLUSION

Fungal population was found to be affected by the application of herbicides in wheat field. Soil samples were studied for micro flora diversity. Results obtained showed *Aspergillus sp*. and *Clodisporium* sp.were of high occurrence.

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Persistence and dissipation of pretilachlor in soil and rice plant under conservation agriculture system in Assam

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Pretilachlor, a popular herbicide of Assam belonging to the acetamide group, is used as pre-emergence weed control of rice and pendimethalin as pre-emergence weed control of mustard and greengram in rice-mustard-greengram cropping sequence in the conservation agriculture experiment. However, this system is more demanding on the soil and has created nutrient imbalance besides increasing problems of specific weeds, pests, and diseases. Continuous application of specific herbicides over years has severely affected weed dynamics and pattern resulting increased population of specific weeds and possibly development of tolerance to the herbicides. The present investigation has taken up with an objective of monitoring and investigating the long term effect of weed control practices on crop productivity, soil health as well as shift in weed flora and their dynamics has become a need of the hour.

METHODOLOGY

The experiment initiated during the year 2016 with acidic in soil reaction at Instructional-cum-Research Farm, Assam Agricultural University, Jorhat-13. The experiment was consisting of five treatments, *viz*. T_1 and T_2 – conservation tillage (transplanted); T_3 and T_4 – conservation tillage (direct-seeded); T_5 – conservation tillage (direct-seeded) with plant residue incorporation and Basundharaas transplanted rice and direct seeded rice variety. Representative surface soil samples (0 – 15 cm) were collected periodically from the day of herbicide application (within 4 hours of herbicide application) till the harvesting of winter rice (1st rice crop) and dried under shade. The soil samples were processed and stored in polythene bags for analysis of various physico-chemical parameters and pretilachlor residue. The soil of the experimental field was sandy loam in texture with CEC 6.28 c mol(p^+)/kg, organic Carbon 0.92%, available N 260 kg/ha, available P_2O_5 19 kg/ha, available K_20 86 kg/ha.The recommended dose of NPK was 40:20:20 and the rate of application of pretilachlor was 750 g/ha. The representative paddy grain (20 g), straw (20 g) and soil (50 g) sample were processed and cleaned up for the estimation of pretilachlor residues, which were analysed analysed in GC-1000 and ECD as detector. Recovery investigation was done for validation of the method described for the sample preparation. The retention time was recorded 11.013 minute.

RESULTS

The recoveries obtained for the substrates were in acceptable range of 84.34- 99.0%.The calibration curves obtained by plotting the concentration against average peak area were linear over the range 0.05 – 0.25 µg/mL (Fig. 1). The regression equation and correlation coefficient (R^2) for pretilachlor was as follows:

$$Y = 189.91683x + 0.21436. R^2 - 0.9998$$

The limit of detection (LOD): 0.016 mg/kg

The limit of quantification (LOQ): 0.05 mg/kg

The dissipation of pretilachlor in soil followed a pseudo first order equation. The decrease in residue levels during the days after treatments in soil is presented in Table (a). revealed thatpretilachlor residue level ranged 3.14- 3.92 microgram/kg on the day of application of pretilachlor and observed upto the ranged 0.001-0.013 microgram/kg on the 21st day of application of pretilachlor. This lower persistence of residue may be due to higher microbial population towards the later part of pretilachlor application as reported by Dharumarajan *et al.* (2011) and Kaur *et al.* (2015).The pretilachlor residue level was recorded at BDL from the 30th day of applicationand in after harvest soil as well as in plant samples. Similar inferences on lower persistence of herbicide with high soil organic matter had reported (Fajardo *et al.* 2000a and Fajardo *et al.* 2000b). In the present study concluded that pretilachlor in soil dissipated below detectable level (BDL) within 30 days after application as well as after harvest soil and plant samples.Irrespective of treatments, residues are persisted up to 21 days of application in soil.

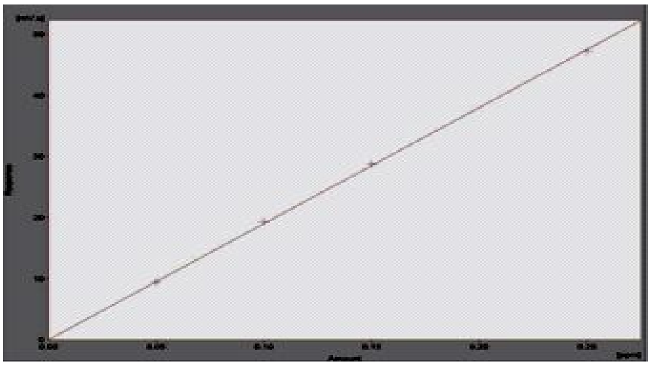

Fig. 1. Pretilachlor standard calibration curve

Table 1. Pretilachlor residues in soil in long term Conservation agriculture experiment during 2016

Treatment	Pretilachlor residue(µg/kg)					
	0 days	3 days	7 days	15 days	21 days	30 days
Transplanted	0.364	0.248	0.170	0.087	0.009	BDL
	0.352	0.255	0.168	0.013	0.006	BDL
Transplanted	0.386	0.265	0.157	0.027	0.005	BDL
	0.375	0.278	0.183	0.036	0.001	BDL
Direct seeded	0.332	0.238	0.169	0.025	0.004	BDL
	0.328	0.242	0.174	0.018	0.001	BDL
Direct seeded	0.314	0.234	0.198	0.024	0.006	BDL
	0.318	0.229	0.158	0.097	0.013	0.002
Direct seeded	0.392	0.289	0.186	0.066	0.008	BDL
	0.386	0.292	0.196	0.026	0.005	BDL

BDL- Below Detectable Limit

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Residual Effect of pendimethalin and other herbicides applied in pigeonpea on succeeding crop of greengram

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Field experiment was conducted during 2012 and 2013 in the Research Area of College Farm, Navsari Agricultural University, Navsari to study the effect of residual behavior of pendimethalin applied in pigeonpea on succeeding greengram crop grown in rotation. Residual effect of pendimethalin was assessed by conducting bioassay studies on greengram in a randomized block design with three plant population levels 83,333 plants/ha (P_1)' 55,555 plants/ha (P_2) and 41,666 plants/ha (P_3) and eight weed management practices *viz*. (W_1) Unweeded control, (W_2) weed free (HW at 20 and 40 DAS), (W_3) pendimethalin 1 kg/ha as pre-emergence (PE), (W_4) imazethapyr 75 g/ha (POE) at 20 DAS, (W_5) quizalofop-ethyl 40 g/ha (POE) at 20 DAS, (W_6) pendimethalin 1 kg/ha (PE) + imazethapyr 75 g/ha (POE) at 40 DAS, (W_7) pendimethalin 1 kg/ha (PE) + quizalofop-ethyl 40 g/ha (POE) at 40 DAS and (W_8) pendimethalin 1 kg/ha + hand weeding at 40 DAS were evaluated in factorial randomized block design with three replications. After harvest of pigeonpea, greengram crop was planted after slight disking without disturbing the original layout. pendimethalin applied in pigeonpea was found to persist even after 35 days after its application in pigeonpea and its residues in the soil medium do not caused phytotoxicity to succeeding crop of greengram. Plant population, plant height, number of branches per plant, dry matter weight and yield of greengram were non-significantly by pendimethalin. The residual effect of pendimethalin on greengram was not found to be significant. Neither the growth parameters nor the yield of greengram were not affected significantly by plant populations in wheat. Therefore, it can be inferred that increasing plant populations not helped in degradation of pendimethalin and greengram should be planted in rotation with pigeonpea where pendimethalin has been applied in pigeonpea.

Controlled release formulation technology for sustainable herbicides application

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In recent years, the development of modified natural polymers as controlled release devices in agro-industries has emerged as a new technology with better commercial viability than conventional synthetic polymers as latter are known to have various environmental concerns. Therefore, the research programming now a day are more orientated toward finding the suitable alternative for film-forming membrane material that can be safely used in agro-industries. Starch is a natural polymer available in large amounts from several renewable plant sources. It is cheap, non-toxic, bio-degradable and can be effectively used in native form or after derivatization and cross-linking as an encapsulating matrix for the controlled release of herbicides (Chen *et al.* 2008). The present article provides an approach for direct encapsulation of various herbicides within the matrix of natural starch and a co-polymer of starch- starch-g-poly (L-lactide). This can results in precise release of herbicides needed for weed control over a desired time period with other benefits like reduced herbicides availability for leaching, increased period of weed control in short-lived herbicides, low herbicide losses from volatilization, photolysis and degradation along-with reduced crop injury and better efficacy.

METHODOLOGY

Preparation of starch/agrochemical composite films for encapsulating herbicides involves gelatinization of the starch obtained from a natural source like corn. For gelatinization 2 g dry starch base was dissolved in 20 ml distilled water to form dispersion in a beaker maintained over thermostat oil bath at 90ºC for 30 minute. Blend the agrochemical directly into the hot gelatinized starch paste with glass rod and allowing natural retrogradation, a physical process by which hydrated or soluble starch molecules reassociate and revert to water-insoluble forms. The extruded materials were cooled, dried, ground, and sieved to obtain granular products of 10-20 and 20-40 mesh. For preparation of starch-g-PLLA/agrochemical composite films the starch surfaces was modified by reacting the hydroxyl groups on the starch with L-lactic acid, and then the St-g-PLLA was synthesized in situ by the ring-opening graft-polymerization of L-lactide (LLA) monomers onto the modified surfaces of the starch granules in the presence of $Sn(Oct)_2$ as a catalyst. Starch-g-PLLA (2 g) and herbicide to be formulated (0.2 g) was dissolved in DMSO (30 ml). The solution was stirred for 0.5 hrs at room temperature and then cast in a Teflon coated Petri-dish. The solvent was allowed to evaporate slowly at 60ºC.

RESULTS

Although the natural starch is an effective material for agrochemical encapsulation but it is a polysaccharide

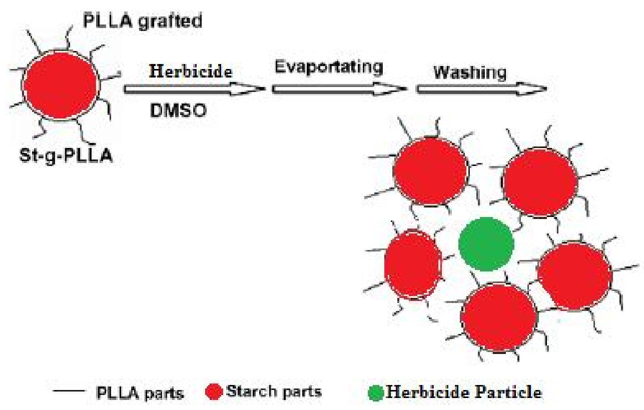

Fig. 1. The mechanism of the urea encapsulation film formed by the PLLA modified starch

polymer with many hydroxyl groups that make the starch matrix hydrophilic and capable of absorbing water and swelling dramatically in aqueous solution. Consequently, the matrix provides an effective control over the herbicides encapsulated in the starch only for a relatively short period of time after rainfall or irrigation, which reduce the survival life in field uses, especially in heavy water environments. In order to improve starch encapsulation properties for hydrophobic behavior, it can be co-polymerized with L-lactide. The St-g PLLA exhibits relatively low swelling in nature, large encapsulating capacity and slow-release rate. It can be applied especially to herbicides and fertilizers also with higher water solubility. The water-resistance of the matrix could be improved by increasing PLLA graft efficiency on the starch granules. At the time of synthesis of St-g PLLA some homo-poly(L-lactide) (PLLA) may be generated because of the initiation by free OH groups or the trans-esterification of the growing molecular chains. The graft copolymer and homo PLLA could be easily separated based on their different solubility in toluene.

CONCLUSION

Both native starch/urea and PLLA-grafted starch/urea composite films can be prepared and used but St-g-PLLA is more effective material for encapsulating water-soluble agrochemicals.

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Theme 4

Non-chemical methods of weed management

Effect of plant based products on weed index and yield attributes in organic brinjal

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Brinjal (*Solanum melongena* L.) is an important commercial vegetable crop. It belongs to the family solanaceae. Brinjal is also variously known as Egg plant or Aubergine (French name) or Guineasqaush. It is one of the most common, popular and principal vegetable crops grown in India and other parts of world. India is regarded as the centre of origin of brinjal crop. Weeds pose most serious problem in organic brinjal cultivation because of liberal use of farmyard manure and frequent irrigations that help the weeds to grow vigorously. It has been well established that losses from weeds accounts for 45% more than when compared to insect, pest and diseases about 30 and 20%, respectively. In most of the vegetables crops, the early growth period is the most critical stage at which stresses of any kind affects the economic yields. Weed competition is one such important stress during this period. Besides, this period coincides with the season of peak labour activity leading to scarcity of labour for weeding. This adds to the already high costs of production. So proper non chemical weed control method, therefore, is the prime need and very much essential to obtain maximum productivity. Use of plant based products for weed control have gained importance in recent days and also serves as one among the eco friendly methods to control weeds.

METHODOLOGY

Field experiment was conducted at organic farmer's field Annur, Coimbatore during 2015. The experiment was laid out in randomized block design with three replications. Treatments were pre-emergence application of corn flour 1.0 t/ ha, pre-emergence application of corn flour 1.0 t/ha along with one hand weeding on 60 DAT, pre-emergence application of sunflower dried stalk solution 1:10 w/v basis, Pre-emergence application of sunflower dried stalk solution 1:10 w/v basis along with one hand weeding on 60 DAT, live mulching with Navathaniam (multi varietal crops) and sunnhemp, mechanical weeding, hand weeding twice during 30 and 60 DAT and control. Recommended organic management and plant protections were followed.

RESULTS

The observations revealed that application of corn flour 1.0 t/ha with one hand weeding recorded lower weed index (2.70%) with higher weed control efficiency of 94.10% followed by PE application of sunflower dried stalk solution along with one hand weeding with weed index of (16.00%) with weed control efficiency of 93.50% at 90 DAT in organic brinjal. The number of leaves, number of branches, number of fruits per plant and yield were significantly higher in the plots were application of corn flour 1t/ha with one hand weeding was done which was followed by PE application of sunflower dried stalk solution along with one hand weeding.

Table1. Influence of different non chemical weed management practices on weed density and weed dry weight and weed control efficiency in organic brinjal

Treatment	Weed Index (%)	No. of fruits/ plant	Individual fruit weight (g)	Fruit yield kg/plant	Fruit yield t/ha
T_1 : Livemulching with sunnhemp after 30 days of growth	40.81	15.3	47.3	0.72	20.0
T_2 : PE application of Corn flour 1.0 ton/ha	23.74	17.9	52.1	0.93	25.8
T_3 : T_2+ Hand Weeding at 60 DAT	2.70	20.7	57.5	1.14	32.9
T_4 : Livemulching with multi varietal crops (Navathaniam) after 30 days of growth	46.77	14.3	45.7	0.63	18.0
T_5 : PE application of dried sunflower stalk solution on w/v basis 1:10 lit/ha	29.90	17.3	49.6	0.86	23.7
T_6 : T_5 + Hand Weeding at 60 DAT	16.00	18.7	54.8	1.02	28.4
T_7 : Mechanical weeding twice using twin hoe weeder on 30 & 60 DAT	20.71	18.3	52.9	0.94	26.8
T_8 : Hand weeding twice on 30 & 60 DAT	17.26	18.6	54.4	1.01	28.0
T_9 :Weed free check	0.00	21.0	58.0	1.22	33.8
T_{10}: Unweeded check	65.40	10.1	41.9	0.42	11.7
LSD (P=0.05)	-	3.3	9.3	0.18	3.4

Figures in parenthesis are mean of original values; Data subjected to square root transformation, PE-Pre Emergence DAT- Days After Transplanting

CONCLUSION

Hence, it is concluded that application of corn flour at 1t/ha or spraying of sunflower dried stalk solution at 1:10 w/ v basis along with one hand weeding will be a viable and ecologically sustainable options to maintain less weed competition with higher weed control efficiency, lower weed index and higher yield in organic brinjal.

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Effect of different herbicides and dissolvents on spring planted sugarcane

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Sugarcane an old energy source for human beings and more recently, a replacement of fossil fuel for motor vehicles, was first grown in South East Asia and Western India. Uttar Pradesh has the prime position in area and production of sugarcane, it accounts for about 2.1 mha area and 133.2 mt production (IISR 2014). Weed infestation in sugarcane is very high due to slow initial growth of crop and wide spacing between the crop rows, frequent and heavy irrigations, application of heavy doses of manures and fertilizers, and the warm and humid climate during a large part of the growing season. Yield losses due to weeds may be checked by keeping their growth under control by adopting mechanical, cultural and chemical means. Use of herbicide for weed control in sugarcane is gaining importance due to paucity of manual labour. While the continuous herbicidal applications can cause herbicide-resistant in weed stand has a negative impacts upon human health and environment. Natural products released from allelopathic and medicinal plant residues may help to reduce the use of synthetic herbicides for weed management (Khan *et al.* 2004).

METHODOLOGY

The present investigation was carried out during two consecutive spring seasons of 2015 at the Agricultural Research Farm, Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.). The experiment was laid The experiment was laid out in a split plot design with 3 main plot treatments (herbicides) and 4 sub plot treatments (aqua based water extract) with replicated thrice. The soil of the experimental field was low in organic carbon, available nitrogen, available sulphur whereas available P and K were medium.

RESULTS

The relative composition of different weed species was markedly influenced by weed control treatments and with dissolvents in sugarcane. However, the maximum relative percentage was *Cyperus rotundus* at 30 DAP while as *Parthenium hysterophorus* contributed maximum percentage over other weeds at 60 DAP. The plots treated with the sequential application of atrazine 2 kg/ha. *fb* halosulfuron-methyl 150g/ha at 60 DAP recorded lesser number of total weeds as compared to other weed control treatments. Among the dissolvents eucalyptus extract (15%) was most effective in reducing weed density as well as dry matter accumulation of the weeds. This might be due to effective management of all categories of weeds during early stages of crop growth by atrazine and during later stages by post-emergence application of halosulfuron-methyl along with eucalyptus dissolvents. Weed control efficiency, a measure of weed growth suppression as computed against lowest weed control practices. The impact of weed control treatments on weed control efficiency are lucidly visible, as shown in table 1. Atrazine 2 kg/ha at 4 DAP *fb* halosulfuron-methyl 150 g/ha at 45 DAP was next treatment in increasing weed control efficiency. The main reason behind this was mainly due to better control of atrazine against grassy weeds and broadleaf weed plus inhibiting action of halosulfuron-methyl against sedges. Among the different dissolvents eucalyptus extract (15%) was most effective than all other dissolvents. Because of its allelopathic action is superior to all other treatments. Similar results were obtained by Singh *et al.* (2008).

Table 1. Total weeds, weed dry matter accumulation and Weed control efficiency as influenced by weed control treatments and their dissolvents in sugarcane

Treatment	No. of total weeds/m^2 at 60 DAP	Weed dry matter accumulation (g/m^2) at 60 DAP	Weed control efficiency (%) at 60 DAP
Main plot (weed control treatments)			
Atrazine *fb* halosulfuron-methyl	170.23	114.18	11.63
Metribuzin *fb* halosulfuron-methyl	181.36	122.15	5.43
Sulm (Triazinone) *fb* halosulfuron-methyl	193.25	129.28	0
LSD (P=0.05)	0.59	0.47	1.83
Sub plot (dissolvants)			
Cow Urine	169.05	128.61	0
Parthenium extract	153.16	110.63	14.06
Eucalyptus extract	145.91	95.98	24.80
Water	162.82	120.76	6.25
LSD (P=0.05)	0.77	0.83	4.66

Table 2. Relative composition of different weed species at 30 and 60 DAP as influenced by weed control treatments and dissolvent in sugarcane

Treatment	Relative composition (%)							
	30 DAP				60 DAP			
	Cyperus rotundus	*Cynodon dactylon*	*Parthenium hysterophorus*	Other weeds	*Cyperus rotundus*	*Cynodon dactylon*	*Parthenium hysterophorus*	Other weeds
a_1b_1	32	21	18	8	12	23	32	9
a_1b_2	30	19	17	6	11	22	31	8
a_1b_3	29	18	16	5	10	21	30	8
a_1b_3	31	20	18	7	12	22	31	9
a_2b_1	37	23	20	9	14	25	34	11
a_2b_2	35	21	19	8	13	24	32	9
a_2b_3	34	20	18	8	12	23	32	9
a_2b_4	36	22	20	9	14	24	33	10
a_3b_1	39	26	24	13	16	29	36	14
a_3b_2	38	24	21	10	15	26	35	13
a_3b_3	37	23	20	10	14	25	34	12
a_3b_4	38	25	23	12	15	28	35	13

CONCLUSION

From the results of the present field experiment it can be concluded that atrazine 2 kg/ha. *fb* Halosulfuron-methyl 150 g/ha is optimum as it not only gave significantly higher grain yield but also fetched additional income. Among the different dissolvents, the lowest weed density and dry matter were found in eucalyptus (15%).

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Allelopathy: an environmentally friendly method for weed control

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Wide spread use of synthetic herbicides could causes environmental, health and herbicides resistance issues, therefore, a focus has been given since last two decades on the use of plant derived organic substances as alternative to inorganic herbicides for weed control. Allelopathy is an eco-friendly and organic weed management approach, which may be used as a tool in controlling weeds. Alleopathy is defined as both beneficial and deleterious biochemical interaction between plants and weeds and/ or plants and micro organisms through the production of chemical compounds that escape into the environment and subsequently influence the growth and development of neighboring plants. Among different biological methods of weed control, allelopathy could lead to reduced labour costs and increased efficiency, without any adverse effects on the environment. Many of the compounds produced by green plants that are not involved in primary plant metabolism are observed to function as chemical warfare agents against competing plants and pests. Allelochemical higher number of plants that have the ability to control weeds such as cineole, benzoxazinone and QuinoLinic acid are leptospirosis. Among different crops, Rye is the most important crop that can effectively suppress growth of barnyard grass.

Organic weed management: an alternate way to minimize herbicide hazards

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Since the beginning of agriculture, Indian farmers are facing problems with the presence of weeds in their fields. Weeds can be considered a major problem because they are directly associated with decrease in crop yields. They increase competition for water, sunlight, and nutrients with crops while serving as host plants for pests and diseases. Since the invention of herbicides, farmers have used these chemicals to control weeds in the fields, since the large scale use of agro-chemicals has resulted in increased environmental and health problems. These problems can be solved by weed management using organic and biological practices. In case of organic system of weed control, weeds are never eliminated but only managed. A farmer who manages weeds organically must be intimately familiar with the type of weeds and their growth habits to determine which control methods to employ. Organic Methods of weed management involves thermal weed control, soil solarization, stale seedbed, mulching, crop rotation, mechanical weed management, allelopathy and biological weed management.

Theme 5

Emerging problem weeds and their management

Utilization of water hyacinth as livestock feed by ensiling with additives

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Aquatic weeds interfere with the normal functioning of water bodies. Among the aquatic weeds, water hyacinth (*Eichhornia crassipes* (Mart.) Solms) is listed as one of the most productive plants on earth, but it is also considered as the world's worst aquatic weed. Various ways of combating its proliferation and methods of eradication have not proved much because of its survival strategies. An alternate option is to utilize this weed for various purposes such as fibre, animal feed, and manure. Tham (2012) reported that improved silage could be made from water hyacinth by the use of additives such as molasses and rice bran. Molasses is a universal additive but not so easily available to common people. Lowilai (1993) reported the use of cassava flour instead of molasses. Presently, little bag silage in polythene bags is recommended for small holders. Considering the above options, an experiment was conducted to utilize water hyacinth as a feed by ensiling.

METHODOLOGY

The experiment was carried out at the College of Horticulture, Kerala Agricultural University, Thrissur during 2015. The treatments included combination of wilted and fresh water hyacinth with or without rice straw or guinea grass and additives such as molasses, cassava flour, and rice bran. The experiment was laid out in completely randomized design with three replications. Both petiole and leaves were cut in to 4-5 cm pieces, spread on plastic sheets and was wilted in shade for two days. Depending on treatments, additives were added and was thoroughly mixed. Afterwards, these were filled in little bags made of polyethylene 5 kg/cover. The mixtures were compressed by hand to remove as much air as possible. The covers were tightly tied and stored indoors. All the covers were opened after 45 days. Observations on pH, colour, and odour were noted and the data on pH were subjected to analysis of variance.

RESULTS

In all the cases, the silage was ready to use after 45 days. A main quality criteria of silage is pH, and based on pH, silage is generally classified as very good (pH 3.8 to 4.2), good (pH 4.2 to 4.5), and fair silage (pH >4.5) (Thomas 2008). In this experiment, wilted water hyacinth along with cassava powder (10%) seems to have good quality as it showed pH of 4.19 (Table 1). The odour of this silage was rated 'very high'. All the treatments with 10 per cent cassava powder showed low pH values. Quality wise, rice bran added silages were poor in terms of pH values, which were above 6.36. The results revealed that wilted water hyacinth plus cassava powder (10%), wilted water hyacinth plus rice straw (10%) plus cassava powder (10%), wilted water hyacinth plus grass (10%) plus cassava powder (10%), and fresh water hyacinth plus rice straw (10%) plus cassava powder (10%) are equal in quality with respect to pH. The odour of these combinations was rated either 'good' or 'very good'. The colour varied based on the ingredients used, mostly brownish green or grey.

Table 1. Effect of additives on quality of water hyacinth silage

Treatment	pH	Colour	Odour
Wilted water hyacinth + molasses (5%)	4.53[d]	dark brown	good
Wilted water hyacinth + cassava powder (10%)	4.19[d]	brownish green	very good
Wilted water hyacinth + rice bran (10%)	6.36[b]	greenish brown	foul
Fresh water hyacinth + rice straw (10%) + molasses (5%)	5.44[c]	golden yellow	very good
Fresh water hyacinth + rice straw (10%) + cassava powder (10%)	4.37[d]	grey	good
Fresh water hyacinth + rice straw (10%) + rice bran (10%)	6.58[b]	brownish	bad
Wilted water hyacinth + rice straw (10%) + molasses (5%)	7.15[b]	dark brown	bad
Wilted water hyacinth + rice straw (10%) + cassava powder (10%)	4.38[d]	grey	good
Wilted water hyacinth + rice straw (10%) + Rice bran (10%)	8.30[a]	brown	fair
Wilted water hyacinth + grass (10%) + molasses (5%)	6.36[b]	brownish green	good
Wilted water hyacinth + grass (10%) + cassava powder (10%)	4.24[d]	grey	Very good
Wilted water hyacinth + grass (10%) + rice bran (10%)	7.24[b]	greenish brown	foul
LSD (P=0.05)	0.904		

CONCLUSION

Palatable silage can be made from water hyacinth with additives such as molasses, cassava flour, and rice straw.

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In vivo generation of hydroxyl radical by titanium dioxide nano catalyst to break the dormancy of the world's worst weed purple nutsedge

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Purple nutsedge (*Cyperus rotundus* L.) is one of the most invasive perennial sedge weed considered as the world's worst weed, competing with crops for natural resources, results in heavy losses of crops. The tubers are the primary means of reproduction (Bangarwa *et al*. 2008). Phenols present in the tubers control the germination of tubers. Degrading the phenol break open the dormancy and induce the germination of all buds present in the tubers at once. Once tubers are germinated, it can be controlled by either chemical or cultural means results in reduced weed seed/tuber bank size. The newly emerging science, the nanotechnological approach throws some light to manage this world's worst weed with the help of nanoparticles (Gu *et al*. 2009). The novel titanium dioxide nanoparticles (nano-adsorbent) are quite efficient for degrading phenols present in the *Cyperus rotundus* tubers.

METHODOLOGY

A laboratory experiment was carried out at the Department of Nano Science and Technology, Tamil Nadu Agricultural University, Coimbatore to break the dormancy of *Cyperus rotundus* tubers using titanium dioxide nanoparticles by degrading the phenols. The titanium dioxide nanoparticles (TiO_2) were synthesized by chemical precipitation method (Wang *et al.* 2007) and characterized by Fourier Transform Infrared Spectroscopy (FTIR), X-Ray powder Diffraction (XDR) and Scanning Electron Microscope (SEM). Tubers were treated with synthesized TiO_2 nanoparticles at the rate of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 g/kg of tubers. It was sonicated for 20 minutes and kept undisturbed for 24 hours. Phenol estimation was done with this sample using folin-ciocalteau method.

RESULTS

Titanium dioxide nanoparticles at 2.5 g/kg tubers recorded higher percentage of phenol degradation *i.e.* 69.7% over control, which was on par with 2.0 g/kg tubers *i.e.* 68.8% over control. Titanium dioxide nanoparticles were degrading phenols by means of Advanced Oxidation Process (AOP). Among all AOPs, using photocatalytic such as titanium dioxide nanoparticles shows a better result. In AOPs powerful reactive species like hydroxyl radicals were generated by specific chemical reactions in aqueous solutions. Increased reactive hydroxyl radicals results in the oxidation of phenol into other intermediates. Phenols are converted into relatively benign and less persistent end products. Increased degradation efficiency with increasing dosage of titanium dioxide can be attributed to the increasing active sites. When compared with the lower dosage, increased dose of titanium dioxide nanoparticles recorded reduced rate of phenol degradation (3.0 g). Increasing the dosage reduced the degradation efficiency might be due to the increased turbidity, which detracts the amount of light reaching the sample. It causes agglomeration of nanoparticles. TiO_2 nanoparticles at 2.5 g/kg of tubers recorded higher germination percentage *i.e.* 41.7%. It was on par with titanium dioxide nanoparticles at 3.0 g/kg of tubers. Once all the dormant tubers are germinated they could be effectively checked by several management means and reduction in the enlargement of weed bank.

Table 1. Effect of TiO_2 nps on *C.rotundus* phenol degradation and germination percentage

Treatment (g TiO_2 nps/kg of tubers)	Concentration of phenol (mg/ g of tubers)	Germination (%)
0.5 g TiO_2 nps/ kg tuber	8.40	21.6
1.0 g TiO_2 nps /kg tuber	4.60	27.1
1.5 g TiO_2 nps/ kg tuber	4.00	32.6
2.0 g TiO_2 nps /kg tuber	3.80	37.5
2.5 g TiO_2 nps /kg tuber	3.70	41.7
3.0 g TiO_2 nps/ kg tuber	5.60	40.2
Control	12.20	13.3
LSD (P=0.05)	0.60	1.70

CONCLUSION

It was concluded that titanium dioxide nanoparticles were act as an effective catalyst to degrade the phenols present in the tubers. By breaking the germination inhibitor, the tuber germination percentage was increased. All the germinated tubers can be effectively managed by available control methods. It may useful to eradicate the total weed tuber bank present in the soil.

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Managing the broomrape menace in Indian mustard with different dates of sowing

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Orobanche popularly known as broomrape, is an annual, branched, achlorophyllous, noxious and obligate root parasite that reproduces only by seeds (Press *et al.* 1986, Punia *et al.* 2012), belongs to family *Orobanchaceae*. They are prevalent, infesting nearly 1.2 per cent of the world's arable land. In India, *O. cernua* and *O. aegyptiaca* cause severe infestations of tomato and *Brassica* and have threatened its cultivation in major growing areas. More than 0.25 million ha mustard grown area is infested with *Orobanche aegyptiaca* in Bhiwani, Hisar and adjoining areas of South-western Haryana. A single broomrape plant can release more than 50000 seeds and these can stay viable for decades in the soil. This provides the parasite with a great genetic adaptability to environmental changes, including host resistance, agronomical practices and herbicide treatments (Rathore *et al.* 2014).

METHODOLOGY

An intensive survey was conducted during *Rabi* 2013-14 to determine the status of *Orobanche* infestation in Indian mustard in Bhiwani and Hisar districts of Haryana. From each district, 90 locations were selected at random *i.e.* 9 villages from each block of Bhiwani and 10 villages from each block of Hisar district were selected randomly. One field was surveyed from each of these villages to record the *Orobanche* infestation in mustard.

RESULTS

Perusal of data regarding the mean *Orobanche* population in districts Bhiwani and Hisar are shown in Fig. 1. Significant difference was observed in mean population of *Orobanche* in both the districts. Infestation of *Orobanche* in Bhiwani (38.5/m^2) was significantly higher as compared to Hisar (11.3/m^2) *i.e.* almost 240 per cent higher population of the parasitic weed which made mustard crop more vulnerable in Bhiwani district. It might be because of the differences in soil texture and irrigation methods in these districts.

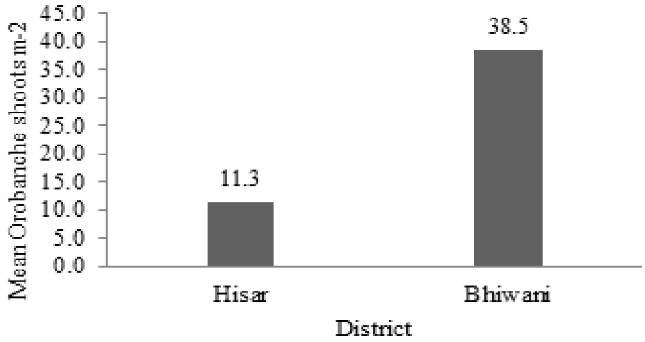

Fig. 1. Infestation of *Orobanche* in Indian mustard during *Rabi* 2013-14

Table 1. Population of *Orobanche* in Indian mustard as influenced by date of sowing

Date of sowing	Hisar		Bhiwani	
	Mean *Orobanche* shoots/m^2	F_{cal} (0.05)	Mean *Orobanche* shoots/m^2	F_{cal} (0.05)
Before 15th Oct	19.27		42.05	
15th Oct- 31st Oct	8.11	2.71*	39.80	2.13*
After 1st Nov	2.50		7.60	

Values of F_{cal} having * shows significant difference in mean *Orobanche* population

Data presented in Table 1 revealed that there was a decreasing trend of mean *Orobanche* population/m^2 with the delay in date of sowing over both the districts. However, in Hisar, it was found that sowing of mustard after 15th Oct significantly reduced the population of *Orobanche*/m^2 compared to sowing before 15th Oct (19.27). There was no significant difference in *Orobanche* population if the sowing of mustard was done between 15th Oct to 31st Oct (8.11) and after 31st Oct (2.50), whereas in Bhiwani, it was found that sowing of mustard after 31st Oct (7.60) significantly reduced the mean population of *Orobanche*/m^2 compared to sowing before 31st Oct. No significant difference in *Orobanche* population was observed when the sowing was done before 15th Oct (42.05) and 15th Oct - 31st Oct (39.80).

CONCLUSION

During the survey, it has been observed that infestation of *Orobanche aegyptiaca* in mustard crop in Bhiwani district was more as compared to Hisar. Also, delay in date of sowing significantly decreased the *Orobanche aegyptica* population in mustard in both the districts.

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Management of *Orobanche* in mustard

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Indian mustard (*Brassica juncea* L.) is a major crop of rapeseed-mustard group, which occupy more than 75% of the area under this group of crops. Although the crop is being exposed to many abiotic and biotic stresses but of late *Orobanche aegyptica* has become endemic in many semi-arid tracts causing devastation to the crop. *Orobanche or Broomrape* is an obligate root parasite that lack chlorophyll and obtain carbon, nutrients, and water through haustoria which connect the parasite with the host vascular system. Herbicides used in mustard do not kill this weed effectively. While mechanical control after emergence is impractical and by this time significant loss to the crop has already been made. Recently, use of sub-lethal doses of glyphosate, neem cake + pendimethalin and soybean oil has been advocated for *Orobanche* management (Rathore *et al*. 2014). The efficacy of low doses of glyphosate, neem cake, pendimethalin and metalaxyl was evaluated in the present experiment.

METHODOLOGY

A field experiment was conducted in *Rabi* season 2014-15 and 2015-16 at Research Farm College of Agriculture, Gwalior (M.P.). The soil was sandy clay loam in texture with organic carbon 0.21% and having 7.5 pH, low in available nitrogen and medium in phosphorus and potassium. The experiment was laid out in randomized block design having six treatments with four replications (Table 1). The mustard variety Rohni was sown in line at the row distance of 30 cm apart on 6 and 9 November, 2014 and 2015 and harvested on 28 and 20 March, 2015 and 2016. Basal dose of 40:40:20 NPK kg/ha were applied at sowing time and remaining half dose of nitrogen (40 kg/ha) was applied after irrigation at PF stage. Herbicides were sprayed by using spray volume of 500 liter water/ha with the help of knapsack sprayer fitted with flat fan nozzle. Orobanche population were recorded at 60, 75, 90 and 120 DAS/harvest stage of crop.

RESULTS

Effect on weeds: The major weeds associated with mustard were *Chenopodium album*, *Chenopodium murale*, *Cyperus rotundus*, *Anagalis arvensis* and *Orobanche*. In general very less population of orobanche emerged in experimental field which may be due to less infestation of Orobanche in the field. Orobanche penicles started emerging 75 and 90 DAS in 2014-15 and 2015-16 respectively. Orobanche penicles did not emerged in treatments glyphosate 25 and 50 g/ha at 25-30 and 55-60 DAS with or without 1% AS at 75 DAS in 2014-15 and in 2015-16 no orobanche emerged up to harvest. In treatment neem cake at 400 kg/ha fb soil drenching of metalaxyl MZ 0.2% at 25 DAS *fb* glyphosate at 40 g/ha at 45 DAS, significantly low orobanche population was recorded as compared to weedy check. at 120 DAS in both the years. Neem cake 400 kg/ha *fb* pendimethalin 0.75 kg/ha PE fb metalaxyl MZ reduced the orobanche population in 2015-16 at 120 DAS only. Punia (2015) reported 63-100% control of orobanche in Indian mustard by post emergence application of glyphosate at 25 and 50 g/ha with 1% solution of $(NH4)_2SO_4$ at 25 and 55 DAS in experimental fields and large scale farmers' fields in Haryana.

Table 1. Effect of different treatments on emergence of Orobanche penicles, seed yield and stover yield of mustard

Treatment	*Orobanche* panicles/m^2					Seed yield (t/ha)			Stover yield (t/ha)		
	75 DAS	90 DAS		120 DAS		2014-15	2015-16	Mean	2014-15	2015-16	Mean
	2014-15	2014-15	2015-16	2014-15	2015-16						
Glyphosate 25 & 50 g/ha at 25-30 and 55-60 DAS	0.71 (0.00)	0.74 (0.04)	0.71 (0.00)	1.01 (1.03)	0.71 (0.00)	1.50	1.33	1.42	4.29	4.57	4.43
Glyphosate 25 & 50 g/ha with 1% $(NH_4)_2$ SO_4 at 25-30 and 55-60 DAS	0.71 (0.00)	0.75 (0.07)	0.71 (0.00)	1.01 (1.07)	0.71 (0.00)	1.53	1.38	1.45	4.53	4.88	4.70
Neem cake 400 kg/ha at sowing *fb* soil drenching of metalaxyl MZ 0.2%at 25 DAS *fb* glyphosate at 40 g/ha at 45 DAS	0.77 (0.10)	1.11 (0.78)	0.75 (0.07)	1.40 (2.01)	0.83 (0.20)	1.40	1.18	1.29	3.75	4.41	4.08
Neem cake at 400 kg/ha at sowing *fb* pendimethalin at 0.75 kg/ha PE *fb* metalaxyl MZ 0.2% at 25 DAS	0.85 (0.23)	1.06 (0.65)	0.81 (0.15)	1.63 (2.69)	0.89 (0.29)	1.38	1.08	1.23	3.75	4.30	4.02
Neem cake at 400 kg/ha at sowing *fb* soil drenching of metalaxyl MZ 0.2% at 25 DAS	0.80 (0.17)	1.24 (1.07)	0.78 (0.12)	1.83 (3.36)	0.83 (0.19)	1.32	1.05	1.19	3.71	3.97	3.84
Weedy check	0.90 (0.35)	1.28 (1.19)	0.82 (0.17)	1.82 (3.34)	0.97 (0.43)	1.13	1.02	1.08	2.96	3.88	3.42
LSD (P=0.05)	NS	0.23	0.05	0.31	0.08	0.27	0.20	0.23	0.64	NS	0.68
Transformation	$\sqrt{x+0.5}$	$\sqrt{x+0.5}$	$\sqrt{x+0.5}$	$\sqrt{x+0.5}$	$\sqrt{x+0.5}$						

Effect on Crop: In 2014-15, 5-15% toxicity to mustard in terms of marginal leaf chlorosis was recorded with glyphosate 25 g/ha at 25 DAS, which was recovered within 15 – 20 days. Highest significant seed yield was recorded under glyphosate 25 and 50 g/ha with 1% AS at 25-30 and 55-60 DAS followed by glyphosate 25 and 50 g/ha at 25-30 and 55-60 DAS and these treatments were significantly superior over weedy check. The increase in yield in these treatments were 35.0 and 31.6% respectively.

CONCLUSION

Highest significant yield of mustard with mimimum population of orobanche was obtained under glyphosate 25 and 50 g/ha with 1% ammonium sulphate and glyphosate 25 and 50 g/ha at 30 and 60 DAS.

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Chemical control of *Orobanche aegyptiaca* L. in brinjal

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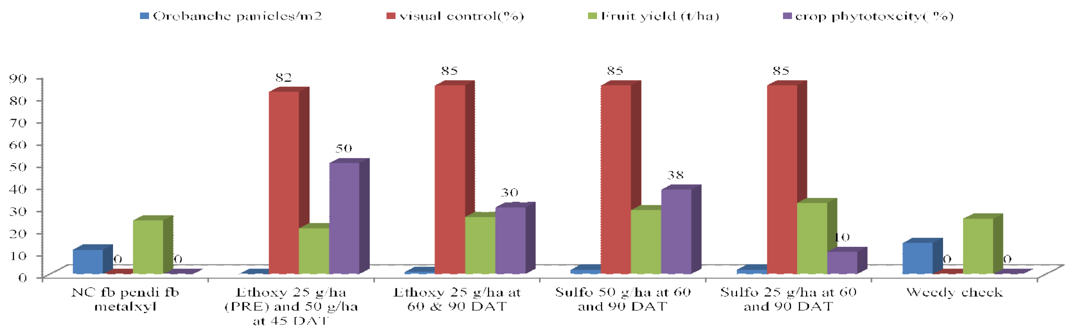
Egyptian broomrape (*Orobanche aegyptiaca* Pers.) locally known as Margoja /Rukhri/Khumbhi/Gulli is an achlorophyllous, phanerogamic troublesome root parasite that is responsible for 10-30 % loss in fruit yield in Nuh, Ferozepur Jhirka, Nagina, Taoru areas of Mewat in Haryana. Studies conducted earlier in European countries demonstrated effectiveness and selectivity of sulfosulfuron and other ALS inhibiting herbicides to control broomrape in brinjal. The conventional methods of weed control are time consuming, expensive and laborious. In these circumstances, chemical control through herbicides application can be an effective measure for *Orobanche* management. Information on chemical control of *Orobanche* in brinjal under Indian conditions is not available. To generate information under Indian context, present investigation was planned to assess the efficacy of various sulfonylurea herbicides against *Orobanche aegyptiaca* in brinjal.

METHODOLOGY

Brinjal hybrid 707 was planted at farmers' field in V. Bivan tehsil Nuh, Distt. Mewat (Haryana). Crop was grown as per university recommended package of practices for brinjal except herbicide treatments. Quantity of water applied in post emergence treatments was 375 litres/ha. Observations on number of broom rape spikes/m^2 by different treatments were recorded at 60, 90, 120 DAP and at harvest and broom rape visual control (0-100 scale) was recorded at 120 DAP and harvest. Data on plant height, length of broom rape spike were recorded at 120 DAP. Number of fruits/plant was recorded from five tagged plants were averaged to compute values/ plant. Crop phyto-toxicity due to different treatments was assessed at 30, 60 and 120 DAP on a scale of 0-100, where 0 means no injury and 100 = complete mortality of tomato plant.

RESULTS

Application of neem cake at sowing in combination with pendimethalin or metribuzin followed by soil drenching of metalaxyl MZ 0.2 % at 20 DAT did not cause any inhibition in broom rape (*Orobanche*) emergence (Fig. 1). Metribuzin applied at 3 DAP proved highly toxic to brinjal resulting in complete mortality. Although excellent control of *Orobanche* was obtained with POST or PRE plus POST treatments of sulfosulfuron and ethoxysulfuron when compared with non treated controls but proved phytotoxic to brinjal crop. *Orobanche* stalks to the tune of 1-3 panicles/m^2 appeared in various herbicide treatments which was significantly less than untreated control. Broom rape spikes which emerged in ethoxysulfuron and sulfosulfuron treatments were very weak and small sized.



Treatments of ethoxysulfuron 25 g/ha (PRE) were more phytotoxic than POST and brinjal exhibited 50-60% growth reduction under pre treatments resulting in cracked and wrinkled fruits. Developmental delay in brinjal was observed with ethoxysulfuron applied PRE or 30 DAS at 25 g/ha. Only 10% suppression on brinjal plant was recorded with use of post emergence application of sulfosulfuron at 25 g/ha at 60 and 90 DAP, resulting in 85% control of *Orobanche*. Maximum fruit yield (32.0 t/ha) was recorded from use of sulfosulfuron 25 g/ha at 60 and 90 DAS, respectively which was which was 22.1 % higher than untreated check and significantly higher than all herbicide treatments.

Performance of water hyacienth and cattail in water quality improvement of polluted river water

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Agriculture has been victim of soil and water pollution in respect of entering heavy metals in food and animal chain through crops irrigated with untreated drain water emanated from sewage and industrial sources. In order to prevent contaminants entry, phytoremediation by macrophyte treatment of polluted water at source is the low cost option. However, for selection of plants, phytoremediating agents should meet the major criteria of fast growth with high rate of biomass production and ability to accumulate metals even from low external metal concentration (Raskin and Enslay 2000). The investigation was therefore carried out to evaluated performance of aquatic weeds for heavy metals removal from Pariyet river water prior to irrigation to vegetable crops.

METHODOLOGY

In order to test the performance of aquatic weeds at contaminated site, a pilot scale aquatic weed based water treatment system is established at Urdua village of Panagar locality of Jabalpur (M.P.). The treatment system comprises of the collection tank, settling tank followed by treatments zone. The aquatic weeds, *Eichhornia crassipes*, *Pistia stratiotes* were planted in 1st year in separate treatment tanks followed by *Typha latifolia* in all tanks during 2nd year. The river water was pumped into collection tank and passed to settling tank and retained in treatment zone in which aquatic plants were grown. The water samples were collected from inlet and outlet zone of each tank after treatment of 2 to 7 days. The various water parameters were analyzed by multi-parameter water analyzer model Photolab RS12A (WTW make) and heavy metals by Atomic absorption spectrophotometer.

RESULTS

Performance of aquatic weeds: The lower concentration of sulphate, sodium, chloride and phenol to the extent of 6, 31, 29 and 0.54 ppm was recorded in treated water in tank grown with *Eichhornia* crassipes than *Pistia Stratiotes* as compared with untreated drain water (20, 52, 64, 2.75 ppm) during 1st run of the system after 7 days of hydraulic retention time. During 2nd run of the pilot scale system, except slight change in electrical conductivity, no change in pH, temperature and total hardness were recorded in water treated with *Pistia stratiotes* and *Eichhornia crassipes*. However, as compared with the turbidity of drain water (64.2 Ntu), lower turbidty of 20.43 and 6.93 Ntu was recorded in water treated with *Pistia* and *Eichhornia* respectively. Besides turbidity other parameters viz, total dissolved salts (TDS), sodium, sulphate, chloride and chromium in water were reduced to the extent of 18.0, 39.1, 43.1 and 78.3.3 percent by *Eichhornia* after treatment with for 5 days HRT respectively (Fig 1).

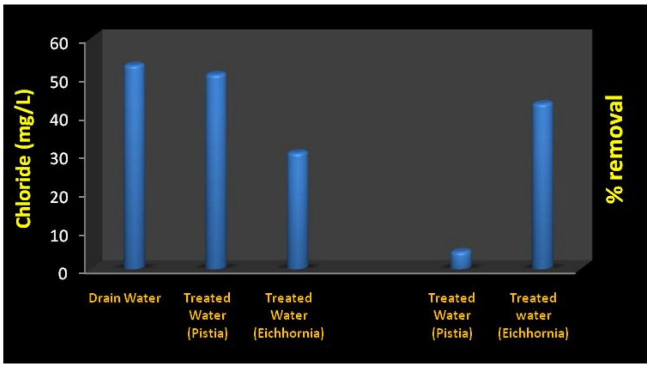

Fig. 1a. Chloride

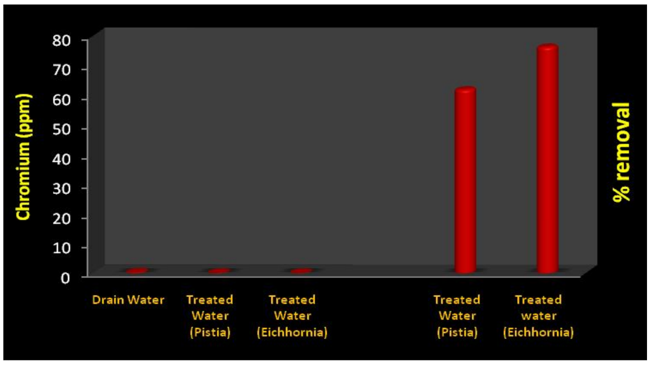

Fig. 1b. Chromium

The *Typha* treatment system reduced the chromium, nickel and lead to the extent of 66.1, 73.4 and 36.4 respectively as compared to the untreated drain water.

CONCLUSION

The evaluation of the higher aquatic and terrestrial plants such as *Eichhornia crassipes, Arundo donax* and *Typha latifolia* which effectively accumulate heavy metals like chromium, nickel, cadmium, lead have indicated their potential as a heavy metal phytoremediating agents. These aquatic weeds have great potential if grown properly in an engineered manner in artificial constructed wetlands for prevention of entry of pollutants in agricultural soil and for protection of surface water bodies such as ponds, lakes, tanks from eutrophication.

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Morphological diversity in weedy rice biotypes of Madhya Pradesh

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Weedy rice (*Oryza sativa f. spontanea*) is recognized largely as a potential notorious weed in direct seeded rice system. It bears the traits of both cultivated and wild rice (Rathore *et al*, 2013; Meenal *et al.*, 2016). Weedy rice has become a common problem in most rice growing areas in Madhya Pradesh. The main objective of the experiment was to compare the growth and morphological diversity of weedy rice biotypes and rice cultivars under field condition. Available biotypes weedy rice, wild rice and rice cultivars were evaluated for the morphological characteristics i.e. plant height, number of tillers and 1000-grains weight. Morphological data evaluated in the present study would be of significance to understand biology of weedy rice.

METHODOLOGY

A field experiments were conducted during kharif session of 2016 at ICAR-Directorate of Weed Research, Jabalpur. Twenty biotypes of weedy rice cultivated from different regions of Madhya Pradesh, three cultivated rice and two wild rice were grown in the field. First seeds were of all the biotypes/cultivars were grown in plastic trays having autoclaved soil. Two weeks seedlings were transplanted in field in randomized complete block design in three replicates. Plant height (cm) was measured from base to tip at 60 days after transplanting. Number of tillers/plant were counted at 60 days after transplanting. Test weight of each biotype was measured by weighing 1000 filled grains after harvesting. Results of the above measured parameters are given in Figure 1.

RESULT

In this present investigation we have differences in weedy rice biotypes, wild rice and cultivated rice. Plant height is an important morphological parameter to observe competitive ability as taller weedy rice competes more efficiently for natural resources than the cultivated rice. The tallest biotype of weedy rice 'MRWR-26' had height of 150.6 cm, wild rice biotype 'WIR-5' had 117.6 cm while rice cultivar 'C-8' had only 111.8 cm height. Height of the smallest weedy rice biotype 'MRWR-18' was observed 83.8 cm while cultivated rice 'C-7' attained a height of 102.6 cm. Results showed that weedy rice biotypes not necessarily taller than the cultivated rice. Weedy rice biotypes having height less or similar to cultivated rice are more difficult to manage as compared to the biotypes which are taller than cultivated rice. The highest number of tillers (44) was recorded in weedy rice 'MRWR-18' followed by wild rice 'WIR-5' (43) while in cultivated rice 'C-9' 32 tillers/plant were recorded. Tillering in rice crop is an imperative agronomic attribute for grain production. High degree of tillering is well known in weedy rice which provides an edge over cultivated rice in terms of competitiveness. The highest value of 1000-grains weight (30.40 g) was highest in weedy rice biotype 'MRWR-26' followed by cultivated rice and wild rice. Results of our investigations suggest that weedy rice biotype provide a tough completion to cultivated rice and may be a big detrimental factor for rice production in under direct seeded rice system.

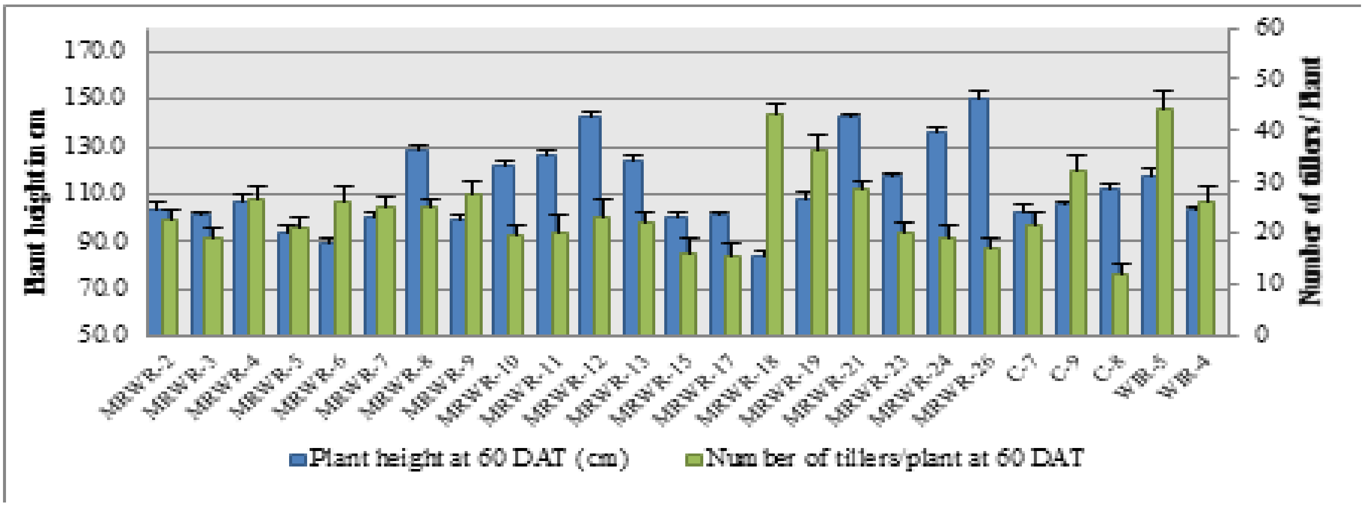

Fig.1. Morphological diversity between of weedy, cultivated and wild rice on the basis of Plant height and total tillers number

CONCLUSION

Comparative study amongst weedy, cultivated and wild rice revealed that plant height, total tiller number and 1000-grains weight had higher values in weedy rice, however, in few accessions, height, tiller number and 1000-grains weight had lower values compared to cultivated and wild rice.

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Management of *Parthenium hysterophorus* L. in wastelands of Himachal Pradesh

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Parthenium has spread alarmingly like a wild blaze to almost all the states in India including Himachal Pradesh and was established as a naturalized weed. From road sides or in locations of hydro-electric projects and other civil engineering works it has spread to undisturbed ecosystems of the hills like pasture and grasslands, forests and orchards through water, wind and migratory sheep and goat (Angiras and Kumar 2010). The spread of this weed has threatened the biodiversity of hills, reduced productivity of pasture and grasslands, orchards and forests apart from its pollution to the environment affecting health of animals and human beings. In Himachal Pradesh more than 45% of the total geographical area is under pastures, grasslands, fallow lands and other non-cultivated lands which provide favorable conditions for invasion by this alien weed. Since these lands provide support to the agriculture by providing fodder to the livestock of the state, it is imperative to control this weed effectively by adopting effective herbicidal management strategy.

METHODOLOGY

An investigation was carried out in wasteland ecosystem with heavy infestation of *Parthenium* in Bairghatta Panchayat ($31^0$532 172 2 to $31^0$532 492 2 N latitude and $76^0$292 052 2 to $76^0$292 472 2 E longitude) of Jaisinghpur Tehsil in Kangra District of Himachal Pradesh to standardize the dose and time of application of different herbicides to control *Parthenium* in waste land ecosystem. Thirteen treatments, *viz*. metsulfuron methyl (0.005 and 0.01%), 2, 4-DEE (0.30 and 0.20%), atrazine (0.20 and 0.30%), metribuzin (0.25 and 0.50%) and glyphosate (0.50 and 0.75%) each at two doses and manual cutting, uprooting and untreated check were evaluated for the control of *Parthenium hysterophorus* in randomized block design with three replications. The plot size was 5.5m x 4m. The herbicides were applied when plants of Parthenium were 22.8-47.8 cm in the month of June. The herbicides were sprayed with knapsack power sprayer using 600 L water per hectare. *Parthenium* infestations were assessed in terms of its density and dry matter by sampling in one sq. m area using quadrates in wasteland ecosystems. Likewise, the population of other vegetation (*Ageratum conyzoides, Bidens pilosa* and local grasses) was recorded before spray and after 4 and 7 months of spray to evaluate the efficacy and phytotoxicity of the herbicides.

RESULTS

It was revealed from Table 1 that glyphosate 0.5 and 0.75%, metribuzin 0.25 and 0.50%, metsulfuron methyl 0.005 & 0.010%, 2,4-DEE 0.2 & 0.3% and atrazine 0.2 & 0.3% applied before flowering were significantly effective to control the existing flush of *Parthenium* as compared to manual treatments. All herbicidal treatments were effective to control *Parthenium* upto four months after treatment with 100% kill. The effectiveness of glyphosate, metribuzin, metsulfuron methyl, 2,4-DEE and atrazine in controlling *Parthenium* in cropped and non-cropped lands has been documented by Reddy *et al*. 2007. None of the treatments gave lasting satisfactory reduction in weed count and dry weight, though there was significant reduction in *Parthenium* count and dry weight under herbicidal treatments as compared to untreated control. The effective suppression of *Parthenium* due to different herbicidal treatments led to occupy the land by other vegetation. The population of other vegetation in all herbicidal treatments except glyphosate 0.5 and 0.75% was significantly higher than the unsprayed check and manual cutting after 7 months of treatment. Even at 4 months of spray, glyphosate 0.5 and 0.75% also resulted in significantly lower population of other vegetation over rest of the treatments. Therefore, inference can be drawn that though all the herbicides treatments resulted in significantly lower density and dry weight of *Parthenium* as compared to other weed control treatments up to four months after treatment but metribuzin, 2,4-D, metsulfuron methyl and atrazine were effective without any phytotoxic effects on local grasses.

Table 1. Effect of treatments on population of *Parthenium and other vegetation* and dry matter of *Parthenium* at different stages in wasteland ecosystem

Treatment	*Parthenium* dry matter (g/m^2)			*Parthenium* count ((No/m^2)			Other vegetation count (no./m^2)		
	Before spray	4 MAT	7MAT	Before spray	4 MAT	7MAT	Before spray	4 MAT	7MAT
Glyphosate 0.5%	8.4(70.0)	1.0(0.0)	5.9(34.0)	6.9(48.0)	1.0(0.0)	2.7(6.2)	9.4(88.0)	5.9(34.0)	4.8(22.1)
Glyphosate 0.75%	8.4(70.2)	1.0(0.0)	4.5(20.0)	6.4(40.0)	1.0(0.0)	2.5(5.4)	9.6(92.0)	6.2(38.2)	5.0(24.5)
Metribuzin 0.25%	8.3(68.8)	1.0(0.0)	4.3(18.0)	6.8(46.0)	1.0(0.0)	2.8(6.7)	9.7(94.0)	8.3(68.7)	7.0(48.7)
Metribuzin 0.50%	8.1(64.6)	1.0(0.0)	4.5(20.0)	6.5(42.0)	1.0(0.0)	2.3(4.2)	9.5(90.0)	8.4(70.2)	6.9(46.5)
MSM 0.005 %	8.5(72.2)	1.0(0.0)	5.3(28.0)	6.7(44.0)	1.0(0.0)	2.7(6.2)	9.8(97.0)	8.5(72.8)	6.8(45.7)
MSM 0.01%	8.4(70.4)	1.0(0.0)	5.1(26.0)	6.8(46.0)	1.0(0.0)	2.5(5.1)	9.4(88.0)	8.3(68.0)	6.6(42.7)
2,4-DEE 0.2%	8.3(68.8)	1.0(0.0)	5.5(30.0)	6.9(48.0)	1.0(0.0)	2.7(6.1)	8.8(78.0)	8.2(66.5)	6.7(44.6)
2,4-DEE 0.3%	8.2(66.4)	1.0(0.0)	5.3(28.0)	7.1(50.0)	1.0(0.0)	2.6(5.6)	8.7(76.0)	7.9(62.0)	6.9(44.7)
Atrazine 0.2%	8.4(70.1)	1.0(0.0)	5.5(30.0)	6.8(46.0)	1.0(0.0)	2.5(5.2)	9.5(90.0)	8.4(71.2)	7.1(50.1)
Atrazine 0.3%	8.3(68.8)	1.0(0.0)	5.5(30.0)	6.7(44.0)	1.0(0.0)	2.6(5.7)	10.9(120.0)	8.3(68.4)	7.3(52.4)
Manual uprooting	8.7(76.2)	2.5(5.3)	6.8(46.0)	6.5(42.0)	2.0(3.2)	3.9(14.4)	10.5(110.0)	8.3(68.0)	6.2(38.1)
Manual cutting	8.5(72.2)	3.0(8.6)	8.1(66.0)	6.9(47.0)	2.3(4.2)	4.7(20.8)	9.5(90.0)	8.5(72.0)	4.7(21.5)
Unsprayed control	8.5(72.3)	6.3(40.0)	12.2(150)	7.1(50.8)	5.7(31.2)	6.8(45.2)	9.4(88.0)	7.8(61.2)	4.8(22.4)
LSD (P=0. 05)	NS	0.17	0.41	0.4	0.12	0.31	0.27	0.30	0.44

MAT, month after treatment/spray; values given in parentheses are the means of original values

CONCLUSION

To make the wastelands free from majority of weeds including *Parthenium*, glyphosate 0.5 % was found to be the best herbicide. However, in situation with the scope of getting local grass yield metribuzin 0.01%, 2, 4-D 0.20%, metsulfuron methyl 0.50% and atrazine 0.20% are the better herbicides to be adopted in *parthenium* infested area.

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Genetic diversity and phylogenetic relationship among biotypes of Indian weedy rice using SSR markers

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Weedy rice (*Oryza sativa* f. *spontanea*) is one of the major issues of rice cultivation worldwide. Different weedy rice populations can be distinguished based on variable morphological and physiological traits; however, little is known about genetic differentiation and origin of weedy rice populations. The infestation of weedy rice has huge impact on rice yield (Pantone and Baker 1991). The objective of this study was to characterize different weedy rice biotypes at molecular level using SSR markers.

METHODOLOGY

Sample collection: In this study total 107 biotypes of weedy rice germplasm were collected from 8 different regions of India having four different agro-climatic zones including some accessions of wild and cultivated rice with diverse origin. Amplification was achieved using 18 highly polymorphic SSR primers.

DNA extraction: Genomic DNA were extracted using DNA extraction kit (Thermo Scientific) with high purity.

Polymerase chain reaction (PCR): The polymerase chain reaction was carried out by modified method of Song *et al.* (2003). The PCR products were electrophoresed in a 4% agarose gels and the individual bands were scored on the basis of molecular weight for further analysis.

Data analysis: All the biotypes were scored for the molecular weight of the amplified products (bands). Data were entered into a matrix as discrete variables. The Excel file containing the allelic data was imported into DARwin software-Version 6.0 to find out diversity structure. Description based on distance methods for dissimilarity matrix was worked out. Further, this allelic matrix was imported into Power marker software, Version-3.25 for allelic frequency, gene diversity and PIC (Polymorphism information content) analysis. For the population genetic analysis, this data matrix was imported into POPGENE software version 1.31 which is based on Nei's regular and unbiased genetic distance measures. By using Structure Harvester (Version 2.3.4), admixing of populations was worked out by identifying distinct genetic populations, assigning individuals to populations, and identifying migrants and admixed individuals.

RESULTS

Genetic diversity is the key factor in genotypic characterization and conservation strategy. On the basis of structure with no-admixture/independent model three population groups were formed. By using Popgene here, Shannon's Information Index (I) is higher (0.78) in population 'DWSR' and lowest (0.11) in 'Tamilnadu' which shows the measure of gene diversity. The number of polymorphic loci and their percentage is also higher in population 'DWSR' which is 16 and 88.89% respectively but lowest in 'Tamilnadu' population which is 3 and 16.67%. Nei's (1973) exp. Heterozygosity is higher (0.44) in 'DWSR' population and lowest in population of 'JKD' (0.10) which shows the genetic variation in natural population (Fig. 1).

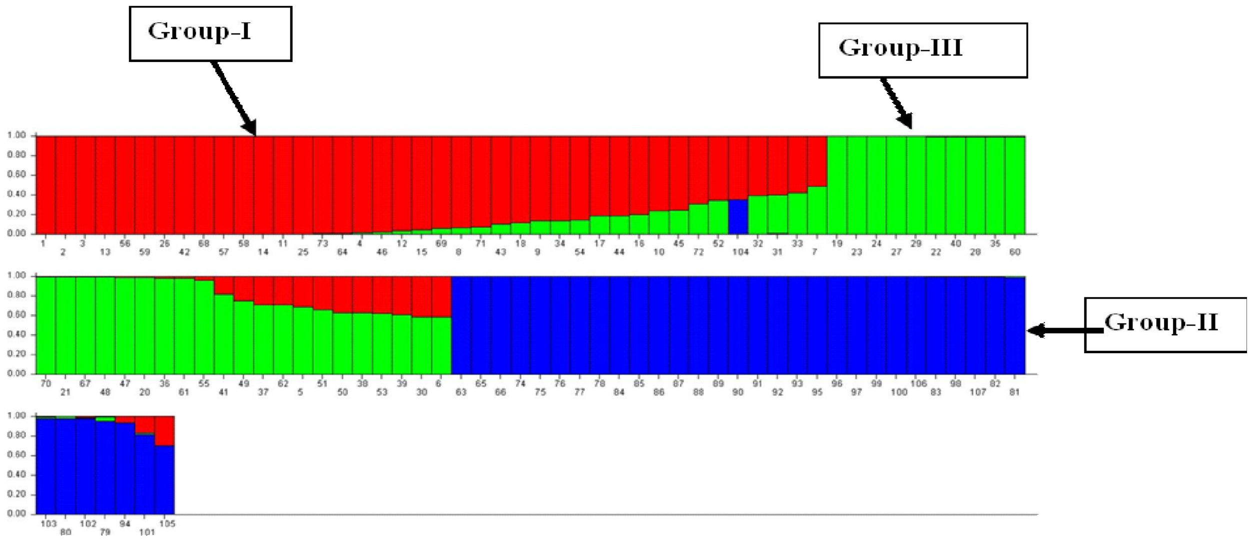

Fig. 1. Population structure of 107 accessions based on no-admixture model with frequency independent

CONCLUSION

It is inferred only weedy rice biotypes clustered into three distinct groups. However, a significant number of biotypes also showed considerable degree of admixing among populations which indicates either these are getting gene flow from each other or may be previously linked. Between cultivated and wild rice accessions, wild rice not showing any allele sharing with other population structure.

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Frost heaves and weedy invasion as a threat for pastoral restoration in cold arid region

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Ladakh in the NW Himalayas is often termed a "cold desert" (Chowdhery and Rao 1990). Due to the remoteness of Eastern Ladakh, the local flora is little affected by plant invasions even though human activities, such asgrazing of domestic animals and collection of fire wood, have influenced the vegetation substantially despite low human population and Eastern Ladakh has a harsh climate, where plants are subjected to multiple biotic and abiotic stresses such as low precipitation (50–100 mm per year), extreme diurnal temperature fluctuations, strong winds, salinity and animal migration significantly.

When temperatures dip below the freezing, ~~the~~ soil also freezes; changing the water in the soil from a liquid to ice and the soil expands correspondingly resulting into the heave upward. This pushes objects in the soil, like rocks and the roots of plants, toward the surface. Over the time, repeated cycles of this action will pop plants out of the ground, especially new plants with undeveloped root systems.

METHODOLOGY

A survey was carried out by Regional Research Station, ICAR-CAZRI, Leh-Ladakh during 2015-16 and 2016-17 to understand the occurrence, types and use of Frost heaves at various clonal systems and weedy invasion on pastoral systems of Nubra, Leh and Changthang valleys having natural semi-arid grasslands with less than 10-50 mm snowfall at an altitude above 4500 metres msl. Data on size of frost heaves in different land use systems, search of invasive species on frost heaves and associated flora preferred by pastoral animals, effect on pasture resources were recorded.

RESULTS

Keeping in view the impact of multiple biotic and abiotic stresses on pasture ecosystems in a changing climate, a survey was carried out on the occurrence, types and use of Frost heaves at Leh, Nubra and Changthang valleys. Frost heaves are typical landforms that are associated with cold climates and are best known as wintertime uplift of the ground. The term 'Heave' describes a displacement. The common feature is their systematic growth under marshy, swampy or at places with abundant surface or subsurface water flow. The dominant use of these lands is the grazing. While, under wetland condition, these surfaces act as excellent grazing lands, under dry and desiccated conditions, the topsoil of the landform turns amorphous and degraded with no grass or vegetation. The survey found two dominant patterns of their formation; single or complex. The shape may be rounded, elongated or massive. In a spring site and under a pastoral or grazing landuse system at Saboo, the clustered and massive frost heaves were 5 m long, 0.8 m wide and 1 m high while the small and single formations measured 0.35 m long, 0.3 m wide and 10 cm high. The narrow and elongated heaves measured 1.8 m long and 18 cm high. At Stakmo, under boulder filled surfaces, the heaves were 0.8 m long, 20 cm high but their circumference was maximum 2.2 m. This represented a situation in which subsurface was dry which might have prompted collapse of the soil.

Simultaneously, in these region, eight major vegetation types such as salt marshes, animal resting places, water bodies, shrubby, steppes, wet meadows, screes and sub-nival zones (Klimesova et al 2010) were recorded. Amongst these clonal communities, steppes and alpine grasslands (mostly grazed by sheep, goat and yaks) upto 5600 metres) (Jina 1995, Holzner and Kriechbaun, 1998) dominated the grasslands. Typical vegetation association at Saboo were a cluster of *Kobresia*, *Astragulus*, *Glaux* spp, *Taraxacum* spp, *Cirsium arvense* while at higher altitude-Hunder, species were *Kobresia*, *Phragmites* spp, *Cirsium arvense* and *Carex* spp. In case of Changthang region, the vegetation was mostly dominated tiny rosette, sedges, and other cohesive group of vegetation such as *Kobresia* spp, *Carex*, *Leontopodium pusillum*, *Astragalus strictus*, *Helerpestus* spp, *Triglochin* spp., *Puccinellia* spp. and *Glaux maritima*. Although these pastures are dominated by one of the smallest Cyperaceae endemic growing not taller than 2 to 3 cm of covering more than 90%, and consist of only 8 to 10 mostly tiny rosette species (e.g. *Thalictrumal pinum*, *Potentilla saundersiana*, *Aster flaccidus*, *Primula walshii*, *Pedicularis spp.*, *Cortiella caespitosa*). The open humic soil is colonized by rosettes like *Lancea tibetica*, *Lagotis brachystachya*, *Potentilla bifurca*, *Przewalskia tangutica*, *Persicaria glacialis*, *Lasiocaryum densiflorum*.

While studying the effect of frost heaves on growing and existing pastures, it was found that frost heaving processes exert a great pulling force on roots and is so strong that tap roots of grasses are stretched and broken. Frequent freezing and thawing (melt) literally push grasses out of the ground, exposing their roots and possibly killing the entire plant. Frost heaving has been observed to be a frequent cause of failure to obtain satisfactory grass stands (Biswell, 1953).Frost heaving requires a frost-susceptible soil, a continual supply of water below (a water table) and freezing temperatures, penetrating into the soil. Frost-susceptible soils are those with pore sizes between particles and particle surface area that promote capillary flow. Silty and loamy soil types, which contain fine particles, are examples of frost-susceptible soils. On the other hand, weeds like *Cirsium arvense* with higher allelopathic potential may become adapted invasively in some regions or habitats and may displace desirable vegetation if not properly monitored. It has been estimated that agricultural and environmental weeds cost a lot in ~~a~~ Indian sub-continent especially. Pastoralists may regard them as noxious weeds that invade grazing land. Invasive Alien Species (IAS), such as weeds, pests and diseases, are extremely adaptable to climatic variability as shown by their current large latitudinal ranges. Frost heaving creates raised-soil landforms in various geometries, including circles, polygons and stripes in soils that are rich in organic matter, such as peat, or more mineral-rich soils.

Invasive species like *Poa annua*, although desirable colonize fast in deglaciated areas and increase in root biomass, which largely determines the weed's ability to tolerate climatic extremes such as high temperature, and water scarcity. This adaptation enables IAS top redominate over native species that are more susceptible to environmental extremes as also observed Canadian thistle has been observed invading the frost heaves and expected to replace allelopathically and strongly the native species in Changthang areas. This is cause for alarm. Continuous feeding pressure posed by Nomadic livestocks and other wild animals reduce the grass covers from the top of frost heaves in the pasture and other invasive species like *Cirsium arvense* may take over the charge and affect the temperature differences between bare soils and covered one. Feeding may have slightly colder soils as compared to soils covered by weeds. The surface temperature of bare soils was generally 1 °C to 3 °C warmer than soils with grass and weed cover crops taller than 0.05 m during February and March.

When grass or weeds are present in a pasture, more sunlight is reflected from the surface resulting enough amount of energy stored in the soil during the day is reduced by cover crops and hence there is less energy available for upward heat transfer during frost nights. The vegetation also affects energy transfer from the soil up to the radiating surface at the top of the vegetation and this might have an effect on temperature differences between bare soil and cover crops. Therefore, an orchard or vineyard with a grass or weed cover crop is more prone to frost damage than one with bare soil between the rows (Blanc et al., 1963; Bouchet, 1965; Snyder, Paw U and Thompson, 1987). Wide variations in the temperature effects of cover crops are reported in the literature, but they all generally agree that the presence of a cover crop will increase potential for frost damage. For example, frost heaving may significantly damage alfalfa plants, leaving stands with much less or even zero yield potential. Plants may initially appear undamaged, but taproots are typically broken and unable to pick up enough nutrients or moisture, and stands eventually die. Frost heaving of alfalfa happens when repeated freezing and thawing pushes the tap root and crown out of the soil.

CONCLUSION

Frost heaves, because of their common association with wetlands are the ideal grazing lands. However, either due to topographical conditions, heat stress or edaphic conditions, such landforms indicate a wide variety of patterns, or grasses sprouting on them are equally found to be affected as an impact of abiotic stresses under changing climate too. Simultaneously new species finds a space and invade the affected native ones and become invasive in region like Ladakh facilitate competitive stress by increasing ecosystem susceptibility to climatic and other parameters.

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Theme 6

Weed dynamics under climate change and herbicide resistant weeds and crops

Crop- weed competition for nutrients in soybean

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Weeds are the greatest bottleneck for successful crop husbandry. Weeds are generally hardy in nature and have a vigorous growth with well-developed root system which efficiently competes with cultivated crops for the nutrients, moisture and sunlight. In soybean, nutrients uptake by crop mainly depends on the dynamics of biomass accumulation. Decreased uptake of nutrients by the crop was noticed with increase in severity and duration of weed infestation (Stoimenova 1995).

METHODOLOGY

The experiment was conducted at Agriculture Research Station, TNAU, Bhavanisagar during 2013-14, in order to collect the data on the effect of early weed competition on soybean, including the competition for nutrients and the possible rate of nutrient removal by weeds. The experiment was laid out in a randomized block design with three replications and ten treatments. The soil of the experimental field was red sandy clay loam in texture belonging to *Typic Paleustalfs*. The nutrient status of soil during start of the experiment was low in available nitrogen (215 kg/ha), medium in available phosphorus (17.5 kg/ha) and high in available potassium (260 kg/ha). Soybean variety '*CO (Soy) 3*' with duration of 85-90 days released by TNAU was selected for this study.

RESULTS

Weed flora: In the experimental field, grassy weeds, *Panicum flavidum, Bracharia reptans and Dactyloctenium aegyptium* were the dominant ones and *Cyperus rotundus* was the only sedge present. The predominant among broad-leaved weeds were *Euphorbhia hirta, Trianthema portulacastrum, Portulaca quadrifida*, *Boerhaavia diffusa, Digera arvensis, Parthenium hysterophorous* and *Tridax procumbens*.

Nutrient removal by weeds: All the weed control treatments had noticeable influence on NPK removal by weeds at 25 DAS and are presented in Table 1. Lower N, P, and K removal by weeds was recorded in PE flumioxazine at 250 g/ha. It was followed by 150, 112.5 g/ha and PE Pendimethalin 1.0 kg/ha. The higher N, P and K removal was recorded by unweeded check and hand weeding twice. Similarly, Nutrient depletion by weeds in soybean was 26.1, 2.7 and 79.9, N, P and K kg/ha respectively (Kannan and Gurumurthy 1999).

Nutrient uptake by crop: At 25 DAS showed that NPK uptake was higher with PE application of flumioxazine at 112.5 g/h. It was followed by 100 g/ha of PE flumiozaxine and PE pendimethalin 1 kg/ha. Whereas, unweeded check recorded significantly lower NPK uptake.

Table 1. Effect of treatments on nutrients removal by weeds and uptake by crops in soybean

Treatment	Removal by weeds (kg/ha)			Uptake by crops (kg/ha)		
	N	P	K	N	P	K
PE flumioxazine 50% SC 100 g/ha	1.72	0.45	2.07	3.72	1.39	3.01
PE flumioxazine 50% SC 112.5 g/ha	1.64	0.39	1.41	3.74	1.41	3.08
PE flumioxazine 50% SC 125 g/ha	1.61	0.34	1.30	3.50	1.34	2.87
PE flumioxazine 50% SC 150 g/ha	1.50	0.28	1.22	3.13	1.32	2.70
PE flumioxazine 50% SC 250 g/ha	1.39	0.22	1.01	2.94	1.29	2.65
PE pendimethalin 30% EC 1.0 kg/ha	1.72	0.54	1.51	3.61	1.36	2.95
PE oxyflourfen 23.5% EC 125 g/ha	1.84	0.62	1.80	2.82	1.25	2.71
EPOE chlorimuron-ethyl 25% WP 9 g/ha	2.43	0.98	1.82	2.78	1.19	2.67
Hand weeding on 25 and 45 DAS	9.93	1.83	3.78	1.17	0.77	2.04
Unweeded check	9.98	1.93	3.10	1.74	0.66	1.72
LSD (P=0.05)	0.44	0.15	0.18	0.19	0.21	0.15

CONCLUSION

On the basis of result, it could be concluded that, nutrient removal by weeds was lower in PE application of flumioxazine at 250 g/ha, and the uptake of nutrients by the crop was higher with PE application of flumioxazine at 112.5 g/ha.

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Bioassay techniques for determination of the dose of pendimethalin for maize under different tillage system

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In weed research, bioassay is used to measure the biological response of living plant to herbicide and to quantify its concentration in a substrate. Bioassay is usually conducted with sensitive plant species also referred to as indicator or test species. Bioassay is being used widely as a useful tool to regulate herbicide doses in a particular crop. This technique also leads to identify the herbicide that is safe for a crop in terms of phyto-toxicity and growth reduction by relating the different herbicidal doses with percent reduction in fresh weight as individual plants. (Tag *et al.* 1981). The objective of this study was as follows:

- To determine selective dose of pendimethalin.
- To find out the dose of pendimethalin for maize in a particular region in a particular season.
- Comparative performance of pendimethalin under zero and conventional tillage system.
- To bioassay experiment was planned to determine the degree of selectivity through the measurement of selectivity index of the herbicide in different cultivars in concentration with their sensitivity and tolerance against the action of herbicides and count the selectivity index of the herbicides.

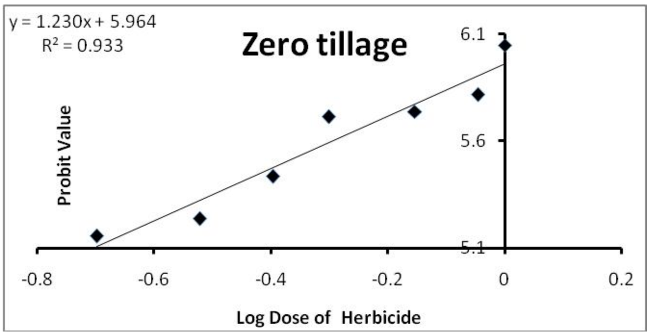
METHODOLOGY

Field experiment was carried out during the Pre *Kharif* season of 2010 in the farm of Uttarbanga Krishi Viswavidyalaya located at Pundibari, Coochbehar, (W.B). The soil of the experimental site was sandy loam in character. Eight treatments under each of conventional and zero tillage system were setup with plot size of 2 x 2 m^2 in maize verity (A*ll-rounder*). The dose of pendimethalin were 0.00, 0.20, 0.30, 0.40, 0.50, 0.70, 0.90 and 1.00, kg/ha under both tillage systems.

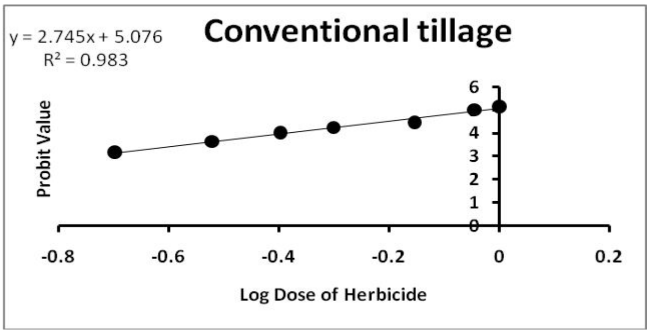
Visual observations were made every day to observe the changes in growth behaviors of the plant and appearance of phototoxic symptoms owing to herbicidal toxicity on plant at different doses. Biological response of plant to herbicides was determined by measuring the fresh wt of the plants grown in herbicide treated soil with different doses.

RESULTS

Pendimethalin have been found weakly leaching herbicides in soil, these are restricted primarily to the top 0-6cm. soil layer (Raj *et. al.* 1999). Leaching of herbicides to the crop seeds and root zone may on one side injure crops and other side result in poor weeds control. From different plot fresh weight we got the % growth reduction from the control plot. Now we plotted the probit value in the Y axis and the log dose value in the X axis. By that we got a straight line and a regression equation. These reflect the response of the maize plant at different doses of pendimethalin. The proportional increase in the plant response in terms of growth reduction to herbicide dose led to identify the level at which the plant produce 10% and 50% growth reduction response, which is known as GR_{10} and GR_{50}. These represent the relative sensitivity of maize to the pendimethalin. The phytotoxicity effect of the maize crop was manifested with characteristic yellowing and necrotic symptom that appeared in zero tillage maize.



Calculation:
For Zero Tillage Maize:
Y= 1.2307x + 5.9643 and r^2 =0.933.
Calculation of GR_{10}
Y= Probit value of 10% growth reduction of zero tillage maize i.e. 3.7184
3.7184 = 1.2307x + 5.9643
Then x = -1.8248
Anti log of -1.8248 = 0.01496, then GR_{10} = 0.01496 kg/ha dose of pendimethalin………………(1)
Calculation of GR_{50}
Y = Probit value of 50% growth reduction of zero tillage maize *i.e.* 5.0000
5.0000 = 1.2307x + 5.9643.
X = -0.7835 and antilog of -0.7835 = 0.1646.
Then GR_{50} = 0.1646 kg/ha dose of pendimethalin……………(2)



Calculation:
For Conventional Tillage Maize:
Y= 2.7459x + 5.0769 and r^2 =0.9832.
Calculation of GR_{10}
Y= Probit value of 10% growth reduction of Conventional tillage maize i.e. 3.7184
3.7184 = 2.7459x + 5.0769.
Then x = -0.4974
Anti log of -0.4974 = 0.3201, then GR_{10} = 0.3201 kg/ha dose of pendimethalin………………(1)
Calculation of GR_{50}
Y = Probit value of 50% growth reduction of Conventional tillage maize *i.e.* 5.0000
5.0000 = 2.7459x + 5.0769.
X = -0.02800 and antilog of -0.02800 = 0.9375.
Then GR_{50} = 0.9375 kg/ha dose of pendimethalin……………(2)

CONCLUSION

Up to 0.32 kg/ha pendimethalin can selectively used for Maize under conventional tillage system. However, only 0.01 kg/ha of pendimethalin can under zero tillage system. Therefore, we may conclude that the efficiency of pendimathalin is higher under zero tillage condition rather than conventional tillage system.

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Yield losses due to weeds in different cotton genotypes

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Cotton is the world's most important crop grown in tropical, sub-tropical and temperate countries. Three quarters of the world's crop is grown in less developed countries; largest producers are China (25% of the world's production), India (13%) and Pakistan (9%). Even after the adoption of Bt cotton, India having largest area under cotton, has productivity less than world average of 720 kg lint per ha. Among the agronomic constraints of cotton production, weed infestations have historically been a major issue. Besides reduction in yield, weeds cause several other indirect negative impacts, such as increasing production costs, reducing irrigation efficiency, and serve as hosts and habitats for insect-pests and disease-causing pathogens. During the early stages of cotton development, weeds can compete with cotton seedlings and cause serious damage by reducing the plant vigor, which often results in a reduction in formation of squares and bolls. When the crop gets established, the cotton plants are competitive against weeds; and weeds emerging late does not directly interfere with crop growth, but indirectly reduces the yield through increased insect-pest incidence. Although, weeds have the potential to reduce the cotton production by more than 35%; together with insect-pests and disease pathogens, these can cause a yield loss of >80% in this crop (Oerke 2006).

METHODOLOGY

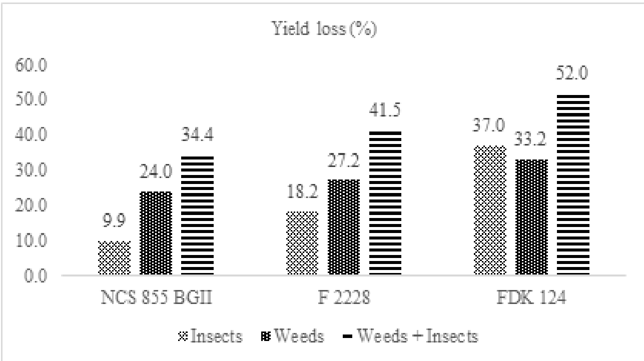
A field experiment was conducted at Punjab Agricultural University Regional Research Station during *Kharif* 2016 season to isolate the yield losses due to different pest categories. Four natural pest scenarios (only insects, only weeds, weeds + insects and pest free) were maintained by controlling the weeds and/or insects in main plots, with three genotypes (*NCS 855 BGII*–Bt hybrid, *F 2228* – Amercian cotton, *Gossypium hirsutum* genotype and *FDK 124* – Desi cotton, *Gossypium arboreum* genotype) in sub-plots. The treatments were replicated three times in split plot design. The fertilizer application and other agronomic practices were followed as per University recommendations. Data on weed flora was recorded at initiation of boll opening, and the cotton yield data was recorded from four pickings at 15-20 days interval.

RESULTS

Dactyloctenium aegyptiacum was the dominant weed in the experimental field followed by *Digera arvensis*, *Echinochloa crus-galli* and *Tribulus terrestris*. Maximum population of *Dactyloctenium aegyptiacum* was found in *Gossypium arboreum* genotype FDK 124, having higher plant height as compared to other two *Gossypium hirsutum* genotypes, while most of the *Echinochloa crus-galli* population was recorded in Bt cotton hybrid NCS 855 BGII; F2228 had maximum population of *Digera arvensis*. Although, there was no effect on plant height of cotton genotypes, these four weeds found in all the cotton genotypes offered severe competition and reduced boll retention on the crop plants, thereby decreasing the number of bolls significantly as compared to pest free crop and damage due to insects (Table). Highest seed cotton yield was obtained in pest free crop (3403 kg/ha) followed by crop with insects (2685 kg/ha), crop with weeds (2453 kg/ha); lowest yield was obtained in crop suppressed by weeds and insects both (1968 kg/ha). Among different genotypes, the yield trend was as expected; Bt hybrid NCS 855 BGII yielded higher (3098 kg/ha) than American cotton genotype F 2228 (2559 kg/ha) and lowest yield was obtained from desi cotton genotype FDK 124 (2225 kg/ha). There was no statistical interaction between pest scenarios and cotton genotypes.

While comparing genotypes for yield losses due to pests, maximum yield loss (52%) due to weeds and insects was found in FDK 124 (Figure). In this variety, yield reduction due to insects was more than weeds only, which might be due to the fact that being *Gossypium arboreum* genotype, it is very sensitive to slight attack of bollworm, which result in severe boll shedding thereby causing significant yield reduction. However, in Bt cotton hybrid NCS 855 BGII, the losses due to insects was only 9% as against 24% due to weeds only, while, both the pest categories together cause 34% reduction in yield. Similarly, in another *Gossypium hirsutum* genotype F 2228, weeds alone caused 27% reduction, while together with insects, these caused 42% loss in the seed cotton yield. Mushtaq and Cheema (2008) also reported about 30% reduction in yield due to weeds in cotton crop.

Treatment	Plant height (cm)	Bolls / plant	Boll weight (g)	Seed cotton yield (kg/ha)
Pest free	174	58.8	3.24	3403
Insects only	167	56.3	2.90	2685
Weeds only	160	48.1	2.88	2453
Weeds + insects	153	38.5	3.05	1968
LSD (P=0.05)	NS	5.4	NS	148
NCS855 BGII	162	69.7	3.42	3098
F 2228	158	44.0	3.34	2559
FDK 124	171	37.7	2.29	2225
LSD (P=0.05)	NS	4.1	0.24	201



CONCLUSION

Gossypium arboreum has been found quite sensitive to weeds, which caused maximum yield reduction of 33 % if left uncontrolled, while, the yield losses were 24-27% in *Gossypium hirsutum* genotypes. Weeds have emerged as more important pest which can cause higher yield reduction in *Gossypium hirsutum*; for Gossypium arboreum, weeds are second to insects, while considering yield loss.

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Herbicide tolerant crop technology as an efficient component of integrated weed management in corn and cotton

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Crops made resistant to herbicides by biotechnology are being widely adopted in various parts of the world. From the genesis of commercialization during 1996 to 2016, herbicide tolerant crops have consistently been the dominant traits. Over the past few years, several herbicide resistant crops (HTCs) have become available in many countries for commercial cultivation (Alberto, 2016). But in India, the technology of herbicide tolerant crops is in initial stage of field evaluation. Research efforts have been made with an objective to evaluate and consolidate the agronomic management and advantages of herbicide tolerant transgenic corn and cotton.

METHODOLOGY

Herbicide tolerant stacked traits of maize and cotton have been evaluated under Bio-safety Research Level (BRL I) as confined field trials for its agronomic efficiency on weed control and enhanced crop productivity at TNAU, Coimbatore and PAU, Ludhiana for three years (2010 to 2013). In both crops, potassium salt formulation of glyphosate was sprayed at different doses (900, 1350, 1800, 2700, 3600 and 5400 g a.e./ha twice at 25 and 60 DAS in cotton and 900,1800 and 3600 g a.e./ha at 25 DAS in maize). Weed control efficiency, yield and economics of corn and cotton were observed.

RESULTS

Results of trials at TNAU, Coimbatore, revealed that application of glyphosate at 2700 g/ha recorded lower weed density, dry weight and higher WCE in cotton. But, from the trials of PAU, Ludhiana, it is inferred that potassium salt of glyphosate at 900 and 1800 g/ha applied twice as PoE gave effective weed control and produced significantly higher seed cotton yield (Table1). PoE glyphosate at 900 and 1800 g/ha registered lower weed density, dry weight and higher WCE in transgenic Hishell and 900 M Gold maize hybrids (Table 2.).

Table1.Glyphosate on weed control and yield in transgenic cotton

Weed management	TNAU, Coimbatore		PAU, Ludhiana	
	Weed Control (%)	Seed cotton yield (kg/ha)	Weed Control (%)	Seed cotton yield (kg/ha)
Glyphosate 900 g/ha	92.3	2539	95.9	1126
Glyphosate 1350 g/ha	93.7	2708	96.5	1435
Glyphosate 1800 g/ha	96.6	2915	97.2	1346
Glyphosate 2700 g/ha	97.3	3144	-	-
Hand Weeding 15 & 30 DAS	85.2	2504	84.3	1032

Table 2. Weed control and grain yield in transgenic maize hybrids

Weed management	TNAU, Coimbatore		PAU, Ludhiana	
	Weed Control (%)	Grain yield(t/ha)	Weed Control (%)	Grain yield(t/ha)
Hishell POE glyphosate at 1800 g/ha	96.69	10.34	95.2	8.50
900 M Gold POE glyphosate 1800 g/ha	95.41	10.46	90.8	8.14
Hishell PE atrazine at 0.5 kg/ha + HW+ IC	91.54	9.23	68.6	7.71
900 M Gold PE atrazine at 0.5 kg/ha + HW+ IC	88.38	8.77	74.4	7.16
Proagro PE atrazine at 0.5 kg/ha + HW+ IC	84.84	7.43	69.9	5.98
CoHM 5 PE atrazine at 0.5 kg/ha + HW+ IC	82.92	7.08	71.7	7.73

Transgenic hybrids with glyphosate applications recorded higher maize grain yield, net return and B:C ratio as compared to university recommendation practices in transgenic or non-transgenic maize hybrids.

Results of field trials at PAU, Ludhiana also clearly revealed that glyphosate at 900 and 1800 g/ha applied at 25 DAS recorded effective control of weeds and significantly reduced weed density and dry weight (Table 2). Higher yield of herbicide tolerant transgenic cotton recorded with glyphosate at 2700 g/ha (Table 1) due to efficient control of weeds(Chinnusamy,2016) as observed at TNAU, Coimbatore and PAU, Ludhiana. Glyphosate at 2700 g/ha recorded with higher gross and net returns and B: C ratio in herbicide tolerant transgenic cotton. Higher grain yield was recorded with POE application of glyphosate at 900, 1800 and 3600 g/ha in Hishell and 900 M Gold transgenic hybrids (Table 2), even though higher and comparable weed control and yield were obtained with glyphosate at 900 and 3600 g/ha, higher net return and benefit cost ratio were recorded in glyphosate at 1800 g /ha in transgenic 900 M Gold.

CONCLUSION

Herbicide tolerant crops in general provide broad spectrum of weed control, better performance in terms of yield and higher profitability**.** In maize and cotton transgenic crops, post emergence weed management with glyphosate proved to be the better management option for the control of weeds.

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Crop-weed interaction under the regime of climate change

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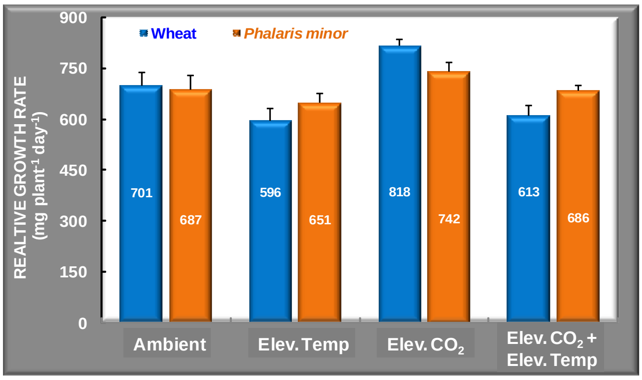
Predictive models suggest unprecedented increase in atmospheric CO_2 and temperature during last and current century. Changes in these factors are likely to have significant direct and indirect effects on biology of crops and weeds and competition among them (Ziska *et al.* 2010, Naidu *et. al.* 2015). Weeds are known to possess better adaptability to the changing environment by virtue of greater genetic diversity and evolutionary potential than crops. Evidences indicate that weeds may show a strong response to changes in climate. Hence, efforts have been made to study effect of elevated CO_2 and temperature individually and in combination on crop and dominant weeds at physiological, biochemical and molecular level.

METHODOLOGY

The present study was conducted in open top chambers (OTCs) in rice-wheat-summer greengram cropping sequence along with dominated weeds in each crop. Mix population of crops and important weeds (rice + weedy rice + *Echinochloa crus-galli*; wheat + *Phalaris minor* + *Avena ludoviciana*; greengram + *Euphorbia geniculata* + *Amaranthes viridis*) were grown in OTCs in their respective seasons. Plants of each species were subjected to long-term exposure to ambient conditions, elevated CO_2 (550 ± 50 ppm), elevated temperature (ambient + 3 ºC) and combination of these two (elevated CO_2 and elevated temperature). For comparison, control treatment was maintained at ambient CO_2 (390 ± 5 ppm) and ambient temperature. Morpho-physiological, phenological, biochemical, activity of soil enzymes and molecular observations were recorded in each species periodically. Efficacy of herbicides like sulfosulfuron against *P. minor,* and bispyribac-Na against *E. colona* was also examined under same set of treatments.

RESULTS

Elevated CO_2 had a positive effect on overall growth of crops as well as weeds, however, elevated temperature alone or in combination of elevated CO_2 had adverse effect on phenology, growth and development of the crops (more so in rice and wheat). Photosynthesis, antioxidant defence mechanism and expression analysis of gene involved in photosynthesis and antioxidant defence have been studied in detail in crops and weed species. Regulation of new iso-forms of antioxidant enzymes in response to elevated CO_2 and elevated temperature and combination of these two was evident in species-specific manner. Weeds exhibited stronger antioxidant defence as compared to crop counterparts. Expression of genes involved in photosynthesis and defence pathways was found to be altered in species-specific and treatment-specific manner. Expression of genes involved in antioxidants defence pathway altered which points towards involvement of these genes in adaptation to high temperature and high CO_2 environment. Elevated CO_2 and elevated temperature individually and in combination affect phenology



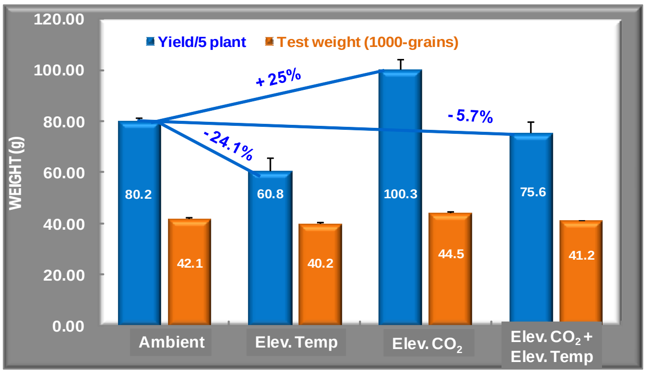


Fig. Effect of elevated CO_2 and temperature on growth rate and yield of wheat and *P. minor*

of crops as well as weeds depending on the species. Elevated CO_2 and temperature influenced the activity of soil enzymes (FDA hydrolysis, dehydrogenase and urease) in rhizosphere of crops and weeds. *E. crus-galli* responded positively with respect to the soil enzymes at elevated CO_2 alone or in combination of temperature. Efficacy of sulfosulfuron against *P. minor*, and bispyribac-Na against *E. colona* reduced at elevated CO_2 and elevated temperature suggesting that weed management would be more difficult due to climate change.

CONCLUSION

At elevated CO_2 and temperature, crop-weeds interaction altered in species-specific manner. Physiology and phenology of crops especially rice and wheat affected adversely, while associated weed species perform better than crops.

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Optimizing rates of propaquizafop 2.5% + imazethapyr 3.75% microemulsion for weed control in cluster bean

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Cluster bean (*Cyamopsis tetragonaloba* L.) is rainy season crop and due to frequent rains the weed population increases tremendously which compete for nutrients, moisture, and space with crop causing considerable yield reduction. Weeds competition between 20-30 DAS has been identified as most critical and reduces crop yield ranging from 47-92% (Bhadoria *et al*. 2000). Manual weeding is often limited by high cost; effective post-emergence herbicides may provide economically viable options for broad spectrum weed control in cluster bean. The number of herbicides available for cluster bean are limited and their alone application often been found ineffective against complex weed flora. Micro emulsions are clear, thermodynamically stable suspensions of liquid or dissolved pesticide in surfactant micelles. Surfactant- micro emulsions enhances herbicidal efficacy (Abribat *et al*.,2004). Therefore, pre-mix herbicide formulation of propaquizafop 2.5% + imazethapyr 3.75% ME was evaluated to optimize its rate for weed control in cluster bean.

METHODOLOGY

Two season field trials were conducted during Rainy (*Kharif*) season of 2014 and 2015 to evaluate the effect of different rates of pre-mix formulation of propaquizafop 2.5% + imazethapyr 3.75% ME on weeds in cluster bean at farmer's field in Vindhyan Region of Eastern Uttar Pradesh. The soil at the location was sandy loam in texture and soil was deficient in Nitrogen and medium in phosphorus and potassium. Three rates of propaquizafop 2.5% + imazethapyr 3.75% ME (46.88+70.31, 50+75 and53.13+79.69 g/ha) was compared with recommended rates of component herbicide propaquizafop 10% EC 75g/ha, imazethapyr 10% SL 150g/ha as POST and pendimethalin 30% EC 1500 g/ha as PRE. Ammonium sulphate 1.5 g/l was added in mixture 2 as a tank mix. Herbicide treatments were compared with two hands weeding at 20 and 40 days after sowing and untreated control (weedy) treatments in a randomized complete block design replicated thrice. Weeds enclosed in 1.0m^2 area were uprooted and sun dried and then transferred to hot air oven for drying at 60^0 C. Weeds dry weight of each sample was recorded in g/m^2 and weed control efficiency was calculated in relation to untreated plots. The crop was harvested at maturity and pod weight was recorded in kg/plot and converted to q/ha.

RESULTS

The major weed species in the crop were *Echinochloa colona*, *Digitaria sanguinalis* and *Digera arvensis* among monocot and *Amaranthus viridis* was major broad leaf weeds. Pre-mix micro emulsion of propaquizafop 2.5% + imazethapyr 3.75% 2125 ml/ha followed by 2000 ml/ha were significantly superiorin reducing weeds dry weight than to individual component herbicides in mixture and also to pendimethalin (Table1). As a consequence of this effect, maximum crop yield and benefit was also observed in these treatments.

Table 1. Effect of propaquizafop 2.5% + imazethapyr 3.75% ME on weed control efficiency, yield and cost benefit ratio in cluster bean

Treatment	Rate (ml/ha)	*Echinochloa* spp. 45 DAA	*Digitaria* spp. 45 DAA	*Digeria arvensis* 45 DAA	*Amaranthus viridis* 45 DAA	Cluster bean yield (t/ha)	CBR
Propaquizafop 2.5% + imazethapyr3.75%	46.88 + 70.31	5.98 (2.55)	6.15 (2.58)	6.36 (2.62)	7.65 (2.85)	3.32	1:1.74
Propaquizafop 2.5% + imazethapyr3.75%	50 +75	2.37 (1.69)	2.31 (1.68)	2.57 (1.75)	2.84 (1.83)	3.80	1:6.66
Propaquizafop 2.5% + imazethapyr3.75%	53.13 + 79.69	2.10 (1.61)	2.13 (1.62)	2.32 (1.68)	2.64 (1.77)	3.83	1:6.57
Propaquizafop 10% EC	750	3.07 (1.89)	3.05 (1.88)	16.22 (4.09)	20.28 (4.56)	3.32	1:2.89
Imazethapyr 10% SL	1500	3.40 (1.97)	3.29 (1.95)	3.33 (1.96)	3.65 (2.04)	3.58	1:4.74
Pendimethalin 30% EC	5000	3.63 (2.03)	3.57 (2.02)	3.64 (2.03)	3.99 (2.12)	3.50	1:4.02
Weed free check	-	1.94 (1.56)	1.94 (1.56)	2.15 (1.63)	2.45 (1.72)	3.91	-
Untreated control	-	18.74 (4.39)	18.89 (4.40)	20.08 (4.54)	24.46 (5.00)	3.16	-

CONCLUSIONS

Form the present sturdy it can be concluded that propaquizafop 2.5% + imazethapyr 3.75% ME 50+75 g/ha as post emergence can be recommended, for effective control of weeds and higher yield and income in Cluster bean

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Optimisation of sowing time and weed management option for winter irrigated *Bt* cotton hybrid

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Cotton (*Gossypium hirsutum* L.) is a long season and highly sensitive crop to climatic factors. Current climate change leading to raise in temperature and shift in rainfall pattern, bring new threats for cotton cultivation and weeds also pose a serious problem. In India, most often manual weeding is practiced and the average cost incurred by a farmer is about 32% of total production cost. A combination of pre and post emergence herbicides at optimum climatic condition has proven effective in controlling weeds with lesser cost and enhanced the cotton productivity. Hence, a field trial was laid out in winter irrigated *Bt* cotton hybrid with an objective to develop integrated weed management options under varied agro climatic conditions as resultant of different time of sowing.

METHODOLOGY

Field experiment was carried out at Tamil Nadu Agricultural University, Coimbatore during 2015-16, with four dates of sowing (1^{st} and 15^{th} August and 1^{st} and 15^{th} September) in the main plots and six weed control treatments (PE pendimethalin 30% EC at 1.0 and 38.7% CS at 0.68 kg/ha *fb* POE quizalofop-ethyl 50 g and pyrithiobac sodium 62.5 g/ha at 2-3 leaf stages of weeds, HW on 20 and 40 DAS and weedy check) in the sub-plots. Trial was laid out in split plot design with three replications. PE herbicides were sprayed on 3 DAS and POE herbicides at 2-3 leaf stages of weeds. Growing Degree Days (Jones and Wells 1998) and Weed Control Efficiency (Mani *et al.* 2007) were worked out as detailed below.

$$\text{GDDs } (°\text{C day}) = \frac{(T_{max} + T_{min})}{2} - T_b$$

T_{max} - Daily maximum temperature, (^{0}C)

T_{min}- Daily minimum temperature (^{0}C)

T_b- Base temperature as 15.5 ^{0}C

$$\text{WCE } (\%) = \frac{W_{Dc} - W_{Dt}}{W_{Dc}} \times 100$$

W_{Dc}- Weed dry weight (g/m^2) in control plot W_{Dt}- Weed dry weight (g/m^2) in treated plot

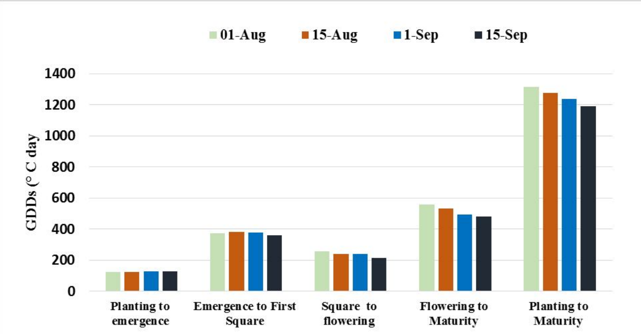

Fig.1 GDDs of cotton phenological stage at different time of sowing

RESULTS

Results indicated that, cumulated thermal time (GDDs) was maximum (1375) in early sown cotton (1^{st} August) beyond 15^{th} August sowing experienced minimum cumulative GGDs (Fig 1) in 15th September (1189). Higher weed density and dry weight were noticed in delayed sowing time from 1^{st} August to 15^{th} September. PE pendimethalin at 0.68 kg/ha followed by POE pyrithiobac sodium at 62.5 g/ha recorded lower weed density (48.0 No. /m^2), dry weight (29.7 g/ m^2) and higher weed control efficiency (86 %) at 40 DAS (Fig 2). Better growth, higher yield parameters and seed cotton yield were recorded in 1^{st} August sowing (1.50 t/ha) and lower seed cotton yield was observed at 15^{th} September (1.20 t/ha) sowing (Table 1). The optimum heat unit system facilitated cotton through higher photosynthesis, which might have led to higher number of symbodial branches, bolls/plant and seed cotton yield as compared to late sown *Bt* cotton hybrid.

Table 1. Time of sowing and weed management on weeds and yield attributes and yield of *Bt* cotton hybrid

Treatment t	Weed density (no./m^2)	Weed dry weight (g/m^2)	Sympodial branches /plant	Bolls/ plant	Seed cotton yield (t/ha)
Sowing time					
M_1- 1^{st} August	9.01 (80.6)	6.57 (42.7)	22.2	70.7	150
M_2-15^{th} August	8.94 (79.4)	6.83 (46.1)	23.1	64.4	1.38
M_3-1^{st} September	9.26 (85.3)	7.18(51.0)	18.7	58.9	1.24
M_4- 15^{th} September	10.67 (113.3)	8.11 (65.2)	16.4	56.5	1.20
LSD (P=0.05)	0.37	0.29	1.1	3.1	0.06
Weed management					
S1-PE pendimethalin (38.7) 0.68 kg/ha *fb* HW 40 DAS	7.34 (53.4)	5.74 (32.4)	20.7	59.6	1.17
S2-PE pendimethalin (38.7) 0.68 kg/ha *fb* PoE pyrithiobac Na 62.5 g/ha	6.96 (48.0)	5.50(29.7)	23.6	81.5	1.64
S3-PE Pendimethalin (38.7) 0.68 kg/ha fb PoE quizalofob-ethyl 50 g/ha	7.08 (49.6)	5.76(32.7)	23.2	60.0	1.52
S4-PE Pendimethalin (30)1.0 kg/ha fb HW 40 DAS	7.71 (59.0)	6.01 (35.6)	19.0	70.9	1.26
S5-HW 20 and 40 DAS	11.09 (122.4)	8.51(72.0)	21.1	64.4	1.28
S6-Weedy check	14.35 (205.4)	10.28 (101.2)	12.9	35.4	1.09
LSD (P=0.05)	0.71	0.55	2.0	5.6	0.12
Interaction	0.33	0.26	0.9	2.5	0.05

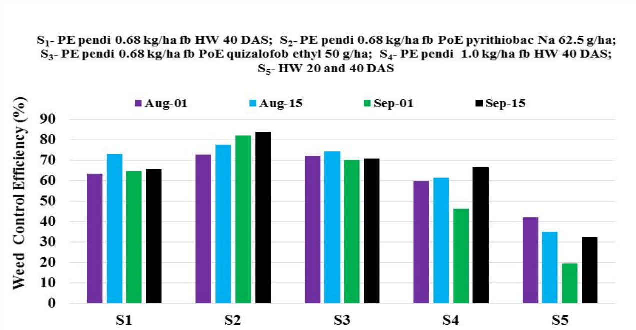

Fig 2. Time of sowing and weed management on WCE (%) of *Bt* cotton

CONCLUSION

Early sowing of (1^{st} August) *Bt* cotton hybrid with higher GDDs of 1314 decreased the weed interaction accompanied by integrated weed management of PE pendimethalin38.7% CS at0.68 kg/ ha followed by post emergence pyrithiobac sodium at 62.5 g/ha and quizalofop-ethyl at 50 g/ha recorded higher weed control efficiency and seed cotton yield.

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Evaluation of post emergence herbicides for the control of resistant little seed canary grass in wheat at farmers' fields of Haryana

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Phalaris minor is the most dominant weed of wheat in the rice-wheat cropping system (RWCS) in the north-western Indo-Gangetic Plains of India. During the eighties isoproturon provided very effective control of this weed, but its continuous use resulted in the evolution of resistance in *P. minor* biotypes in north-western India. Alternate herbicides *viz*. clodinafop, sulfosulfuron and fenoxaprop were recommended to control isoproturon resistant population of *P. minor* during 1997 provided effective control of this weed up to 2007 (Chhokar and Sharma 2008), but over the years, loss of efficacy to these herbicides has made the task of managing herbicide resistant *P. minor* biotypes more daunting (Dhawan *et al*. 2009). Presently, its control has become even more difficult after it evolved multiple herbicide resistance to recommended herbicides. so present experiment was planned to evaluate the bio-efficacy of available herbicides, their mixtures and sequential use for management of the resistant *P. minor.*

METHODOLOGY

For the control of the resistant little seed canary grass (*Phalaris minor*) and other weeds in wheat, farmers' participatory field trials were conducted at village Kheri Raiwali in Kaithal district of Haryana during winter seasons of 2011-12 and 2012-13 The experiment with plot size of 160 m^2 replicated thrice included treatments of pinoxaden 50 and 60 g/ha, clodinafop 60 and 120 g/ha, fenoxaprop 120 g/ha, sulfosulfuron 25 g/ha, mesosulfuron + iodosulfuron (RM) 14.4 g/ha, fenoxaprop+ metribuzin (RM) 100+175 g/ha, clodinafop+ metribuzin (RM) 60 + 210 g/ha, sulfosulfuron+metsulfuron (RM) 32 and 40 g/ha, and sulfosulfuron + metsulfuron (RM) 32 g/ha before irrigation (25 DAS) *fb* sulfosulfuron + metsulfuron (RM) 32 g/ha after irrigation (40 DAS).

RESULTS

Application of clodinafop 60 g/ha, fenoxaprop 120 g/ha and sulfosulfuron 25 g/ha at 35 days after sowing (DAS) did not provide satisfactory control of *P. minor*; however, mesosulfuron + iodosulfuron 14.4 g/ha provided better control (85-90%). Pinoxaden 50 g/ha resulted in 80% control of *P. minor* during first year but it provided only 55% control during second year. Ready-mix combination of metribuzin with fenoxaprop and clodinafop significantly improved the control of *P. minor* and broadleaf weeds as compared to alone application of fenoxaprop and clodinafop. Maximum weed control efficiency (WCE) and highest grain yield (5.2 t/ha) was recorded with the application of sulfosulfuron+metsulfuron 32 g/ha during 2011-12, which was statistically at par with mesosulfuron + iodosulfuron and clodinafop + metribuzin, whereas during the second year, sulfosulfuron + metsulfuron 40 g/ha resulted in highest grain yield. Sequential application of sulfosulfuron+metsulfuron 32 g/ha at 25 DAS *fb* sulfosulfuron + metsulfuron 32 g/ha registered 97% WCE.

CONCLUSIONS

The study indicates that there is an urgent need of a new post emergence herbicide with different mechanism of action (MOA), which must be integrated with non-chemical weed control strategies and used in rotation with other herbicide MOAs for management of resistant *P. minor* and prevention of herbicide resistance.

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Effect of ALS inhibitors on physiology of the rice plant

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Uma and jyothy are two popular rice varieties of Kerala commonly grown for commercial rice cultivation in the Kole, Kuttanad and Palakkad regions of Kerala. Herbicide application has become an integral component of rice production. The popular herbicides currently used in rice cultivation are the ALS & ACC ase inhibitors. These herbicides are used in minute quantities and there are no visual systems of toxicity on the rice plant. Singh *et al.* (2010) has reported reduction in nitrate reductase activity and increase in catalase enzyme activity by application of herbicides. Menon (2012) reported reduction in morphological attributes of rice crop by application AC Case and ALS inhibiting herbicides. Hence a study was undertaken to find the effect of popular post emergent herbicides belonging to the group ALS inhibitors viz. Azimsulfuron and Bispyribac-sodium on the most popular rice varieties of Kerala.

METHODOLOGY

The trial was done during the season of 2012-2013 and 2014-2015 using the varieties *'Jyothi'* and *'Uma'* in the kole lands of Thrissur and at ARS mannuthy respectively. Herbicides were applied on the 20[th] day as per normal recommendation. Leaf samples were collected on the 7[th] day and analyzed for nitrate reductase enzyme activity, total soluble proteins, catalase enzyme activity, IAA content, chlorophyll content and proline content using standard procedures. The net photosynthesis and stomatal conductance was also measured using Infra-Red Gas Analyser model LI -6400 of LICOR inc.

RESULTS

The result of the study showed that the biochemical parameters such as nitrate reductase activity, soluble protein content, chlorophyll content, IAA content and soluble protein content showed an initial decline when estimated one week after herbicide application in both the rice varieties. This might have contributed to a decrease in stomatal conductance and net photosynthesis of the rice varieties. The accumulation of proline and increase in catalyse enzyme activity indicates that the plants were subjected to stress though no visible symptoms are seen. However, recovery was observed when these parameters were again tested at the time of flowering. The slight set back experienced by the plant by herbicide application seems to influence the yield of the crop. The response of different rice cultivars to the herbicides also showed variation. The variety Jyothi was found to be more sensitive than the variety Uma. Among the herbicide Azimsulfuron contributed to higher growth suppression as compared to Bispyribac-sodium. However as compared to unweeded control the yield reduction contributed by the herbicide is meagre Mitigation treatment with micronutrients is found to reverse the condition and improve the yield of the crop.

Table.1. Physiological parameters of rice varieties after 7 days of herbicide application

Parameters	Hand weeding		Azimsulfuron		Bispyribac-sodium	
	Jyothi	*Uma*	*Jyothi*	*Uma*	*Jyothi*	*Uma*
Stomatal conductance (mol$H_2O/m^2/s$)	1.41	0.91	0.92	0.58	1.29	0.73
Net Photosynthesis (µmole$CO_2/m^2/s$)	44.3	31.56	39.4	42.79	30.76	31.47
IAA content (mg/g of unoxidised auxin/g/hr)	0.884	1.04	0.788	0.847	0.71	0.91
NRAase activity (µmoleNO_2formed/g freshweight/hr)	493	438	365	378	450	405
Chlorophyll content (mg/g freshweight)	2.44		2.03		2.33	
Total soluble Protein content (mg/gfreshweight)	40.80	37.6	33.15	32.6	40.65	36.5
Catalase enzyme activity (catalase enzyme units/g fresh weight)	10.21	4.39	17.73	5.80	11.28	5.24
Proline content (µmoles /g fresh wt.)	80	179	131	228	84	213
Grain yield (t/ha)	6.037	4.00	4.95	3.98	5.733	4.00
Straw yield (t/ha)	7.19	4.88	5.97	4.66	6.727	4.94

CONCLUSION

Application of ALS inhibiting herbicides as post emergence spray resulted in a reduction in the growth promoting physiological parameters of rice which might be due to the stress experienced by the plants and this resulted in reduction in yield as compared to the hand weeded control.

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Evaluation of competitive ability of wheat and pea with winter season weeds

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Weed management is more demanding because weeds are rapidly becoming resistant to herbicides so a farmer prohibits use of herbicides. This has led the scientific community to use other management strategies such as crop cultivation in weed free condition or without competition. Generally, the interspecific competition (between plants of different species) is more severe it always exists between crops and weeds. Weed competition is very intense during early stages of crop growth. The critical period for weed control is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses and first thirty to seventy days are critical, depending of the type of crop cultivar and the method of crop establishment (Zimdahl 1988). Hence the present study was carried out to evaluate the competition of three problematic weed species of winter season with wheat and pea and estimate crop yield losses.

METHODOLOGY

The field experiment was carried out during the winter season of 2014- 15, at the Norman E. Borlaug Crop Research Centre, GB Pant university of Ag. and Tech. Pantnagar. For studies on crop-weed competition, both wheat (*UP-2526*) and pea (*P-25*) were sown in plots (5.0 x 5.0 m). The treatments included weedy and weed free situation for both the crops. The crops were maintained with recommended management practices.

RESULTS

The plant height of wheat under weed free condition was increased from 14.9 cm at 30 DAS to 85cm at 90 DAS whereas in weedy condition, the height was significantly less as compared to the weed free at maturity. It was 14.9cm at 30 DAS and increased up to 72 cm at 90 DAS. Under weedy condition, there was 15.29% decrease in plant height at 90 DAS. In case of pea under weed free condition, the shoot length was increased from 10.0cm at 30 DAS to 64.9 cm at 90 DAS. In weedy situations, it was severely affected as compared to weed free situation at later growth stages.

The data on crop dry weight is presented in figure2. The dry weight of wheat in weed free condition was significantly more than the weedy plot in each growth stage. The biomass of weed free wheat was 3.15g/m^2 at 30 DAS which increased to 80.5 g/m^2 at 90 DAS. Under weedy condition, there was significant reduction in dry weight. It was 2.38 g/m^2 at 30 DAS while at 90 DAS, it was 62 g/m^2. Thus, there was 22.8% reduction in dry weight at 90 DAS due to weed competition. The dry weight of pea in weed free condition was significantly more than the weedy plot in each stage of growth. The biomass of weed free pea was 2.16 g/m^2 at 30 DAS which increased to 54.5 g/m^2 at 90 DAS. Under weedy condition, there was significant reduction in dry weight. It was 1.65 g/m^2 at 30 DAS while at 90 DAS, it was 33 g/m^2. Thus, there was 39.4% reduction in dry weight at 90 DAS due to weed competition.

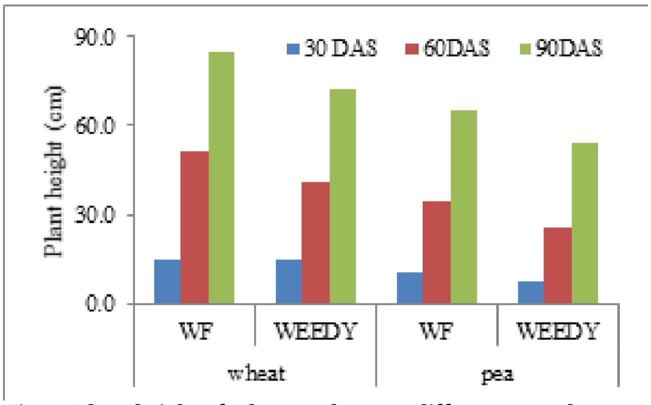

Fig. 1. Plant height of wheat and pea at different growth stages under weed free and weedy condition

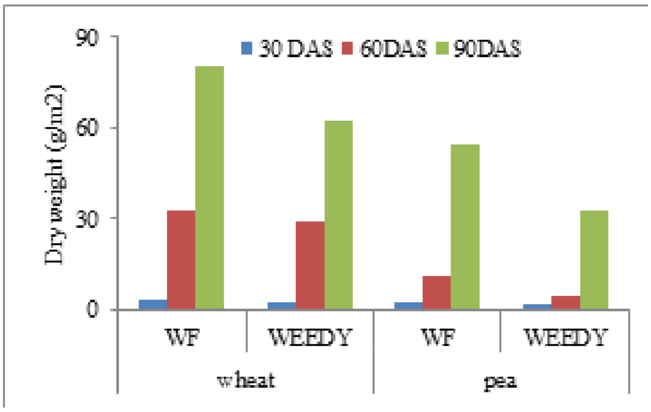

Fig. 2. Dry weight of wheat and pea under weedy and weed free conditions at different growth stages

CONCLUSION

The competitive ability of any crop is strongly influenced by relative emergence time, weed type, weed density and management practices. If crop emergence occurs before weeds, they will be able to use much of the limited resources as compared to weed plants which will ultimately give rise to a competitive advantage. Critical period of competition is in the early stages during 45-60 days after treatment and hence the growth of crops slows down and grain yield decreases (Jacob and Syriac 2005).

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Chlorophyll florescence status of isoproturon resistant population of little seed canary grass

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Phalaris minor is a highly competitive weed of wheat crop in India and can cause yield reductions of up to 100% (Chhokar *et al.* 2008). Isoproturon was recommended against *P. minor* in late 1980s which reduced huge losses in wheat and was largely accepted by the Indian farmers, due to its broad-spectrum weed control and its selectivity with crops. Extensive use of Isoproturon over many years has led to the evolution of resistance in *P. minor* in north-west India and resulted total crop failure (Malik and Singh 1995). After reporting resistance in 1992-93, many biotypes of *P. minor* have been found resistant to Isoproturon in Punjab and Haryana and therefore its recommendation was withdrawn in 1997. Hence the present study was carried out to find out the reduced efficacy of Isoproturon to *P. minor* and further confirmation of mechanism resistance in Uttarakhand state.

METHODOLOGY

Present study was carried out in Department of Plant Physiology, College of Basic Sciences and Humanities. G.B. Pant University of Agriculture and Technology Pantnagar. Seeds collected from farmer's field were sown in pots. Isoproturon was applied at recommended dose *i.e.*1.0 kg/ha at 2-3 leaf stage. All the treatments were replicated thrice. Observation were recorded at one day and seven days after spraying.

RESULT

Effect of different treatments of Isoproturon on different sources of *P. minor* is shown in Figure 1. The results showed that chlorophyll florescence was significantly different ($p<0.05$) at different time period and between the treatments and control. It was observed that in comparison to control Fv/ Fv ratio of Isoproturon treated were significantly decreased. However, in comparison to resistant biotypes the Fv/Fm ratio of susceptible biotypes is was less decreased. Among the susceptible biotypes, S1 showed maximum reduction *i.e.* 0.632 in chlorophyll florescence.

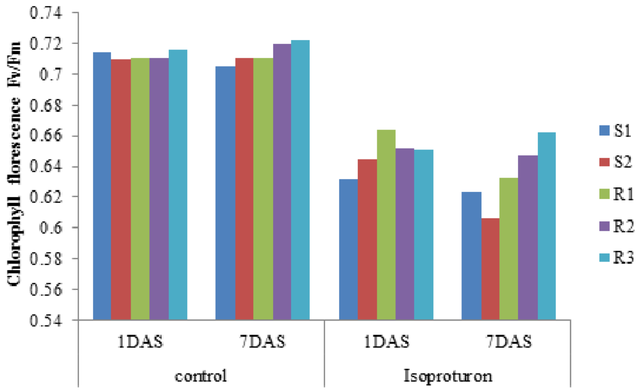

Fig. 1. Chlorophyll florescence (Fv/Fm) of different sources of *P. minor* at 1 DAS and 7 DAS

CONCLUSION

Investigations into the status of Fv/Fm ratio of resistance biotypes revealed that after seven days of spraying isoproturon herbicide the Fv/Fm ratio of resistant population was comparatively less decreased as compared to susceptible biotypes of *P. minor.*

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Large scale screening for post-emergence herbicide tolerance in diverse set of fieldpea genotypes

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Fieldpea is an important cool season food legumes crops of the world. Seeds are rich source of proteins (20%), carbohydrates and other vitamins, which are good for human and livestock consumption. Among the all crop management factors which affect the crop yield weeds are crucial one. Slow initial growth of fieldpea and wide spacing provide congenial environment for weeds to grow and compete with crop. Weeds are highly competitive to the crops for absorption of the nutrient and water from soil, subsequently, the performance of crop reduces and it causes drastic yield reduction. The weeds under uncontrolled situation cause more than 75% yield reduction (Singh *et al.* 2016). It is well established that plant resistance is the most potential and successful way to minimize losses due to weeds. Herbicides are the most successful weed controlling agents. So far there is no report of fieldpea genotypes having tolerance to post emergence herbicides. Present investigation was attempted to identify the sources of resistance to the post-emergence herbicide.

METHODOLOGY

Total eight hundred twenty eight fieldpea genotypes including advanced breeding lines, germplasm accessions and released varieties were ascertained for preliminary screening against popular post-emergence herbicide metribuzin 500 g/ha. The experiment was conducted in the field in a augmented design at New research centre, ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh, India. The plants were grown on 1-m long rows with 60 cm spacing between rows and 10 cm between plants. The herbicide sprayed during cooler hours of the day when there was little or no wind. The plants were scored for herbicide tolerance 15 days after spray on a 1–5 scale (Gaur *et al.* 2013)

RESULTS

The results of experiment exposed that there was huge amount of genetic variation for tolerance against metribuzin. In view of the visual observations and toxicity on fieldpea plants five genotypes, *viz*. *P-729, P-637, P-1297-35-1, P-2016* and *P-706* were found highly tolerant against metribuzin. Moreover, the genotypes were grouped in five categories i.e. highly tolerant (5), tolerant (21), moderately tolerant (133), susceptible (369) and highly susceptible (300) based on visual observation and toxicity. The susceptible lines exhibited different magnitude of leaf burning within 7 days of herbicide application.

Before herbicide spray

After herbicide spray

CONCLUSION

The large genetic variability identified in fieldpea for herbicide tolerance will encourage further research efforts towards development of herbicide tolerant cultivars. It would also promote to move forward for further screening of a more germplasm collection to find even more robust and diverse sources of herbicide tolerance. The herbicide tolerant genotypes identified in present study would be useful in genetic and physiological studies and in development of herbicide tolerant cultivars. Therefore, aforesaid promising genotypes after further confirmation could be utilized as donor to accelerate breeding programme and in mapping of genes for herbicide (metribuzin) tolerance.

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Management of herbicide resistant wild oat in wheat

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Wheat is one of the most important crops among the cereals and staple food of world's large population. India is second largest producer of wheat in the world after China with about 12% share in total world wheat production. Wheat is the dominant crop in the temperate countries not only for human food, but also for livestock feed. Its success largely depends on its adaptability to environmental conditions and agronomic practices. Productivity of wheat is governed by many factors, but one of the most serious and less noticed causes of low yield is the presence of weeds in wheat. A lot of research work has been done on weeds in wheat, which support that wild oat (*Avena ludoviciana*) and wild canary grass (*Phalaris minor)* are two most dominant grassy weeds, significantly reducing wheat yields. Wild oat is one of the ten worst annual weeds in the world and difficult to control. While the weeds are a strong competitor for water and nutrients; wild oat has been reported to cause significant yield loss to wheat when its population increased from 0 to 100 plants/m^2. Not only weeds, but also the knowledge about the herbicides is vital to promote the growth and getting higher yield of wheat with efficient weed control. Herbicide application is a preferred method for its control due to lesser feasibility of mechanical or manual weeding in wheat because of its morphological similarity with wheat, narrow spacing, as well as scarce and costly labour. Contrarily, depending only on herbicides as the sole method of weed control is also fraught with dangers, if not used judiciously. Continuous use of herbicides of the same modes of action has resulted in large scale resistance in *P. minor* in N-W India and may happen with weeds in other crops and herbicides.

A population of *A. ludoviciana* was reported to have no control with clodinafop in wheat in a farmer's field in Siswal village of Hisar district (Haryana), India. For the control of *A. ludoviciana*, clodinafop was used continuously since 2000 with only one rotation of herbicide and near continuous use of clodinafop for about 10-12 years resulted into reduced control of *A. ludoviciana* and even with double the recommended rates failed to control it. There is a greater need of new herbicide with different mode of action and change in the agronomic practices to manage resistant *A. ludoviciana*. Experiment were conducted *in situ* in two resistance affected farmer's fields in Siswal village using several PRE and POE herbicides, either alone or in combinations to manage resistant *A. ludoviciana*. Six putative resistant populations collected from farmers fields during March-April 2016 were subjected to dose response studies in pots using half, recommended and double of the recommended rates of herbicides used in the fields and compared with known susceptible population from University Farm of CCS HAU Hisar.

Significant variations were observed among the seven populations; three Siswal populations exhibited significantly higher resistance to clodinafop followed from Dadu (Sirsa). Among the three Siswal populations, one was highly resistant to clodinafop.

Among different treatments PRE application of pyroxasulfone + pendimethalin provided higher per cent control of resistant *A. ludoviciana* population as compared to pyroxasulfone, pendimethalin + metribuzin (Ready-mix), metribuzin, flumioxazin and flumioxazin + pendimethalin both under pots and field conditions. Pendimethalin was least effective and has to be followed up with pinoxaden for effective control of *A. ludoviciana*. Post emergence application of pinoxaden gave higher per cent control of resistant population as compared to sulfosulfuron, metribuzin, isoproturon and clodinafop; though under lower rates in pots the propensity in one population was discernible giving an early warning that if used continuously, resistance may evolve with pinoxaden as well. The consequences of this will be very serious as there will be no effective POE herbicide to manage the resistant population of *A. ludoviciana*. PRE application of metribuzin, flumioxazin and flumioxazin + pendimethalin exhibited crop injury wherever higher moisture was present and may not be a suitable option to manage resistant *A. ludoviciana*. Agronomic practices of delayed sowing to promote emergence of *A. ludoviciana* with pre sowing irrigation and its destruction with non-selective, no-residual herbicide or field preparation; selection of competitive wheat cultivars, fertilizer application, manual uprooting and mechanical control along with other potential methods need to be integrated with herbicides for effective control of resistant *A. ludoviciana*.

Weed flora status in buckwheat - a consequence of negligence in Assam condition

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Buckwheat is one of the most promising winter season-bound crops for Assam as well as entire Northern and North-eastern foothill regions of the country, and quite adventitious cash crops for easy inclusion in the existing cropping systems. This Polygonaceous crop, belonging to *Fagopyrum esculentum* and *F. tataricum*, bears several useful characters with good market potentialities in India and World, viz. (i) its seeds are good substitute of common cereals with nearly 65% carbohydrate (mostly as starch), rather richer in essential amino acid 'Lysine', (ii) young parts of the plant and flowers of *F. esculentum* has additional demand as vegetable, which also possessed good nutraceutical value and rich in 'rutin', (iii) floral nectar is a good source of honey, (iv) possessed very short life span (60-70 days) and (v) adaptability in a wide range of soil situations, especially the light textured soil that frequently suffer from severe draught (Thakuria *et al.*, 2012), (vi) possessed requirements of minimal soil fertility, compared to cereal crops, (vii) relatively quick establishment and high competitive ability, (viii) good smothering ability, (ix) insect repellent ability including leaf rollers (Lepidoptera : Tortricidae- Stephens *et al.*, 1998) and (x) allelopatic activity (Iqbal *et al.*, 2003). However, mostly because of its better competitive ability and early vigor, very meager importance is paid on its weed management. But, in moderately warm and high humid condition of Assam, it is seen that a number of partially shade loving winter weeds, as well as fast growing perennial rhizomatous or stoloniferous plants used to grow well under the canopies of buckwheat. And hence, a study was undertaken during 2014 to 2017 to record such weeds which compete well with buckwheat for nutrient and space; because, though weed management activities are neglected in buckwheat in many parts of the country, it is a common practice in UP (Narain, 1979), and other countries like Lithuania (Sakaiene *et al.*, 2008) and Slavonia (Knezevic & Baketa, 1989).

METHODOLOGY

The conventional quadrat method was followed for the study.

RESULTS

The study revealed that the grass flora comprising mostly of *Cynodon dactylon, Eleusine indica, Eragrostis unioloides* and *Oplismenus burmanii* dominated the ground vegetation in Tinsukia district where buckwheat is extensively cultivated in Sadiya subdivision from the banks of the river Brahmaputra to the foothills of Arunachal Pradesh. The grassy weed flora in Kokrajhar and Chirang districts was comprised of *Axonopus compressus, Cynodon dactylon, Eragrostis unioloides, Oplismenus burmanii* and *Paspalum conjugatum*. Interestingly that in Bongaigaon and Dhubri district was made up of *Cynodon dactylon* and *Panicum repens* only as dominant grasses. Prevalence of the sedge *Cyperus rotundus* was also quite low in LBV zone, but occupied amongst the top four weeds in Tinsukia district. Out of several possible factors, the impact of soil moisture might be one of the reasons, which was comparatively higher in Eastern Himalayan foothill regions of Kokrajhar, Chrang and Tinsukia, while lesser in plains of Bongaigaon and Dhubri districts. Available soil seed bank, as a consequence of tillage operations and cropping history in the buckwheat growing fields might also be other important factors for such differences of narrow-leaved weeds. Amongst the broad leaved weeds, *Polygonum plebeium*, *Stellaria media* and *Hydocotyle sibthorpioides* were highly populated and mostly dominant species in LBV zone. These weeds grow in mass and their populations reduced tremendously during the course of vegetative development through intra- and inter-specific competitions. That is why, their population density varied from several thousands to less than 100/m^2 within the study period. In contrary, the variation in weed dry weight was lesser than that of population density; its mean value varied from 53.2 (± 10.2) to 58.9 (± 4.5) g/m^2 in the Eastern Himalayan foothill districts, with a range from 24.6 g/m^2 to 79.0 g/m^2 (Figure 1). However, in the plains of LBV zone, the variation of weed dry weight was comparatively higher than the Eastern Himalayan districts; the mean value was 54.8 (± 22.7) g/m^2 as recorded during 2016-2017 and the range varied from 22.0 to 81.8 g/m^2.

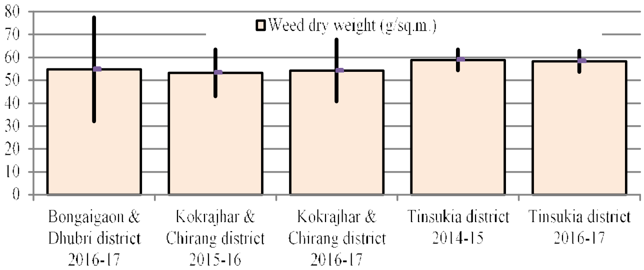

Fig. 1. The mean and variation of weed dry matter (g/sq m) in Buckwheat fields in different districts of Assam during 2014-2017

CONCLUSION

Such a situation and status of weed flora in the buckwheat fields depicted clearly the yield improvement possibility through appropriate weed management practices.

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Soil dehydrogenase activity effected in rice-wheat sequence by herbicides application

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In the soil environment, dehydrogenases play a significant role in the biological oxidation of soil organic matter (OM) by transferring hydrogen from organic substrates to inorganic acceptors. The co-enzymes hydrogen atoms are involved in the reductive processes of biosynthesis. Due to this fact, the overall DHA of a soil depends on the activities of various dehydrogenases, which are fundamental part of the enzyme system of all living microorganisms, like enzymes of the respiratory metabolism, the citrate cycle, and N metabolism. Thus, DHA serves as an indicator of the microbiological redox-systems in soil. DHA in the soil samples gives us large amount of information about biological characteristic of the soil. It was confirmed that the DHA strongly increases under anaerobic conditions. The effect of various environmental factors and use of herbicides in rice-wheat sequence was assessed in three years (2011-2014).

METHODOLOGY

Soil samples were collected (0-15 cm depth) from long term experiment field during wheat-Rice crop sequence (2011-2014) at the time of harvest and ground and stored in a refrigrator for enzymatic analysis. The most common laboratory procedure used for DHA determination is the method developed by Casida *et al.* (1964). Moist soil samples (4 g) were placed in test tubes to which was added 1 ml of 3% aqueous solution of 2,3,5-triphenyl tetrazolium chloride, 40 mg $CaCO_3$ and 2.5 ml distilled water. The contents of each tube were then mixed with a glass rod and incubated for 24 h at 37ºC. The reduction of colorless, water soluble substrate (TTC) by dehydrogenases present in the soil environment, an insoluble product with red color (triphenylformazan-TPF) is formed. TPF is easily quantified calorimetrically at the range of visible light (485 nm). The dehydrogenase activity was expressed as µg TPF formed/g soil/hrs.

RESULTS

From pooled data of three years (2011-14) on dehydrogenase activity in the soil showed that the dehydrogenase activity always in farmers' practice was found higher rest of the herbicide application in long term experiment on rice-wheat sequence. The continues application of butachlor 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (100% N through fertilizer source) and isoproturon 1.0 kg/ha + 2,4-D 0.75 kg/ha observed the maximum value of dehydrogenase activity when compared to rotational use these herbicides. Among the herbicide application, cyhalofop-butyl 90 g/ha *fb* 2,4-DEE 1.0 kg/ha/ butachlor 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (100% N through fertilizer source) and isoproturon 1.0 kg/ha + 2,4-D 0.75 kg/ha showed minimum enzymatic activity as compare to butachlor 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (100% or 75% N through fertilizer source) and isoproturon alone and continuous applied in rice and respectively. Min *et al.* (2001) observed that butachlor enhanced the activity of dehydrogenase at increasing concentrations of herbicide. The herbicidal treat- ments at the level tested were not drastic enough to be considered deleterious to soil microbial and soil enzymes which are important to soil fertility.

Rice	Wheat	Dehydrogenase Activity (µg TPF/ g soil/hr) Pooled Data (2011-2014)	
		Rice	Wheat
Farmer's practice	Farmer's practice	1.81	1.89
Butachlor 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (100% N through fertilizer source)	Isoproturon 1.0 kg/ha + 2,4-D 0.75 kg/ha	1.64	1.49
Butachlor 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (100% N through fertilizer source)	Clodinafop 75 g/ha *fb* 2,4-D 0.75 kg/ha/ Isoproturon* 1.0 kg/ha + 2,4-D 0.75kg/ha	1.58	1.51
Butachlor 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (75% N through fertilizer source and 25% N through Lantana	Isoproturon 1.0 kg/ha + 2,4-D 0.75 kg/ha	1.54	1.57
Butachlor 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (75% N through fertilizer source and 25% N through Lantana	Clodinafop 75 g/ha + 2,4-D 0.75 kg/ha Isoproturon* 1.0 kg/ha + 2,4-D 0.75kg/ha	1.49	1.55
Cyhalofop butyl 90 g/ha *fb* 2,4-DEE 1.0 kg/ha,/ Butachlor* 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (100% N through fertilizer source)	Isoproturon 1.0 kg/ha + 2,4-D 0.75 kg/ha	1.31	1.38
Cyhalofop butyl 90 g/ha *fb* 2,4-DEE 1.0 kg/ha,/ Butachlor* 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (100% N through fertilizer source)	Clodinafop 75 g/ha *fb* 2,4-D 0.75 kg/ha/ Isoproturon* 1.0 kg/ha + 2,4-D 0.75kg/ha	1.53	1.41
Cyhalofop butyl 90 g/ha *fb* 2,4-DEE 1.0 kg/ha,/ Butachlor* 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (75% N through fertilizer + 25% N through Lantana	Isoproturon 1.0 kg/ha + 2,4-D 0.75 kg/ha	1.52	1.65
Cyhalofop butyl 90 g/ha *fb* 2,4-DEE 1.0 kg/ha,/ Butachlor* 1.5 kg/ha *fb* 2,4-DEE 1.0 kg/ha (75% N through fertilizer + 25% N through Lantana	Clodinafop 75 g/ha *fb* 2,4-D 0.75 kg/ha/ Isoproturon* 1.0 kg/ha + 2,4-D 0.75kg/ha	1.52	1.42
		NS	NS

CONCLUSION

The use of herbicide suppress the dehydrogenase activity but recovered about the time of harvest of crop.

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Cropping system's influence on weeds floristic diversity

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Rice-wheat is the most important cropping system in India. It is most predominant cropping system of the Indo Gangetic Plain also known as "food bowl" or "food basket" of India having 53% of the total area under rice and wheat crops. Rice-wheat system occupies around 42% of the total agricultural area in India. This system has sustained over years and brings together conflicting and complementary practices. But now the productivity of both the crops has stagnated and factor productivity is declining year after year. Crop diversification is an effective strategy to achieve food and nutrition security, income growth, poverty alleviation, employment generation, judicious use of land and water resources, sustainable agricultural development and environmental improvement (Rana and Rana 2013). Weeds, diseases and insect-pests are the serious constraints in diversified cropping systems too. Weeds are dynamic in nature. The crop(s), cropping systems and management practices mainly influence the weed shifts. The present study aimed at having an appraisal of weeds floristic diversity in rice based diversified cropping systems being tested under AICRP-IFS Palampur Centre at the Bhadiarkhar Farm of the university.

METHODOLOGY

Eight cropping systems, *viz.* C_1: rice – wheat, C_2: rice – pea – summer squash, C_3: okra – radish – onion, C_4: turmeric – pea – summer squash, C_5: rice – lettuce – potato, C_6: rice – palak – cucumber, C_7: rice –broccoli – radish, and C_8: colocasia – pea + coriander are being evaluated for their production potential from *Kharif* 2014. An appraisal of weed species associated with different cropping systems has been made during mid-September and mid-October of *Kharif* 2016.

RESULTS

Commelina, *Brassica* sp, *Monochoria* sp and *Ageratum* sp (*A. houstonianum* and *A. conyzoides*) were the major weeds found growing during *Kharif*. *Fimbristylis*, *Cynodon*, *Caesulia axillaris*, *Echinochloa* sp., *Cyperus* sp. (*C. iria*, *C. difformis*, and *C. esculentus*) had predominance in some treatments. *Eleocharis*, *Phyllanthus*, *Aeschynomene*, *Scirpus* had little infestation and sporadic appearance.

Commelina and *Brassica* sp. were found associated in mid September and mid October, respectively, in *Kharif* crops appeared to be the weeds of both kharif as well as lowland situation as is indicated by their presence in all the cropping systems. *Commelina* disappeared before mid-October while Brassica sp appeared after mid September. *Monochoria*, typically a weed of lowland situations was found growing in rice only. It was absent in Okra (C_3), turmeric (C_4) and colocasia (C_8). Therefore, the population of *Monochoria vaginalis* was significantly affected due to cropping systems at both the stages. Conversely, *Ageratum* is a weed of upland situations. Its population was significantly higher under C_3, C_4 and C_8 cropping systems where upland crops viz. Okra, turmeric and colocasia, respectively occupied the land. It invaded rice when the field dried out at a later part of the season. There was significant build-up of *Cynodon dactylon* in turmeric (C_4) followed by Okra (C_3) during mid September when its suckers invades fields from bunds. The association of other weeds viz. *Caesulia axillaria*, *Echinochloa* and *Cyperus* sp was not found to be significantly affected due to cropping systems under study.

Table 1. Effect of cropping systems on total and category-wise weed count

Treatment	Grasses		Broad-leaved		Sedges and cattails		Total weed count	
	Mid Sept.	Mid Oct.	Mid Sept.	Mid Oc.t	Mid Sept.	Mid Oct.	.	Mid Oct.
C_1- rice – wheat	0.7 (0)	2.8 (12)	11.3(138)	9.9(100)	1.8(4)	0.7(0)	11.5(142)	10.5(112)
C_2- rice – pea – summer squash	0.7(0)	1.8(6)	10.2(120)	9.6(92)	2.1(6)	0.7(0)	10.7(126)	9.8(98)
C_3- okra – radish – onion	4.7(28)	4.8(32)	21.9(510)	18.6(348)	0.7(0)	2.1(6)	22.6(538)	19.5(386)
C_4- turmeric – pea – summer squash	9.8(98)	5.0(26)	22.1(538)	12.2(156)	0.7(0)	2.7(18)	24.4(636)	13.9(200)
C_5- rice – lettuce – potato	2.4(8)	3.9(26)	10.3(118)	7.5(58)	1.3(2)	0.7(0)	10.7(128)	9.1(84)
C_6- rice – palak – cucumber	0.7(0)	1.5(4)	17.4(340)	12.6(160)	3.5(26)	0.7(0)	18.4(366)	12.8(164)
C_7- rice –broccoli – radish	0.7(0)	2.9(10)	10.6(122)	12.6(178)	1.3(2)	0.7(0)	10.7(124)	13.1(188)
C_8- colocasia – pea + coriander	2.8(14)	0.7(0)	21.2(468)	14.5(226)	0.7(0)	0.7(0)	21.5(482)	14.5(226)
LSD (P=0.05)	2.5	NS	8.1	4.1	NS	NS	7.5	4.0

Grasses population as a whole was significantly affected when recorded in mid September and was higher in C_4 followed by C_3. This was obvious due to more population of Cynodon in these cropping systems. Population of broad-leaved weeds was affected significantly due to cropping systems at both the times of observations. Population of broad-leaved weeds in all the cropping systems (C_3, C_4 and C_8) was significantly higher over rice – wheat cropping system (C_1). The population of sedges was found to be not significantly affected due to cropping systems under study. Total weed count was significantly affected due to cropping systems during both the times of observations. C_3, C_4 and C_8 had more weeds than C_1.

CONCLUSION

The appraisal of the weeds in different cropping systems clearly indicated their dynamism. This clearly signifies the importance of cropping system or crop rotation approach to manage weed floristic diversity.

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Assessment of CP4 EPSPS based glyphosate tolerant maize hybrids for weed control and crop productivity

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Weeds cause considerable yield loss due to competition for resources with maize crop. Season long competition reduced the grain yield of maize in as much as 70 per cent (Malviya and Singh 2007). Chemical method of weed control is the most economical and effective tool get healthy crop stand and good yield. Herbicide resistant maize plants that confer tolerance to glyphosate by production of the glyphosate-tolerant CP4 5-enolpyruvylshikimate-3phosphate synthase (*CP4 EPSPS*) proteins. As an initiative on transgenic maize in India, transgenic stacked maize hybrids evolved by Monsanto India Ltd., NK603 is the gyphosate tolerant technology for the effective weed management system. The plant becomes tolerant to the herbicide while all other weed flora suppressed after application of herbicides. MON 89034 is 2nd Generation Bt corn technology effective against lepidopteron insect pests with a unique and innovative dual mode of action. Keeping in this view field experiment was conducted with the objective to assess the weed control efficiency and maize productivity.

METHODOLOGY

Field experiment was conducted at Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during *Kharif*, 2009 and *Rabi*, 2009-10. Glyphosate was applied as early post emergence application at 900, 1800 and 3600 g/ha in Hishell and 900 M Gold transgenic maize hybrids and these were compared with non-transgenic counterpart hybrids with pre-emergence application of atrazine at 0.5 kg/ha followed by hand weeding on 40 days after sowing and with and without insect management. Observations on weeds, crop growth parameters such as germination, plant height, yield attributes and yield were recorded.

RESULTS

Broad-leaved weeds were predominant (82%), followed by grassy weeds (10%) and sedges (8%). *Trianthema portulacastrum* among the broad-leaved weeds and *Cynodon dactylon* among the grassy weeds were more dominant. Herbicidal treatments significantly influenced the weed population and dry matter production of weeds in both transgenic and non-transgenic hybrids. Weed dry weight is the most important parameter to assess the weed competitiveness for the crop growth and productivity. Sparse weeds with high biomass might be more competitive for crops than dense weeds with lesser dry matter. Considerable reduction in weed dry weight was recorded with the application of glyphosate at 1800 g a.e ha^{-1} in transgenic 900 M Gold and 3600 g/ha in transgenic Hishell (0.29 and 1.20) at 40 DAS during *kharif* 2009 and *rabi* 2009-10, respectively (Table 1). This might be due to total weed control as achieved by glyphosate. Total weed dry weight was effectively reduced in non-transgenic hybrids with PE application of atrazine at 0.5 kg/ha *fb* HW. The dry weight of weeds exhibited an increasing trend from crop germination to harvest in unweeded checks.

Table 1. Effect of different weed control methods on total weed dry weight and yield of maize

Treatment	Total weed density (no/m^2) at 40 DAS		Grain yield t/ha	
	Kharif 2009	*Rabi* 2009-10	*Kharif* 2009	*Rabi* 2009-10
Transgenic Hishell POE glyphosate 900 g/ha	2.10(2.40)	3.01(7.09)	11.19	8.96
Transgenic Hishell POE glyphosate 1800 g/ha	1.76(1.10)	2.35(3.51)	11.64	9.86
Transgenic Hishell POE glyphosate 3600 g/ha	1.62(0.62)	1.79(1.20)	11.78	10.12
Transgenic 900 M Gold POE glyphosate 900 g/ha	2.23(2.98)	3.26(8.66)	11.30	9.33
Transgenic 900 M Gold POE glyphosate 1800 g/ha	1.51(0.29)	2.29(3.25)	12.01	10.00
Transgenic 900 M Gold POE glyphosate 3600 g/ha	1.53(0.33)	1.82(1.32)	11.68	9.92
Hishell PE atrazine 0.5 kg ha^{-1} + HW + IC	5.06(23.61)	5.39(27.06)	10.52	8.89
Hishell No WC and only IC	10.39(106)	8.25(65.99)	8.05	7.21
900 M Gold PE atrazine 0.5 kg/ha + HW + IC	5.33(26.45)	5.29(26.01)	10.27	9.27
900 M Gold No WC and no IC	9.69(91.92)	9.43(86.89)	7.61	7.19
Proagro PE atrazine 0.5 kg/ha + HW + IC	5.24(25.45)	5.29(26.00)	8.00	6.95
Proagro 4640 No WC and no IC	9.51(88.42)	9.09(80.58)	5.98	5.62
CoHM 5 PE atrazine 0.5 kg/ha + HW + IC	5.35(26.67)	5.34(26.50)	8.04	7.15
CoHM 5 No WC and no IC	10.29(103.95)	9.51(88.50)	6.08	5.73
LSD (P=0.05)	1.42	1.49	1.46	1.69

Among the herbicidal treatments evaluated, post emergence application of glyphosate at 1800 g/ha in transgenic 900 M Gold maize hybrid resulted in higher grain yield of 12.01 t ha^{-1} during *Kharif*, 2009 and POE application of glyphosate at 3600 g/ha in transgenic Hishell maize hybrid resulted in higher grain yield of 10.12 t/ha during *Rabi*, 2009-10. The findings are in accordance with observation of Tharp *et al.* (1999) who had earlier reported that maize yields of herbicide resistant hybrids were maximum with glyphosate at 0.84 kg ae/ha of glyphosate when applied at fifth leaf stage of maize.

CONCLUSION

Post emergence application of glyphosate at 1800 and 3600 g/ha in transgenic maize hybrids resulted in lower weed dry weight and higher grain yield compared to non-transgenic counterpart hybrids with existing pre-emergence weed control method.

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Lolium a new emerging weed of wheat in Haryana and its chemical control

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Wheat (*Triticum aestivum* L.) is the second most important grain crop of India after rice and thus crucial for the food security of the country. Survey of weed flora of wheat fields has shown moderate to heavy infestation of new grassy weed of *Lolium* spp. in north-eastern districts of state under high moisture conditions which have threatened wheat cultivation in some fields. Keeping it in view, survey of wheat fields was undertaken and studies were conducted at farmers fields having severe *Lolium* infestation.

METHODOLOGY

To study infestation level of this new emerging weed species, systematic survey of wheat fields was done in 12 districts Ambala, Yamuna Nagar, Panchkula, Karnal, Kaithal, Panipat, Jind, Sirsa, Fatehbad and Hisar districts of state. 20 fields in each district were surveyed during January - March, 2015, as this period depicted most appropriate representation of majority of weed species and the weeds have cumulative effects of all agronomic practices, soil type, fertilizer and irrigation application and weed control measures adopted during initial crop growing period. The road map of Haryana state was followed and routes were planned to establish sampling localities as equidistantly as possible (about 10 kms) avoiding inhabited areas. Four observations on density of individual weeds were recorded per field at one spot by using quadrate of (0.5 x 0.5 m), 80-100 meters deep inside the fields. Pooled average values of observations of relative density were thus calculated as per method suggested by Misra (1968) and Raju (1977) .To test the efficacy of various herbicides, a field experiment was conducted at farmers' field in V. Danoura Distt. Ambala(Haryana) by keeping a plot size of 150 m^2 with three replications during rabi 2004-15 and 2015-16.Wheat variety HD2967 was planted on 15.11.2014 and 20.11.2015, during first and second years, respectively. Herbicide pendimethalin alone at 1500 g/ha, pendimethalin+ metribuzin 1500+175 g/ha (TM) and pendimethalin 35 % + metribuzin 3.5% (RM) at 1925 g/ha were applied as pre-emergence using 500 litres of water /ha. isoproturon at 1000 g/ha was applied by mixing 10 kg urea 5 days after first irrigation while post emergence herbicides sulfosulfuron at 25 g/ha, meso+iodosulfuron at 14.4 g/ha and pinoxaden at 50 g/ha were applied 40 DAS using 375 litres of water. All herbicide sprays were done by knap sack sprayer using flat fan nozzle. In field experiment data on density and dry weight of weeds was recorded using 0.5 x 0.5meter quadrant from four places in a plot at 75 DAS which was subjected to /^x+1 transformation before analysis. Data on percent control of *lolium* spp. was recorded at 120 DAS which was subjected to arc sin^{-1} transformation before analysis.

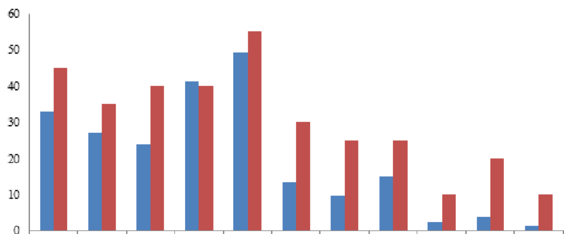
RESULTS

Survey of *lolium* infestation

Data in figure 1 revealed that maximum population of *Lolium* 49.1 plants /m^2 occurred in Yamuna Nagar district with a frequency of 55%, followed by Panchkula (41.32 plants/m^2), Ambala(32.2 plants/m^2), Kurukshetra (27.5 plants/m^2) and Karnal 24.0 plants/m^2. In south western districts of Hisar, Sirsa and Fatehbad although infestation occurred but with less density in a range of 1.45-3.5 plants/m^2 and only at 10-15% locations surveyed.

Chemical control in wheat

All herbicides except pinoxaden and sulfosulfuron proved effective against *Lolium* spp. in wheat. These herbicides proved effective against *P.minor*. Pre-emergence application of pendimethalin alone at 1500 g/ha or in conjunction with metribuzin at 1500 +175 g/ha as tank mixture provided 90-97% control of *P.minor* with only 1.3-4.2 plants / m^2. Isoproturon applied at 1000 g/ha as urea mix after first irrigation proved very effective with 1.7-5.4plants/m^2 exhibiting 85-97 % control of *Lolium*. Ready mix combination of pendimethalin (35%) + metribuzin (3.5%) caused significant reduction in density and dry weight of *Lolium* during both years of study. Grain yield of wheat followed the same trend as density and dry weight of weeds. Weed control efficiency with use of pendimethalin at 1500 g/ha was 91.7 and 87.8% during 2014-15 and 2015-16, respectively which slightly increased by use of metribuzin as tank mixture or in ready mixture with pendimethalin. Grain yield was maximum 4480 and 4900 kg/ha during 2014-15 and 2015-16, respectively in plots treated with meso+iodosulfuron(RM) at 14.4 g/ha which was at par with pendimethalin +metribuzin (TM) and pendimethalin+ metribuzin(RM) applied as pre-emergence due to excellent control of *Lolium* as well as *P.minor* present in the experimental field.



	Ambala	Kurukshetra	Karnal	Panchkula	Yumna Nagar	Jind	Panipat	Kaithal	Sirsa	Fatehbad	Hisar
Density (No./m2)	32.85	27.05	24.05	41.35	49.1	13.4	9.65	14.95	2.3	3.95	1.45
Frequency (%)	45	35	40	40	55	30	25	25	10	20	10

Fig. 1. Density and frequency of Lolium spp. in Haryana (2014-15)

CONCLUSIONS

In north-eastern Haryana, wheat grown under high moisture conditions is severally infested with new emerging grassy weed of *Lolium* spp. Post- emergence use of isoproturon 1.0 kg/ha/meso+iodosulfuron(RM) 14.4 g/ha at 35 DAS or pre-emergence application of pendimethalin+metribuzin(100+175g/ha) either as tank mixture or RM provides excellent control of this weed.

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Abundance, distribution and diversity of weeds in wheat in Haryana

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Wheat (*Triticum aestivum*) crop is infested with both grassy and broadleaf weeds. Losses caused by weeds in wheat vary from 30-50 % depending upon type of weed flora, time, and intensity of weed infestation. Crop type and soil properties have greatest influence on the occurrence of weed species (Streibig *et al*. 1984, Andreasen *et al.*, 1991). The type of irrigation, cropping pattern, weed control measures and environmental factors have a significant influence on the intensity and infestation of weeds (Saavedra *et al.* 1990). Therefore, knowledge of weed species associated with crops in a region is pivotal and necessary to plan and execute a sound and economical weed management schedule. So, to study the abundance, distribution and diversity of weed flora in wheat crop, 14 wheat growing districts of Haryana state were surveyed

METHODOLOGY

To study the floristic composition of weeds in wheat in Haryana, 292 fields were surveyed in Ambala, Karnal, Kaithal, Jind, Sonepat, Rohtak, Faridabad, Rewari, Palwal, Bhiwani, Mahendragarh, Sirsa, Fatehbad and Hisar districts of state during January - March, 2012 and 2013. This period of survey depicts most appropriate representation of majority of weed species and the cumulative effects of all agronomic practices, soil type, fertilizer and irrigation application and weed control measures adopted during initial crop growth stages. The road map of Haryana state was followed and routes were planned to establish sampling localities as equidistantly as possible (about 10 kms) avoiding inhabited areas.

RESULTS

In all 21 weed species (4 grassy and 17 broadleaf) were found to infest wheat fields in Haryana. Grassy weed *Phalaris minor* with IVI values of 43.2 - 97.7 was most dominant weed in all the districts surveyed except Bhiwani, Mahendragarh and Rewari. Another grassy weed, *Avena ludoviciana* with a RD of 0.5 – 21.7% and IVI values of 1.5 - 43.4% showed its presence in south- western districts of Haryana *viz*. Hisar, Fatehabad, Rewari, Bhiwani, Mahendergarh and Palwal whereas this weed was conspicuous by its absence in north-eastern districts of Ambala, Karnal, Jind, Kaithal, Sonepat and Rohtak. Grassy weeds of moist soils *Polypogon monspliensis* and *Poa annua* showed their presence only in north-eastern districts. *Chenopodium album* and *Chenopodium murale, Trigonella polycerata, Melilotus indica, Rumex spinosus, Fumaria parviflora* and *Asphodelus tenuifolius* were dominating broadleaf weeds in south-western districts namely Bhiwani, Rewari, Hisar, Fatehbad, Sirsa, Faridabad and Mahendragarh. Singh *et al*. (1995) also reported the occurrence of *F. parviflora* and *A. tenuifolius* in light textured soil. Robust dicotyledonous weed *Malva parviflora*, adherent to heavy textured soils and zero till planted wheat, was mainly confined in Ambala, Karnal, Kurukshetra, Rohtak, Sonepat and Fardiabad districts. *Convolvulus arvensis*- a broadleaf climber was present in all districts except Ambala and Karnal. *C. arvensis* was mainly found in wheat crop grown after pearl millet and cotton. *Pluchea lanceolata* was present only in Rewari district.

CONCLUSIONS

Grassy weeds *P.minor*, *P. monspliensis* and *P. annua* are important weeds of wheat in north-eastern districtsof Haryana where as in south-western districts, *T. polycerata, M. indica, R. spinosus, F. parviflora* and *A. tenuifolius* were dominating broadleaf weeds .

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Efficient weed management in coriander for higher productivity

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Heavy weed infestation is a common feature in coriander (*Coriandrum sativum L.*) cultivation due to prolonged period for its germination and very slow initial growth. Further, slow growth of crop could not help in smothering weeds due to poor canopy development as in case of coriander and resultantly affect the growth and yield adversely due to intense weed infestation. Uncontrolled weeds could cause coriander yield losses as high as 82% as reported by Sargarka *et al.* (2005). Therefore, weed management is one of the most crucial factors in realising the optimum yields. Manual weeding is the common practice in most of the spice crops including coriander however, timely availability labourers and wages are the major constraints in effective weed management in coriander. Hence there is a need to identify effective herbicide and their appropriate doses for timely weed management in coriander. Besides reducing the dependence on the labourers, weed management through herbicide application seems viable, efficient and cost effective alternative to realise higher yield from coriander.

METHODOLOGY

A field experiment to assess the impact of different weed control measures in coriander was conducted at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during *Rabi* season of 2011-12, 2012-13 and 2013-14. The experiment comprising fourteen treatments including unweeded check (control treatment) was laid out in randomized complete block design (RCBD) with three replications. Pendimethalin (0.50, 0.75, 1.0 kg/ha and 0.50 kg/ha *fb* one hand weeding at 40 days after sowing), Trifluralin (0.50, 0.75, 1.0 kg/ha and 0.50 kg/ha *fb* one HW at 40 DAS) and Oxyflurofen (150, 175, 200g/ha and 150 g/ha *fb* one HW at 40 DAS) were tested against two hand weeding (20 and 40 DAS). The crop was sown in the first fortnight of November and harvested in April every year. Trifluralin was applied as pre-plant incorporation whereas pendimethalin and oxyflurofen were applied as pre-emergence on the next day after sowing by dissolving in 375 litres of water per ha, using knapsack sprayer fitted with flat fan nozzle. The data on weeds, yield attributes and crop yield were recorded at time of harvesting. The weed data were subjected to square root transformation before analysis.

RESULTS

The weed flora in the field mainly consisted of *Rumex dentatus*, *Rumex spinosus*, *Medicago denticulate*, *Chenopodium album, Anagallis arvensis, Malva parviflora, Phalaris minor, Avena ludoviciana etc.* The application of pendimethalin 1.0 kg/ha, pendimethalin 0.5 kg/ha + one hand weeding (40 DAS), two hand weedings (20 and 40 DAS) effectively controlled the weeds. Weed dry weight recorded with application of pendimethalin 1.0 kg/ha was 4.80, 4.19 and 3.65 g/m^2 during 2010-11, 2012-13 and 2013-14, respectively. However, higher weed infestation was observed with the application of lower doses of pendimethalin i.e. 0.50 kg/ha and 0.75 kg/ha than higher dose of pendimethalin (1.00 kg/ha) as well as two hand weedings. The seed yield of coriander with application of pendimethalin 1.0 kg/ha was 790, 737 and 871 kg/ha during 2010-11, 2012-13 and 2013-14, respectively. Lower dose of pendimethalin *i.e.* 0.5 kg/ha followed by one hand weeding at 40 day after sowing (DAS) or two hand weedings at 20 and 40 DAS were also found effective and statistically at par with that of pendimethalin 1.0 kg/ha. *Yadav* et al. (2015) have also reported the superiority of pendimethalin over other herbicides for weed control in coriander. Other herbicides though lesser effective than pendimethalin, registered significantly higher coriander seed yield than the control treatment (unweeded).

CONCLUSION

Application of Pendimethalin 1.0 kg/ha as pre-emergence or pendimethalin *i.e.* 0.50 kg/ha as pre-emergence *fb* one hand weeding at 40 DAS was found most promising in reducing the weed infestation and enhancing the seed yield of coriander.

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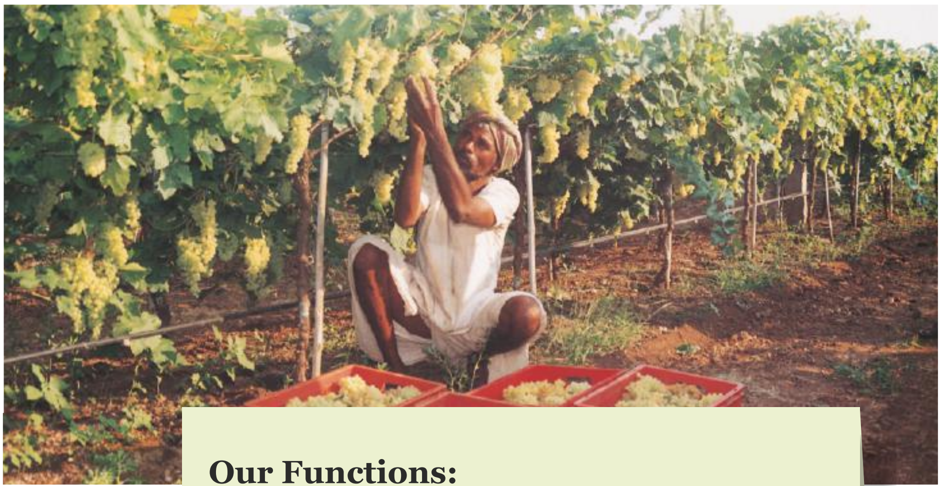

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