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Paradigm shifts in weed science and challenges they pose to India and weed scientists

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ABSTRACT

Inventions are the agents of change and have been the driving force behind the paradigm shifts that occurred throughout human history. There have been several paradigm shifts in the field of weed science too. The first one was the birth of modern weed science seven decades ago in 1944 when 2,4-D became commercially available. Since then, hundreds of newer organic herbicides have been developed and these became the mainstay of weed management in cropping and non-cropping systems around the world. The second paradigm shift was the evolution of herbicide resistance in 1968 when *Senicio vulgaris* was found resistant to 2,4-D. This was followed with hundreds of reports till today. The third paradigm shift in weed science occurred in 1994 when transgenic herbicide resistance crops, beginning with the approval of bromoxynil-resistant BXN cotton developed by Calgene and Rhône-Poulenc and glyphosate resistant soyabean developed by Monsanto, both in USA. These paradigm shifts has led challenges to India and Indian weed scientists too. This paper presents the various research challenges required to be worked, both directly and indirectly by the Indian scientists.

Key words: Challenges, GM crops, Paradigm shifts, Weed science

Inventions, the agents of change, have been the driving force behind the paradigm shifts that occurred throughout human history. Some of these inventions have a long-term effect, both direct and indirect, on the mankind. For example, the German Johannes Gutenberg's invention of printing press in 1445 changed the culture of people. Suddenly, numerous ancient scriptures, written hitherto on palm leaves, skin, bark, cloth, copper plates and the like, sculptured on rocks, engraved on stones, *etc*. became readily available. It also led to printing of voyage routes which aided many European sea explorers and adventurers in their quest for riches that changed the geography and history of the world forever. Similarly, the modern-age inventions of telephone, television, personal computer and the internet have impacted communication besides both personal and global business environments forever.

Paradigm shifts

There have been several paradigm shifts in the field of weed science too. The first one was the birth of modern weed science seven decades ago in 1944 when 2,4-D became commercially available. Its discovery was considered to be "amongst the greatest scientific discoveries of the 20th century" (Fryer 1980). Since then, hundreds of newer organic herbicides have been developed and these became the mainstay of weed management in cropping and non-cropping systems around the world. Other major landmark herbicide discoveries included triazines in 1958, paraquat in 1962, and glyphosate in 1974. These and scores of other herbicides have since saved billions of tons of global crop produce and thus enhanced agricultural productivity by that much.

The second shift was the evolution of herbicide resistance. This has its origin within a decade of continuous application of 2,4-D itself, but not discernable until 1968 when *Senicio vulgaris* was found resistant to it in a Washington nursery in USA where this auxin herbicide was being used since 1958 (Ryan 1970). This phenomenon of evolution of herbicide resistance that began as a trickle became a torrent beginning the mid-1980s consequent to commercialization of acetolactate synthase (ALS) and acetyl-CoA carboxylase (ACCase) herbicides. Currently, 237 species (138 dicots and 99 monocots) have evolved resistance to 22 of the 25 known herbicide sites of action and to 155 different herbicides. These species have spread across 82 crops in 65 countries (Heap 2014). Ninety of these weed species have multiple sites of action ranging from 2 to 11. *Lolium rigidum* has 11 sites of action, while two species *Echinochloa crusgali* var. *crusgalli* and *Poa annua* have nine (Heap 2014).

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Among weed families, Poaceae contributed the most number of resistance species of 75 followed by Asteraceae (37), Brassicaceae (21), Amaranthaceae (12), Cyperaceae (11), Scorphulaceae (9), and Chenopodiaceae (8), Alismataceae (6), Polygonaceae (6), and Caryophyllaceae (5) (Heap 2014). Of the various crops in which herbicide resistant weed species were found so far, wheat tops with 65 followed by maize (58), rice (50), and soya bean (46), rapeseed/ canola (20), and cotton (17) (Heap 2014).

The third paradigm shift in weed science has occurred in 1994 when transgenic herbicide resistance crops, beginning with the approval of bromoxynil-resistant BXN cotton (developed by Calgene and Rhône-Poulenc) and glyphosate resistant soyabean (Monsanto), both in USA. The same year also saw the Davis, California-based Calgene produced world's first transgenically engineered whole food tomato line '*Flavr Savr*', and the European Union approval of tobacco developed to be resistant to bromoxynil.

Transgenic plants, also known as "genetically modified" and "genetically engineered" plants, are plants which have a single or multiple genes transferred from a different species (Rao 2014). The inserted gene(s) may be derived from a completely unrelated kind of organism like bacteria or another plant of the same or a different species. The process of transgenic engineering involves several biotechnology techniques, collectively known as recombinant DNA (rDNA) technology. Its aim is to design plants which have specific characteristics by using artificial insertion technique of genes from other non-plant or plant species. The heritable transgene gene(s), prepared outside, is introduced either directly into the host or indirectly into the host cell or into the cell that is then fused or hybridized with the host as described under (Rao 2014).

a) Locating and identifying gene(s) of interest.

b) Isolating and extracting DNA.

c) Cloning the extracted DNA for mass production.

d) Designing and constructing the gene of interest for plant infiltration by adding a promoter and a selectable marker gene for expression of transgene in the plant.

e) Transformation, *i.e.*, genetic alteration of a cell resulting from the uptake, incorporation, and expression of exogenous material (DNA) from its surroundings and taken up through the cell membrane(s).

f) Testing to ascertain that the inserted gene has been stably incorporated by evaluating first in greenhouse or screen-house, followed by field testing.

g) Repeatedly back-crossing the transgenic crop plants that passed all tests with improved, elite varieties of the crop with elite breeding lines to obtain a high yielding transgenic line; and food and environmental safety assessment of the new transgenic crop variety for possible alteration of nutrient levels, allergenicity, known toxicants, new substances, antibiotic resistance markers, non-pathogenicity to animals and humans, toxicity to non-target organisms, etc.

The transgenic plant thus made now contains genetic material derived from another species. The primary benefit derived from transgenesis is an increase in the amount of genetic variability available for breeders to use beyond that is accessible by conventional breeding methods (Rao 2014).

Generally, there are two approaches in engineering for herbicide resistance (Rao 2014). One is to have the inserted (trans) gene modify a plant enzyme or other sensitive biochemical target of herbicide action to render it insensitive to the herbicide or induce overproduction of the unmodified target protein permitting normal metabolism to occur. The other approach is the introduction of an enzyme or enzyme system that degrades or detoxifies the compound in the plant before the herbicide reaches the site of action. Plants modified by both approaches may be obtained either by selection for resistance against a specific herbicide or by applying gene transfer techniques utilizing genes encoding herbicide resistance determinants.

Scores of transgenically modified herbicide-resistant crops have been developed during the last two decades. Genes used to transfer resistance traits belong to glyphosate, glufosinate, bromoxynil, sulfonyl-ureas, 2,4-D, dalapon, dicamba, atrazine, phenmedipham, paraquat, isoxafutole, mesotrione, *etc*.

Transfer of foreign genes from a wide spectrum of species, including viruses, bacteria, fungi, and animals into transgenic crops, has elicited perceived risks associated with this technology and opposition to their commercial deployment. Besides, concerns of consumers about the health safety and ethical justification of transgenic crops have led plant molecular biologists to employ alternative transformation methods. One of them is based on transfer of native genes (including regulatory elements) from plant sources, commonly known as 'intragenic' transformation. This method transforms crops with plant-derived transfer (P-) DNAs that consist of only native genetic elements, without affecting the overall structure of the plant's genome (Rao 2014). Intragenic method has been used successfully to develop crops resistant to imidazolinone and cyclohexanedione (sethoxydim) herbicides.

The next paradigm shift, the fourth, occurred in 2000. It involved development of 'gene stacks', 'pyramided stacks', 'biotech stacks', or simply 'stacks'. They express two or more genes that code for proteins having different modes of action and different related traits in a single plant. The 'stacked' plant expresses resistance to more than one herbicide as in the case of dual-herbicide and triple-herbicide stacks. Stacking up genes resistant to herbicides with different modes (sites) of action broadens weed control efficiency and provides farmers more flexibility and options in weed management. For example, combining glyphosate-resistance gene *epsps* with the *pat* gene that confers resistance to glufosinate and/or with *dmo* gene conferring resistance to dicamba broadens the range of weeds to be controlled.

Biotech stacks are also engineered to have better chances of overcoming other myriad of problems in the field such as other biotic stresses (insects, diseases, viruses, fungi, nematodes, and parasites) and abiotic stresses (high/low temperature, cold, ozone, salinity, flooding, intense light, and nutrient imbalance, *etc*.) by stacking the concerned genes with those that confer resistance to herbicides so that farmers can increase crop productivity.

Insect pests became the second most important target for transgenic technology. Engineering of plants to express insect-resistance gene (*Bt* gene derived from the soil-dwelling bacterium *Bacillus thuringiensis*) offers the potential to overcome the shortcomings with continued heavy use of insecticides. These herbicide-cum-insect stacks confer resistance to herbicides and insect-pests so that farmers can increase crop productivity. Stacked-trait transgenics have now become an important feature of biotech crops.

The easiest and quickest way to stack up genes into a plant is to make crosses between parental plants that have different biotech traits, an approach known as hybrid stacking. Most of the commercially available biotech stacks are products of serial hybrid stacking which is widely adapted and accepted (ISAAA 2013a). Another method of gene stacking, known as molecular stacking, involves the introduction of gene constructs simultaneously or sequentially into the single locus of the target plant by standard delivery systems such *Agrobacterium*-mediated and biolistic methods (Halpin 2005, Que *et al.* 2010). In some stacks, molecular stacking has been done with conventional breeding approaches to put together the desirable traits (ISAAA 2013a).

The length of time in developing a transgenic plant depends upon the gene, crop species, available resources, and regulatory approval. It may take 6-15 years before a transgenic line is ready for commercial release (ISAAA 2012).

Ever since their first commercialization on 1.73 million ha in 1996 in the U.S., beginning with the glyphosate-resistant maize, farmers around the world have readily adopted transgenic crops such as soya bean, maize, cotton, rapeseed (canola), lucerne (alfalfa), and sugar beet. By 2013, the area under biotech crops reached 175.2 million ha, which is more than 100-fold growth (ISAAA 2013b). The nine major countries adopting transgenics include USA (70.1 million ha), Brazil (40.3), Argentina (24.4), Canada (11.6), India (11.0), China (4.2), Paraguay (3.6), South Africa (2.9), and Pakistan (2.8) in that order which together account for 97 percent of biotech crops (Table 8.1) (ISAAA 2013b). These nations excluding USA covered 100.8 million ha. This accounts for over 57 percent of the global biotech crop area. Over 81 percent of the global area under soya bean and cotton was accounted by transgenic varieties (GM Science Update 2014). These were followed by 35% for maize and 30% for rapeseed.

Currently, two transgenic traits dominate the global biotech crops: herbicide resistance accounting for 65%, insect resistance 15%, and a combination of the two (stacked) for 15%. This makes the herbicide-resistant transgenic crops for 80% of gross global biotech acreage.

The area under transgenic cultivation, which is doubling every five years, now accounts for some 12% of global arable land (GM Science Update 2014). At this rate, the gross area under these crops is poised to reach 400 million ha by 2030 when over 120 crops are expected to be transgenically engineered with desired traits and adopted worldwide (Rao 2014). This makes biotech crops the fastest adopted crop technology in recent history.

In the light of this possibility, the fifth paradigm shift is likely to appear in the next few years when herbicide resistance genes encoding enzymes will be stacked with those that help crop plants withstand other biotic stresses (other than insects) as well as abiotic stresses listed earlier. The more immediate will likely be the crops that carry herbicide resistance-cum-high yielding genes.

Future transgenic technology (second and third generations) is expected to be diversified to enhance both quantitative and qualitative traits of crops. Some of these include a) photosynthetic efficiency, b) nutrient (nitrogen, phosphorus, *etc*.) use efficiency, c) tolerance to salinity, drought, frost, flooding, *etc*., d) plant characteristics (panicle size, seed quantity per panicle, *etc.*), e) nutritional quality (â-carotene, iron, protein, *etc.*), f) antioxidants like flavonols and flavonoids in fruits, *etc*. Currently, active global research is in progress to engineer to insert these traits in plants.

Proponents of biotech crops consider that genetic engineering a panacea to attain the food and fiber needs of the burgeoning global population that is expected to reach 9.2 billion by 2050 from the current figure of 7.3 billion against the prospect of shrinking productive and cultivable land, depleting water/irrigation availability, escalating salinity in irrigated regions, shrinking labor force, enhancing demand for food and feed, increasing undernourishment, growing CO_2 emissions leading to global warming, *etc*.

Challenges

As mentioned earlier, transgenic crops have made a positive contribution to global crop production and food and fiber security and improved the economic status of farmers who adopted them. They provided farmers pecuniary or direct benefits in the form of net gain in farm income or profitability based on crop yields, market value of crop produce, production costs, costs of fuel and labor, *etc*. The most obvious pecuniary benefit is yield increase which is tangible and quantifiable. At the same time, biotech crops also accelerated changes in farming styles, affecting genetic diversity in agro-ecosystems of many countries that have adopted the biotechnology. For example, the adoption of herbicide-resistant transgenic crops has changed traditional weed management practices and the biodiversity of crop and weed species.

However, the commercial cultivation of transgenic crops with various desired, beneficial traits has aroused concerns about their biosafety, risks, and issues followed by debates worldwide by proponents and antagonists. These factors became crucial in the further development of transgenic biotechnology and their utility and wider application of transgenic products in global agriculture.

The risks are broadly grouped into agro-ecological concerns and food safety concerns. Agro-ecological concerns include a) outflow of transgenes from transgenic crops to landraces, wild/weedy relatives, non-transgenic crops, and unrelated organisms, thus leading to unintended consequences; b) evolution of transgenic crop-volunteer weeds; c) effect on soil ecosystem which accounts for 80% of soil-borne communities dominated by microbes (one of the least understood areas in the risk assessment of transgenic crops); d) soil microbe dynamics; and e) uptake and availability of soil nutrients (Rao 2014).

Food safety concerns include a) alteration of nutrient levels of foods and feeds derived from transgenic crops; b) allergenicity as a result of consumption of foods containing proteins and glycoproteins derived from biotech crops; c) horizontal transfer of transgenes from plants used directly as food or indirectly as feed to animals that are used as feed; and d) resistance to antibiotic gene used during transformation process leading to humans' loss of ability to treat illnesses with antibiotic drugs (Rao 2014).

There are several vital issues related to transgenic crops. These include the following (Rao 2014):

a) Production of terminator seeds derived from genetic use restriction technology (GURT) and trait-specific gene use restriction technology (T-GURT).

b) Intellectual property rights (IPR) of inventors granting exclusive ownership rights to their inventions and discoveries in a technical field.

c) Asynchronous approval of transgenic crops due largely to disparate regulatory procedures and standards in the countries that adopted biotech crops.

d) Biopiracy which, in fact, is the misappropriation and commercialization of genetic resources and traditional knowledge of rural and indigenous people of another country and making profit illegally from freely available natural biological materials that belong to it.

e) Coexistence of transgenic crops in the vicinity where non-transgenic, conventional, and organic crops leading to a socio-economic issue, but not necessarily a safety issue unless the foods derived from transgenic crops pose health risks.

f) Coexistence of transgenic and non-transgenic food products in food markets without proper segregation and traceability standards, thus curtailing the consumers' freedom of choice in buying the food they want.

Currently, development of transgenic crops is dominated by agro-biotech industry which considers it more as a profit-driven rather than need-driven process. Therefore, the thrust of the genetic engineering industry is not really to solve agricultural problems, but to create profitability (Altieri 1998). This is evident by the fact that over the last 30 years scores of multinational corporations have initiated transgenic research on a variety of crops around the world. Although several universities and public research institutions are also simultaneously involved in this field, their research agenda is being increasingly influenced by private sector in ways never seen in the past. The challenge these organizations now face is how to ensure that ecologically sound aspects of biotechnology are researched and developed while at the same time carefully monitoring and controlling the provision of applied non-proprietary knowledge to the private sector, farmers, and consumers and making such knowledge available in the public domain for the benefit of society (Altieri 1998).

Challenges to India

Regulation of transgenic crops is one of the most contentious roiling India whose existing regulatory rules have been heavily criticized for incompetence and non-transparency in the decision making process. The current regulatory procedures apparently tilt more in favour of agro-biotech industry rather than farmers and consumers. Besides, there is inadequate scope for, and consideration to, public debate. Many a time, decisions are taken arbitrarily regardless of farmer and consumer interests.

One clear-cut example is the way *Bt* brinjal, developed by Mahyco-Monsanto Biotech, was approved by the Genetic Engineering Approval Committee (GEAC) in October 2009 for commercial cultivation despite the serious concerns expressed by some scientists, farmers, and anti-GM products. Added to this was Monsanto's attempt in collaboration with Maharashtra Hybrid Seed Company to resort to 'biopiracy' of using native brinjal (*Solanum melon-gena*) varieties for the purpose of genetic modification in violation of the country's Biological Diversity Act, 2002 (Mercola 2012). It required the minister of environment to declare indefinite moratorium on the cultivation of *Bt* brinjal that contained the *Cry 1Ac* gene and interference of Supreme Court to decide on the issue of biopiracy.

In response to a public interest petition filed in 2005 for banning GM crops in India because of approval of field trials by GEAC without proper scientific evaluation of biosafety issues, the Supreme Court appointed on 10 May 2012 a five-member Technical Expert Committee (TEC). In its report submitted to the court on 7 October 2012, TEC recommended a 10-year moratorium on commercial release of all GM crops till all the systems are in place for independent research and regulation. It also recommended a moratorium on field trials of herbicide-resistant crops until an independent assessment has evaluated its impact and suitability.

In the long-term interest of farmers and consumers, the government should carefully consider all the facts (benefits, risks, issues, *etc*.) dispassionately, unbiasedly, and non-politically before opening the box. Before that, it should put in place strict regulatory mechanism at every level of administrative and research establishment in the country. Every new technology, though beneficial to mankind, has its own the attendant problems. Wise people foresee and resolve them before they become uncontrollable. The first responsibility of the government is its citizens which elected it, but not the ever profit-seeking industry.

At the moment, the European Union has the most stringent regulatory system than any country. India would do well to follow this system than the one followed by USA which has the same laws that govern health, safety, and efficacy, and environmental impacts of similar products derived by traditional methods. This North American nation which is in the forefront of genetic engineering technology treats foods or products derived from transgenic crops on par with those derived through conventional technology, regardless of the fact that the transgenic crops were the recipients of genes from non-plant sources.

Challenges to Indian weed scientists

Man with hoe has been a classical symbol of weed control for several millennia before the advent of organic herbicides. The early-era weed scientists were essentially botanists involved in taxonomy and biology of weeds. Later, they enlarged their sphere of research by testing these herbicides for crop selectivity and weed management in a wide range of cropping and non-cropping situations. This was further enlarged as herbicide resistant weeds began emerging. In the light of the rapidly expanding field of genetic engineering during the past two decades, the current crop of weed scientists face enormous challenges emanating from the rapid adoption of transgenic herbicide resistant (THR) crops. They are required to involve, both directly and indirectly, in the following areas.

a) Development of THR varieties (events, stacks) in different crops.

b) Interaction with various governments, research organizations, and biotech industry during various stages of genetic transformation.

c) Evaluation of THR varieties during pre-release stage.

d) Integration of THR crops with the existing weed management systems

e) Evolution of herbicide resistant weeds in THR crops.

f) Outflow of transgenes from transgenic crops to landraces, wild/weedy relatives and non-transgenic crops and find ways to contain them.

g) Evolution of transgenic crop-volunteer weeds.

h) Effect of cultivation of transgenic crops on soil ecosystem.

i) Play a decisive role in the THR-related regulatory and adoptive policies of the country and states.

In order for the weed scientists to meet these challenges successfully, they are required to equip themselves with adequate knowledge and expertise in the fast-expanding fields of molecular biology and genetic engineering. Future weed science curriculum in universities and other educational institutions needs to be broad-based to include these fields. This way, weed scientists can play a more active, greater, and vital role in the country's march towards a more open transgenic technology, particularly with regard to herbicide resistance.

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Tillage, crop establishment and weed management in rice under conservation agriculture system

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ABSTRACT

Field experiments were carried out in wetland farm at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu during 2012-13 to study the weed density, weed seed bank, yield and economics of rice under rice based conservation agriculture system. The main plot consisted six treatments with two crop establishment methods and three tillage practices over the seasons. Sub-plot treatments were having three weed management practices. Significantly minimum total weed density, weed seed count and higher grain yield, net returns were recorded in transplanted rice with conventional tillage in CT-CT-ZT system with pre-emergence treatment (PE) of butachlor 1.0 kg/ha for *Kharif*, pretilachlor 1.0 kg/ha PE for *Rabi* + inter crop with daincha (*Sesbania*) incorporation and mechanical weeding on 35 DAT during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013.

Key words: Conservation agrciculture, Rice establishment methods, Seed bank, Tillage, Weed management

Rice is the staple food of more than half of world's population. Among the rice growing countries, India has the largest area (44 million hectares) and it is the second largest producer (131 million tonnes) of rice next to China (197 million tonnes). Traditionally, rice is transplanted after puddling, which requires heavy amount of water and labours and it affects the soil health due to dispersion of soil particles, increase the soil compaction and make tillage operations difficult in succeeding crops requiring much energy. Compared to traditional agriculture, farmers can save up to 40% of time, labour and fuels in conservation agriculture

Therefore, over the past few years in many countries, there has been increasing trend towards conservation agriculture (Chhokar *et al.* 2007). Conservation Agriculture (CA) is an agricultural management practice in which there is minimum soil disturbance, retention of residue for soil cover and rotation of major crops. In conventional-tilled farming, weeds can be effectively controlled by tillage operations, which uproot and bury weeds deep into the soil. Due to lack of tillage, weeds grow and flourish in CA, if effective weed control measures are not taken. Weed control in CA is a greater challenge than in conventional agriculture because there is no weed seed burial by tillage operations and soil-applied herbicides are not incorporated resulting in reduced efficacy (Chauhan and Johnson 2009). Weed infestation, however continues to be a major bottleneck in dry-seeded rice compared to transplanted rice the weed problems may further be increased if dry-seeding of rice is done with zero tillage. Tillage operation can have a major impact on the distribution of weed seeds in the soil on survival (Lutman *et al*. 2002). Tillage as a filter or constraints that influences weed species and weed seed distribution in the soil seed bank. The type of tillage implement and concomitant cultivation can significantly impact the weed seed distribution and composition in soil surface. Direct drilling and shallow tillage can increase the proportion of weed seed retained near the soil surface, compared to conventional system of sowing in rice–wheat system (Yenish *et al.* 1992). The present investigation was undertaken quantify the impact of tillage, rice establishment and weed management methods on weed density, weed seed bank, yield and economics of rice under rice based conservation agriculture system.

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MATERIALS AND METHODS

Field experiments for weed management in rice based conservation agriculture system was carried out during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013 wetland farm at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. The experimental location is situated in north western agro-climatic zone of Tamil Nadu at 11°N and 77°E with an altitude of 426.7 m above MSL. Normal climatic conditions (mean of past 50 years) of Coimbatore are as follows mean annual rainfall of 674 mm was received in 47 rainy days. Annual mean maximum and minimum temperatures were 31.5 ^oC and 21 ^oC, respectively. Mean relative humidity was 84.9% (0722 hours) and 49.1% (1422 hours). Mean bright sunshine hour was 7.3 hours/day with a mean solar radiation of 429.2 cal/cm^2/day. Soil of the experimental fields was clay loam in texture classified taxonomically as 'Vertic Ustochrept', low in available nitrogen (197-216 kg/ha), medium in available phosphorus (12-16 kg /ha) and high in available potassium (420-511 kg /ha).

The experiments were laid out in strip plot design with three replications. Main plot consisted six treatments with two crop establishment and three tillage practices over the seasons. Main plot treatments were T_1-Transplanted rice with conventional tillage for *Kharif* rice - conventional tillage for *Rabi* rice - zero tillage for summer greengram, T_2- Transplanted rice with conventional tillage for *Kharif* rice - zero tillage for *Rabi* rice - zero tillage for summer greengram, T_3- Transplanted rice with zero tillage + crop residue for *Kharif* rice - zero tillage + crop residue for *Rabi* rice - zero tillage for summer greengram, T_4- Direct sown rice with conventional tillage for *Kharif* rice - conventional tillage for *Rabi* rice - zero tillage for summer greengram, T_5- Direct sown rice with conventional tillage for *Kharif* rice - zero tillage for *Rabi* rice - zero tillage for summer greengram and T_6 - Direct sown rice with zero tillage + crop residue for *Kharif* rice - zero tillage + crop residue for *Rabi* rice - zero tillage for summer greengram. Sub-plot treatments were the weed management practices, *viz.* W_{1-} Recommended herbicides (transplanted rice- butachlor 1.0 kg/ha for *Kharif*, pretilachlor 1.0 kg/ha for *Rabi* and direct-seeded rice - pretilachlor (S) 0.45 kg/ha), W_2 - Integrated weed management (transplanted rice - butachlor 1.0 kg/ha for *Kharif,* pretilachlor 1.0 kg/ha for *Rabi* + inter crop with daincha incorporation and mechanical weeding on 35 DAT) (direct seeded rice - PE pretilachlor (S) 0.45 kg/ha + inter crop with daincha (*Sesbania*) incorporation and mechanical weeding on 35 DAS) and W_3- Unweeded check. Rice varieties used foe experiments were '*ADT (R) 45*' for *Kharif* and '*CO 50*' for *Rabi*.

Conventional tillage comprised of one disc ploughing, two cultivators and then puddled with lugged wheel attached power tiller to obtain a soft puddle. The field operations for zero tillage comprised one puddled with lugged wheel attached power tiller to incorporation of crop residue. The main and sub-plots were formed with irrigation and drainage channels.

Seed rate of 60 and 40 kg of paddy seed was used in *Kharif* and *Rabi*. Paddy straw 5 tonnes applied in residue incorporation treatments. Manually operated rice drum seeder developed by Tamil Nadu Agricultural University, Coimbatore was used for direct sown rice. The seeder droped the seeds at 20 cm apart in continuous row. At a time, eight rows of rice seeds were sown. A seed rate of 60 kg/ha was adopted. Twenty one days old seedlings obtained from conventional wet nursery were transplanted at the rate of one seedling /hill at square planting of 25 x 25 cm spacing. Daincha (*Sesbania*) intercrop seeds were sown 25 kg/ha after transplanting/sowing of rice as per the treatment schedule on the day of transplanting/direct sowing.

Recommended rate of fertilizer (150 kg N + 50 kg P_2O_5+ 50 kg K_2O/ha), entire dose of phosphorus were applied as basal in addition to zinc sulphate 25 kg/ha. Nitrogen and potassium were applied in four equal splits at 15 DAS/T, active tillering, panicle initiation and heading stages. All other agronomic and plant protection measures were adopted as per the recommended packages as recommended by the TNAU to the farmers of Tamilnadu. The observations on total weed density was recorded at 30 DAS/T, 60 DAS/T and harvesting stages by using a quadrat of 0.25/m^2 sizes at 4 places in each plot and then species wise total weeds intensity and dry matter/m^2 were determined. For weed seed bank analysis, soil was sampled 1 kg using a 15 cm diameter metal core from 0-15 cm soil depth from each plot before sowing of both the crops. Bulked soil samples were partially air dried and then clods were broken by hands. The collected soil samples were well labelled. Samples were spread on 20 x 20 x 6 cm plastic tray separately in almost homogeneous and uniform layer. The plastic tray was marked for each treatment separately. After this, regular watering was done upto one season. The numbers of germinated weed seedlings were counted under each treatment at 7th, 14th, 21st 28th and 35th and after 35th days germinated weed seedlings were counted at 15 days interval upto 75 days. Finally, total weed seed counts of soil was worked out for each treatment. 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 AND DISCUSSION

Weed flora

General weed flora of the experimental rice field was observed in un-weeded check plots at 60 DAS/T. Weed flora of the experimental field predominantly consisted of three species of grass weeds, seven species of broad-leaved weeds and one sedge weed. The predominant among grass weeds were *Echinochloa colonum* and *Echinochloa crusgalli*. Among the broad-leaved weeds, *Ammania baccifera, Eclipta alba,* and

Marselia quadrifoliata were the dominant ones. *Cyperus difformis* was the only sedge present. Relative density of *Echinochloa colona* 24.9 to 53.3%, *Echinochloa crusgalli* 46.2 to 60.8%, *Ammania baccifera* 2.10 to 7.10%, *Eclipta alba* 1.26 to 3.35% and *Marselia quadrifoliata* 0.8 to 4.27%.

Effect of crop establishment methods on weeds and rice

Total weed density was recorded significantly lower in transplanted rice (TR) during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013 (Table 1). This might be due to smothering effect of the larger canopy and early ground cover by transplanted rice than direct sown rice (DSR) during 30 DAT of crop and at later stages, weed management practices also reduced the grass weeds density in transplanted rice. Significantly higher total weed density was recorded in direct sown rice due to simultaneous germination of both the weed seeds and rice seeds when compared to other establishment methods tried during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. This finding is in line with the findings of Lourduraj *et al.* (2000) who reported reduced the weed density and biomass due to the smothering effect of closely spaced rice cultivation. Singh *et al.* (2008) reported highest density of weeds with direct seeding by zero-till-drill without tillage and lowest with transplanting method of rice establishment.

In soil weed seed bank spectrum, direct sown rice had higher weed seeds count on (0-15 cm) top layer of soil when compared to transplanted rice (Table 2). Conspicuously higher weed seeds count was noticed under direct sown rice with zero tillage + crop residue in ZT+CR- ZT+CR-ZT (T_6) system. The increasing trend was observed in conspicuously higher weed seed population under direct sown rice with zero tillage + crop residue in ZT+CR- ZT+CR-ZT (T_6) system during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. Transplanted rice with conventional tillage in

Table 1. Effect of tillage, crop establishment and weed management methods on total weed density (no./m^2) in rice

Treatment	*Kharif* 2012			*Rabi* 2012-13			*Kharif* 2013		
	30 DAS/T	60 DAS/T	Harvest	30 DAS/T	60 DAS/T	Harvest	30 DAS/T	60 DAS/T	Harvest
Tillage and crop establishment									
T_1- TR (CT-CT-ZT)	7.38 (66.3)	7.72 (72.7)	7.37 (68.5)	5.95 (43.4)	8.26 (84.6)	7.28 (63.1)	5.42 (32.1)	9.02 (96.0)	7.97 (75.2)
T_2- TR (CT-ZT-ZT)	8.44 (81.7)	8.80 (90.1)	8.39 (82.1)	6.82 (54.2)	9.55 (107.4)	8.49 (83.2)	5.64 (32.9)	9.93 (112.7)	8.68 (86.0)
T_3- TR (ZT+CR- ZT+CR-ZT)	9.78 (114.0)	10.12 (122.2)	9.39 (104.7)	7.64 (66.0)	10.61 (130.0)	9.39 (101.6)	6.23 (41.7)	11.14 (137.9)	9.67 (105.2)
T_4- DSR (CT-CT-ZT)	9.11 (95.8)	9.48 (104.2)	8.88 (94.5)	6.76 (54.3)	9.61 (107.6)	8.31 (79.7)	5.67 (35.4)	9.84 (108.3)	8.62 (84.5)
T_5- DSR (CT-ZT-ZT)	9.96 (112.7)	10.25 (119.1)	9.54 (103.6)	7.85 (67.9)	10.85 (133.2)	9.49 (100.7)	5.99 (36.4)	10.83 (130.7)	9.35 (96.1)
T_6- DSR (ZT+CR- ZT+CR-ZT)	11.54 (152.2)	11.63 (154.6)	10.66 (129.6)	8.46 (78.6)	11.67 (151.3)	10.25 (116.2)	7.46 (59.6)	12.39 (168.4)	10.93 (130.3)
LSD (P=0.05)	0.54	0.50	0.52	0.31	0.40	0.47	0.23	0.44	0.46
Weed management									
W1- Recommended herbicides	7.48 (56.0)	7.88 (61.6)	7.15 (50.8)	5.71 (31.4)	7.95 (62.3)	7.06 (48.6)	5.22 (25.7)	8.46 (70.8)	7.40 (53.8)
W2- IWM	5.71 (31.5)	5.82 (32.8)	5.33 (27.2)	4.50 (19.2)	6.34 (39.9)	5.65 (31.0)	4.12 (15.3)	7.10 (49.8)	6.08 (36.1)
W3- Unweeded check	14.93 (223.9)	15.43 (238.7)	14.63 (213.5)	11.53 (131.7)	15.98 (254.9)	13.90 (192.7)	8.87 (77.5)	16.02 (256.3)	14.13 (198.7)
LSD (P=0.05)	0.28	0.30	0.30	0.29	0.49	0.35	0.23	0.69	0.45

Figures in parentheses are mean of original values; Data subjected to square root transformation

TR : Transplanted rice
DSR : Direct sown rice
CT : Conventional tillage
ZT : Zero tillage
CR : Crop residue
W_1 : TR - Pre emergence treatment (PE) butachlor-*Kharif*, PE pretilachlor - *Rabi* DSR- PE pretilachlor (S)
W_2 : TR - PE butachlor-*Kharif*, PE pretilachlor - *Rabi* DSR- PE pretilachlor (S) + IC with daincha incorporation and mechanical weeding on 35 DAT/S
W_3 : Unweeded check

CT-CT-ZT system (T_1) resulted in perceptibly lesser weed seeds count during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. These results were in accordance with the findings of Legere and Sampson (1999) and Barberi and Blo Cascio (2001) who have observed higher weed biomass with more than 60 per cent of weed seedlings emerged from the surface soil layers in non-inversion chisel ploughing and no tillage systems.

Higher grain yield was recorded in transplanted rice with conventional tillage in CT-CT-ZT (T_1) system during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. However comparable higher grain yield was recorded in direct sown rice with conventional tillage in CT-CT-ZT (T_4) system. These were mainly due to lower weed density and higher weed control efficiency and this leads to higher grain yield. Direct sown rice with zero tillage + crop residue in ZT+CR-ZT+CR-ZT (T_6) produced consistently lower grain yield during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively.

Transplanted rice recorded lower cost of cultivation and higher net returns during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. Whereas, direct sown rice registered in lower net returns during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively (Table 3).

Effect of tillage practices on weeds and rice

Lower total weed density was recorded by conventional tillage in CT-CT-ZT (T_1) system tried during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013 it was comparable total weed density was recorded in conventional tillage in CT-ZT-ZT (T_2) system *Kharif* 2012 and 2013 and conventional tillage in CT-CT-ZT (T_4) system during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. This might due to the inversion of surface soil and burial of weed seeds by disc ploughing and puddling. Zero tillage + crop residue in ZT+CR- ZT+CR-ZT system (T_6) was found to record higher grass weed density mainly due to deposition of more weed seeds and propagates of grass weeds seed near the soil surface during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. Higher total weed seed densities in zero tillage systems may be the results of reduced herbicide availability because of adsorption to near-surface organic matter due to application of crop residues (Sadeghi and Isensee 1996). Greater deposition of weed seeds at the soil surface with zero tillage and minimum tillage than conventional tillage was also observed by Clements *et al.* (1996). Chauhan and Johnson (2009) stated that weeds were a greater problem in direct seeded rice than that in transplanted rice because of the absence of the crop seedling size advantage and standing water at the time of crop emergence.Tillage played a significant role in weed seed deposition and weed density rice- rice cropping system. Adoptions of non-inversion tillage practices tend to increase the total weed density.

Tillage practices showed significant difference with respect to weed seeds population. Conventional tillage in CT-CT-ZT system (T_1) resulted in perceptibly lesser weed seeds count. Whereas, conspicuously higher weed seed population was noticed under zero tillage + crop residue in ZT+CR- ZT+CR-ZT (T_6) system. Rotation of conventional tillage – zero tillage in CT-ZT- ZT system (T_2) recorded lower weed seed count compared zero tillage + crop residue in ZT+CR-ZT+CR-ZT (T_3) system. Similar findings were also reported by Gangwar *et al.* (2009).

Significantly more grain yield was observed with conventional tillage in CT-CT-ZT (T_1) system during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. How-

Table 2. Effect of tillage, crop establishment and weed management methods on weed seeds count /kg of soil in rice (0-15 cm)

Treatment	*Kharif* 2012	*Rabi* 2012-13	*Kharif* 2013
Tillage and crop establishment			
T_1- TR (CT-CT-ZT)	4.44 (19.22)	5.57 (37.00)	5.51 (36.11)
T_2- TR (CT-ZT-ZT)	4.77(21.89)	6.95(58.22)	6.65 (51.33)
T_3- TR (ZT+CR- ZT+CR-ZT)	5.66(32.33)	8.54(78.89)	7.99 (69.67)
T_4- DSR (CT-CT-ZT)	5.51(30.67)	6.86(55.22)	6.78 (53.11)
T_5- DSR (CT-ZT-ZT)	5.86(34.22)	9.42(99.67)	8.04 (70.11)
T_6- DSR (ZT+CR-ZT+CR-ZT)	6.56(43.22)	11.45(143.33)	9.70 (102.67)
LSD (P=0.05)	0.26	0.36	0.41
Weed management			
W_1- Recommended herbicides	5.02 (23.50)	6.23 (40.17)	5.97 (35.61)
W_2- IWM	4.10 (15.33)	5.43 (30.56)	4.83 (22.83)
W_3- Unweeded check	7.28 (51.94)	12.72 (165.44)	11.53 (133.06)
LSD (P=0.05)	0.18	0.40	0.30

Figures in parentheses are mean of original values; Data subjected to square root transformation ever, it was comparable with zero tillage in CT-ZT-ZT (T_2). Zero tillage + crop residue in ZT+CR-ZT+CR-ZT (T_6) produced consistently lower grain yield during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013. Conventional tillage in CT-CT-ZT (T_1) system recorded lower cost of cultivation and higher net returns during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. However it was comparable with conventional tillage in CT-ZT-ZT (T_2) system. Zero tillage + crop residue in ZT+CR-ZT+CR-ZT (T_3) system registered higher cost of cultivation compared to other treatments during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively. Whereas, zero tillage + crop residue in ZT+CR- ZT+CR-ZT (T_6) system registered in lower net returns during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013, respectively (Table 3).

Effect of weed management methods on weeds and rice

Regarding weed management practices, PE of butachlor 1.0 kg/ha for *Kharif* and PE of pretilachlor 1.0 kg/ha for *Rabi* and PE pretilachlor (S) 0.45 kg/ha for direct sown rice + inter crop with daincha incorporation and mechanical weeding on 35 DAS/T (W_2) treatment recorded lower grass weed density at all the stages during both the years. This was mainly because of pre-emergence herbicides, which reduced the density of complex weed flora at early stages of crop. Mode of action of pretilachlor is by inhibition of cell division and protein synthesis. In later stage of critical crop weed competition in rice, inter crop with *Sesbania* incorporation and mechanical weeding at 35 DAS/T recorded lower grass weeds density of during *Kharif* 2012, *Rabi* 2012-13 and *Kharif* 2013 which might be due to the reason that in mechanical weeding, all types of weeds especially grassy were removed. Bhanu Rekha *et al.* (2002) reported that hand weeding twice at 20 and 40 DAT resulted in significantly lower grass weed density and dry weight as compared to herbicide treatment and un-weeded check. Suganthi (2002) concluded that pretilachlor at 1.0 kg/ha followed by hand weeding at 40 DAT resulted in effective control of rice weeds and maximized the grain yield. Sunil *et al.* (2010) reported that pre-emergence application of bensulfuron methyl + pretilachlor (6.6 GR) 0.06 + 0.60 kg/ha, respectively + one inter-cultivation at 40 days after sowing recorded significantly lower weed population (Table 1).

Pre-emergence application of butachlor 1.0 kg/ha for transplanted rice and PE pretilachlor (S) 0.45 kg/ha for direct sown rice + inter crop with *Sesbania* incorporation and mechanical weeding on 35 DAS/T (W_2) attained its statistical supremacy by recording higher grain yield. Distinctly lower grain yield was obtained with under unweeded check (W_3).

Higher cost of cultivation and net return was incurred in integrated weed management (Transplanted rice - PE of Butachlor 1.0 kg/ha for *Kharif*, PE of Pretilachlor 1.0 kg/ha for *Rabi* + inter crop with daincha incorporation and mechanical weeding on 35 DAT) (direct seeded rice - PE pretilachlor (S) 0.45 kg/ha + inter crop with daincha incorporation and mechanical weeding at 35 DAS) during *Kharif* 2012 *Rabi* 2012-13 and *Kharif* 2013, respectively. Unweeded check (W_3) incurred lower cost of cultivation and net return during *Kharif* 2012 *Rabi* 2012-13 and *Kharif* 2013 (Table 3).

Table 3. Effect of tillage, crop establishment and weed management methods on yield, cost of cultivation and net returns in rice

Treatment	Yield (t/ha)			Cost of cultivation (x10^3 `/ha)			Net returns (x10^3 `/ha)		
	Kharif 2012	*Rabi* 2012-13	*Kharif* 2013	*Kharif* 2012	*Rabi* 2012-13	*Kharif* 2013	*Kharif* 2012	*Rabi* 2012-13	*Kharif* 2013
Tillage and crop establishment									
T_1- TR (CT-CT-ZT)	5.10	5.59	5.05	35.86	35.29	36.29	36.62	36.89	43.02
T_2- TR (CT-ZT-ZT)	4.93	5.19	4.82	35.86	31.36	36.29	34.40	37.73	37.18
T_3- TR (ZT+CR-ZT+CR-ZT)	4.39	4.53	4.43	37.57	37.36	37.64	25.37	26.34	26.79
T_4- DSR (CT-CT-ZT)	4.67	4.78	4.73	33.14	33.68	33.16	33.62	34.14	34.79
T_5- DSR (CT-ZT-ZT)	4.17	4.15	4.13	33.14	29.18	33.16	26.51	30.28	26.31
T_6- DSR (ZT+CR-ZT+CR-ZT)	3.90	3.11	3.71	34.85	35.18	34.27	20.68	18.12	9.88
LSD (P=0.05)	0.30	0.34	0.28	-	-	-	-	-	-
Weed Management									
W1- Recommended herbicides	4.93	4.87	4.86	34.41	33.06	34.52	35.50	36.32	34.84
W2- IWM	5.46	5.78	5.56	37.01	35.67	37.06	40.46	43.34	44.49
W3- Unweeded check	3.19	3.02	3.01	33.78	32.30	33.83	12.64	12.09	36.32
LSD (P=0.05)	0.34	0.39	0.32	-	-	-	-	-	-

In conclusion, failure of weed management may result in severe losses in terms of yield and economic return. Present study revealed that transplanted rice under conventional tillage in CT-CT-ZT system with PE butachlor 1.0 kg/ha for *Kharif*, PE of pretilachlor 1.0 kg/ha for *Rabi* + inter crop with *Sesbania* incorporation and mechanical weeding on 35 DAT results in lower total weed density, higher grain yield and net returns.

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Effect of herbicides and their combination on weed dynamics in rice-based cropping system

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ABSTRACT

A field experiment was conducted at Zonal Agricultural Research Station, Mandya, Karnataka to study the shift in weed flora of different weed species due to application of pre-sowing, pre-emergence and post-emergence application of herbicides in comparisons with hand weeding and mechanical weeding. The effect of combination of herbicide bensulfuron-methyl + pretilachlor as well as mono-herbicide butachlor and their post-planting application were evaluated for their bio-efficacy either alone or combination with pre-planting application of non-selective glyphosate application. The treatment comprised of eight different weed management practices were laid out in randomised complete block design with three replications. The results revealed that application of glyphosate (15 days before transplanting of rice 0.75 kg/ha) in combination with bensulfuron methyl + pretilachlor applied at 5 DAT recorded higher grain yield of 7.02 t/ha and found significantly superior over other treatments due to reduced weed population and biomass of weeds (10.30 g/m^2) and higher weed control efficiency (64.97%) when compared with weedy check. There was more than 36% reduction in the grain yield of rice due to competition with weeds in weedy plots. The rice yield and weed control efficiency of herbicide combination was at par with recommended practice of hand weeding twice at 20 and 40 DAT. Sequential herbicide application is promising and effective in control of weeds as compared to single herbicide application in rice-based cropping system.

Key words: Chemical control, Cropping system, Herbicide combination, Rice, Weed dynamics

Rice is the most important staple food, accounting for 43% of the total food grain in the country. In Karnataka, rice is grown in an area of 15 lakhs ha with the total production of 55.72 lakh tons and average productivity 4.06 t/ha. Weed infestation in transplanted rice is a critical factor that reduced the yield to the extent of 15-45% (Chopra and Chopra 2003). In transplanted rice *Echinochloa* species, *Cyperus* species, *Commelina* spp, *Fimbristylis miliacea* are dominant weeds. Weeds not only compete with rice at nursery for growth factors but morphological similarities they got transplanted in the field along with rice seedlings. This crop-weed competition leads to significant yield losses to the tune of 35-55% in transplanted rice (Gautam and Mishra 1995, Purushamam 1996). Recent estimates showed that average reduction in yield due to weeds varied from 12 to 72% depending upon weed flora and the extent of competition offered by weeds to the crop. Manual removal of weeds is labour intensive, tedious, back-breaking and does not ensure weed removal at critical stage of crop-weed competition. Rice-rice is the major cropping system in Southern Karnataka wherein long duration varieties of rice adopted by the farmers give less time for field preparation between rice harvest during summer and sowing in rainy season resulting in more weed infestation. Existing pre-emergence herbicides are less effective against weeds like *Echinochloa* spp., *Panicumrepens* spp., *Cyperus* spp. *etc*. Hence, the present investigation was under taken to study the effect of combination of herbicide and their bio-efficacy either alone or combination with pre-planting application of non-selective glyphosate in rice rice based cropping system.

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MATERIALS AND METHODS

The field experiment was conducted at Zonal Agricultural Research Station, V.C. Farm, Mandya, University of Agricultural Sciences, Bengaluru, Karnataka, during rainy season of 2009 and 2010. The soil of the experimental field was red sandy loam in texture, acidic in reaction (pH: 6.68), medium in available N (273 kg/ha), P (20.5 kg/ha), and available K (178 kg/ha) and low in organic carbon content (0.45%). The experiment consisted of eight treatments was laid out in randomized complete block design with three replications. The treatments were as follows: glyphosate (0.75 kg/ha) applied at 15 days before transplanting of rice, butachlor (1.5 kg/ha) applied at 0-5 days after transplanting (DAT), bensulfuron-methyl + pretilachlor

(0.06 + 0.6 kg/ha) applied at 5 DAT, glyphosate (0.75 kg/ha) applied at 15 days before transplanting of rice + butachlor (1.5 kg/ha) applied at 0-5 DAT, glyphosate (0.75 kg/ha) applied at 15 days before crop establishment + bensulfuron-methyl + pretilachlor (0.06 + 0.6 kg/ha) applied at 5 DAT, hand weeded twice (20 and 40 DAT), use of cono-weeder and, non-weeded control. Agronomic practices were followed for raising crop. The rice variety '*BR-2655*' was used in the study. Treatment herbicide combination was applied using knapsack sprayer with a spray volume of 500 l/ha. Hand weeding was done manually, hand and mechanical weeding was done by cono-weeder. Hand weeding with hoe and mechanical weeding with cono-weeder was used in the respective treatments. Recommended dose of 100 kg N, 50 kg P_2O_5, 50 kg K_2O and 20 kg $ZnSo_4$ was given in the form of urea, SSP, MOP and $ZnSo_4$. At the time of transplanting, 50% N and K, full dose of P was applied as basal dose and remaining 50% N was supplemented as top dressing at 30 and 60 DAT and 50% K was applied at the time of panicle initiation. Weed counts were recorded at 30, 60 and 90 DAT with the help of quadrate of $1m^2$ in each plot. Weed biomass (g/m^2) and weed control efficiency (%) were calculated as per the standard formulae given by Patel *et al.*(1987) and Gill and Vijay Kumar 1969. The data of yield, yield attributes were statistically analyzed at 5% level of significance.

RESULTS AND DISCUSSION

Weed flora

The dominating weed flora observed in the experimental field were *Cyperus difformis, Cyperus iria, Fimbristylis woodrowii, Echinochloa crusgalli, Cynodon dactylon, Rotala densiflora* and *Eclipta alba* among the broad-leaved weeds and *Cyperus* spp. among sedges.

Effect on weed biomass

The results indicated that among the different weed management practices, the application of glyphosate (15 days before transplanting of rice 0.75 kg/ha) in combination with bensulfuron-methyl (0.6% G) + pretilachlor (6.0% G) (0.06 + 0.6 kg/ha) applied at 5 DAT recorded lower biomass of weed (29.43 g), followed by the use of cono-weeding at 20 and 40 DAT (32.93 g) and found significantly superior over other treatments. The non-weeded control plot recorded maximum biomass of weed (85.46 g/m^2).

Weed control efficiency

The efficacy of herbicides on the basis of weed biomass indicated that application of glyphosate (15 days before transplanting of rice 0.75 kg/ha) in combination with bensulfuron methyl (0.6% G) + pretilachlor (6.0% G) applied at 5 DAT was most effective with a weed control efficiency of 65.0% followed by use of cono weeding at 20 and 40 DAT (60.5%) and rice field treated with butachlor 50 EC 1.5 kg/ha applied at 5 DAT was least effective 40.4%.

Yield and yield attributes

Among the different weed management practices, the pooled data of two years indicated that the application of glyphosate (15 days before transplanting of rice 0.75 kg/ha) in combination with bensulfuron-methyl + pretilachlor applied at 5 DAT recorded significantly higher grain yield of 7.02 t/ha, *fb* bensulfuron-methyl + pretilachlor applied at 5 DAT (6.73 t/ha)

Table1. Weed biomass and weed control efficiency as influenced by different weed management practices in transplanted rice

Treatment	Dosage	Time of application (DAT)	Weed biomass (g/m^2) at 60 DAT	Weed control efficiency (%) at 60 DAT	Panicle number/m^2			Panicle weight (g)		
					2009	2010	Mean	2009	2010	Mean
Glyphosate	0.75 kg/ha	15 days before crop establishment	16.97	36.03	371	293	332	2.62	2.77	2.70
Butachlor	1.5 kg/ha	5 DAT	19.43	26.76	378	315	347	2.57	2.60	2.59
Bensulfuron-methyl + pretilachlor	0.06 + 0.60 kg/ha	5 DAT	13.2	50.25	395	326	361	3.00	2.90	2.95
Glyphosate + butachlor	0.75 kg/ha + 1.5 kg/ha	15 days before crop establishment + 5 DAT	13.53	49.00	388	380	384	2.84	2.77	2.81
Glyphosate + bensulfuron-methyl + pretilachlor	0.75 kg/ha + 0.06 + 0.60 kg/ha	5 DAT	10.3	61.18	415	396	406	2.89	3.33	3.11
Hand weeded twice		20 & 40 DAT	11.97	54.88	395	313	354	2.78	2.67	2.73
Use of cono weeder		20 & 40 DAT	11.67	56.01	380	384	382	2.60	3.00	2.80
Non weeded control	-	-	26.53		310	265	288	2.32	2.37	2.35
LSD (P=0.05)			5.96		15.27	21.19	18.23	0.22	0.27	0.25

Table 2. Effect of weed management practices on the yield and yield attributing characters in transplanted rice

Treatment	Dosage	Time of application (DAT)	Grain yield (t/ha)			Total cost of cultivation (x10^3 `/ha)	Gross returns (x10^3 `/ha)	Net returns (x10^3 `/ha)	B:C
			2009	2010	Mean				
Glyphosate	0.75 kg/ha	15 days before crop establishment	6.04	5.95	5.99	32.65	85.93	53.28	1.63
Butachlor	1.5 kg/ha	5 DAT	6.26	6.32	6.29	33.64	89.73	56.08	1.60
Bensulfuron-methyl + pretilachlor	0.06 + 0.60 kg/ha	5 DAT	6.66	6.80	6.73	34.60	96.33	61.72	1.78
Glyphosate + butachlor	0.75 kg/ha + 1.5 kg/ha	15 days before crop establishment+5 DAT	6.51	6.60	6.55	33.86	93.60	59.74	1.76
Glyphosate + bensulfuron-methyl + pretilachlor	0.75 kg/ha + 0.06 + 0.60 kg/ha	5 DAT	6.88	7.15	7.02	34.90	100.110	65.21	1.87
Hand weeded twice		20 & 40 DAT	6.64	6.40	6.52	35.60	93.17	57.57	1.67
Use of cono weeder		20 & 40 DAT	6.24	6.94	6.59	34.40	93.84	59.44	1.73
Non weeded control	-	-	4.48	4.51	4.50	32.50	63.66	31.16	0.95
LSD (P=0.05)			0.29	0.33	0.31				

(Table 2). The lowest rice yield was observed with non-weeded control (4.50 t/ha). Higher yield might be due to more number of panicle/m^2 (406) and higher panicle weight (3.11g) compared to non-weedy control (panicle number–288/m^2 and panicle weight - 2.35 g, respectively). All the herbicides treatment showed significantly higher grain yield over the un weeded check. This was due to the fact that the less competition for moisture, light and nutrient uptake by the crop plants. The higher assimilation of photosynthesis in weedicides treated plots may be the reason for higher yield. The result was in close conformity with those of Singh *et al.* (2003), Singh *et al.* (2006), Singh *et al.* (2007).

Economics

Weed management practices in the study showed variation in gross returns, net returns and B: C ratio. Among the different weed management practices, the pooled data of two years indicated that the application of glyphosate (15 days before transplanting of rice 0.75 kg/ha) in combination with bensulfuron-methyl + pretilachlor applied at 5 DAT recorded higher net returns (` 65,210/ha) and B: C ratio (1.87 ), followed by bensulfuron-methyl + pretilachlor applied at 5 DAT (` 61,729/ha and 1.78, respectively). The lower net returns and B: C ratio (` 31,161 and 0.95, respectively) were recorded with non-weeded control. Thus it is inferred that sequential herbicide application is promising and effective to control weeds as comparision to single herbicide application in rice-based cropping system.

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Management of weeds in direct-seeded rice by bispyribac-sodium

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ABSTRACT

A field experiment was conducted during the *Kharif* season of 2011 and 2012 at G.B.Pant University of Agricultureand Technology, Pantnagar to find out the efficacy of bispyribac-sodium in managing weeds in direct-seeded rice. Among the treatments, bispyribac-sodium 20 and 25 g/ha applied at 1-3 leaf stage or at 4-6 leaf stage of the weeds was found the most efficient having lowest weed density and biomass during both the years. Rice grain yield and yield attributing characters (tillers/m^2 and grains/panicle) were influenced by the effectiveness of the treatments. The highest grain yield of rice was recorded with weed free (4.03 t/ha) which was at par with bispyribac-sodium 20 and 25 g/ha.

Keywords: Bispyribac-sodium, Direct-seeded rice, Herbicide, Management, Weeds, Yield

Transplanting of rice seedlings is an age old practice but in the recent years, non-availability of labour for timely transplanting is resulting in the reduced yield of rice (Budhar and Tamilselven 2002). Direct-seeded rice (DSR) has several advantages over puddled transplanted rice like easier planting, timely sowing, less drudgery, early crop maturity by 7-10 days, less water requirement, better soil physical condition for next crop and low production cost and more profit (Kumar and Ladha 2011). However, weeds are the main biological constraints to the production of DSR (Rao *et al.* 2007, Chauhan and Johnson 2010), which may cause 60-80% reduction in grain yield of rice. Hence, present study was carried out to evaluate the efficacy of bispyribac-sodium in managing weeds of direct-seeded rice.

MATERIALS AND METHODS

A field experiment was carried out during *Kharif* 2011 and 2012 at Crop Research Center of GBPUA & T, Pantnagar. The soil was loamy, medium in organic matter (0.67%), available phosphorous (17.5 kg/ha) and potassium (181.2 kg/ha) with pH 7.5. The experiment consisted of nine treatments with three doses of bispyribac-sodium 15, 20 and 25 g/ha as test product at two stages of its application *i.e.* 1-3 leaf stage and 4-6 leaf stage along with bispyribac-sodium (standard check) 20 g/ha, weed free and weedy check. The experiment was laid out in randomized block design with three replications. The rice variety '*Pant Dhan 12*' was sown on June 30, 2011 and June 16, 2012. The crop was raised with recommended package of practices. The data on weed density/m^2 and total weeds biomass were taken at 45 days after sowing. Effective tillers/m^2 area, 1000 grain weight (g) and grain yield (kg/ha) of rice were recorded at the time of rice harvest. The data on density and biomass of weeds were subjected to log transformation by adding 1.0 to original values before statistical analysis. The herbicides were applied by using a Maruti Foot Sprayer fitted with flat fan nozzle with 375 liter/ha water volume.

In addition of bio-efficacy, a separate experiment was also carried out to see the phytotoxicity effect (yellowing, necrosis, scorching, epinasty and hyponasty) of bispyribac-sodium on direct-seeded rice crop and to see the residual effect of bispyribac-sodium on succeeding crop lentil and mustard. Bispyribac-sodium 20 g and 40 g/ha were applied at 3-4 leaf stage of weeds using 375 liter/ha volume of water. Phytotoxicity symptoms were recorded at 5, 10, 15 and 30 days after spraying using rating scale of 0-10, where, 0 = no effect on plant and 10 = complete death of the plant.

Lentil and mustard crops were planted after nine days of harvesting of rice crop in the plots treated with bispyribac-sodium at 20 and 40 g/ha and in weedy check to see the residual effect on succeeding lentil and mustard crops. Untreated check was maintained for comparison. Visual observations on crop phytotoxicity on succeeding lentil and mustard crops were recorded at 15 and 30 days after sowing (DAS) at 0-10 scale.

RESULTS AND DISCUSSION

Weed flora consisted of *Echinochloa colona, Eleusine indica* and *Leptochloa chinensis* among grasses; *Celosia argentia*, a broad-leaved weed and *Cyperus*

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rotundus and *Fimbristylis milliaceae* among sedges. However, very low density of other weeds, *viz. Echinochloa crusgalli, Commelina benghalensis, Phyllanthus niruri* and *Eclipta alba* were also found. Bispyribac-sodium caused significant reduction in the total density and biomass of weeds when compared with weedy check. Post-emergence application of bispyribac-sodium 20 as well as 25 g/ha applied both at 1-3 leaf stage or at 4-6 leaf stage was found effective for the control of *E. colona, E. indica, C. argentia, C. rotundus* and *F. milliaceae*. However, bispyribac-sodium at these rates and stages of application was found less effective for the control of *L. chinenis*. The total density of weeds decreased with increase in dose of bispyribac-sodium at 45 DAS. Among the herbicides, application of bispyribac-sodium (1-3 leaf stage) at higher dose applied 25 g /ha significantly reduced the total weed density as compared to other herbicidal treatments followed by its lower dose at 20 g/ha which was statistically at par with application of bispyribac-sodium 25 g/ha at (4-6 leaf stage) (Table 1). The highest density was observed in unweeded control plots. These results were also in conformity with the findings of Kumaran *et al*. (2012) who registered lower weed density under bispyribac-sodium than other weed management treatments in direct-seeded rice.

Weed biomass

Weed free plots recorded the lowest weed biomass followed by application of bispyribac-sodium (1-3 leaf stage) at higher dose applied at 25 g/ha during both the years (Table 2). The highest weed biomass was recorded in weedy check. The significant reduction of weed biomass by bispyribac-sodium at 30 g/ha than pre-emergence herbicide application in dry-seeded rice was also observed by Walia *et al*. (2008).

Weed control efficiency

The weed control efficiency (WCE) was highest in the weed free plot (Table 2). Among the herbicidal treatments, the highest WCE was recorded with the application of bispyribac-sodium at 25 g/ha applied at 1-3 leaf stage followed by its lower dose *i.e.* 20 g/ha which was at par with application of bispyribac sodium at 25 g/ha applied at 4-6 leaf stage.

Effect on crop

The highest number of tillers/m^2 was obtained with weed free conditions which was at par with the application of bispyribac-sodium 25 g/ha at 1-3 or 4-6 leaf stage and bispyribac-sodium 20 g/ha at 1-3 leaf stage. The highest grain yield of rice was recorded from the weed free plot (4.03 t/ha) which was at par with bispyribac-sodium 20 and 25 g/ha applied at 1-3 and 4-6 leaf stage of weeds. Chemical weed control by the application of selective herbicides often proved very effective in suppressing weeds with sizeable boost in the productivity of variety of arable crops including DSR (Mahajan *et al*. 2009).

Phytotoxicity

There was no phytotoxic effect of bispyribac-sodium at any of the doses on rice crop.

Residual effect on succeeding crops

Data (Table 3) revealed that plant height at 30 days of lentil and mustard, which were grown as succeeding crop after rice harvesting from the plots treated with bispyribac-sodium at 20 and 40 g/ha and untreated check were non-significant. Further bispyribac-sodium at 20 and 40 g/ha did not show any phytotoxic symptoms,*viz.* yellowing, wilting, stunting and deformities on mustard and lentil when observed at 15 and 30 days after sowing.

Table 1. Effect of bispyribac-sodium on weed density at 45 days after sowing (mean data of 2011 and 2012)

Treatment	Dose (g/ha)	Application stage	Weed density (no/m^2)						Total weed density (no/m^2)
			Echinochloa colona	*Leptochloa chinensis*	*Celosia argentia*	*Cyperus rotundus*	*Fimbristylis miliaceae*	Other weeds	
Bispyribac-sodium (TP)	15	1-3 leaf	3.5(36)	2.3(9)	2.7(16)	2.6(15)	1.2(4)	2.1(8)	4.54(93)
Bispyribac-sodium (TP)	20	1-3 leaf	3.0(20)	1.9(7)	2.2(9)	1.7(9)	0.0(0)	1.2(4)	3.97(52)
Bispyribac-sodium (TP)	25	1-3 leaf	2.3(13)	2.2(9)	1.8(5)	1.9(7)	0.0(0)	1.0(3)	3.64(37)
Bispyribac-sodium (TP)	15	4-6 leaf	3.7(44)	2.4(11)	2.8(17)	3.0(20)	1.5(7)	2.7(15)	4.82(123)
Bispyribac-sodium (TP)	20	4-6 leaf	3.2(27)	2.2(9)	2.6(13)	2.6(13)	1.0(3)	2.2(11)	4.41(89)
Bispyribac-sodium (TP)	25	4-6 leaf	2.9(19)	2.1(8)	2.1(8)	2.2(9)	0.5(1)	1.8(5)	3.99(53)
Bispyribac-sodium (SC)	20	4-6 leaf	3.4(31)	2.2(9)	2.6(13)	2.4(12)	1.8(5)	2.4(12)	4.47(86)
Weed free	-	-	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)	0.0(0)
Weedy	-	-	5.3(221)	2.6(15)	3.8(48)	4.2(70)	2.6(15)	3.3(28)	6.01(410)
LSD (P=0.05)	-	-	0.6	0.8	0.6	1.1	1.1	1.1	0.45

Figures in parentheses are original values, which are subjected to log transformation, TP = Test product, SC = Standard check

Table 2. Effect of bispyribac-sodium on weed biomass and weed control efficiency at 45 days after sowing in direct-seeded rice (mean data of 2011 and 2012)

Treatment	Dose (g/ha)	Application stage	Weed biomass (g/m^2)			Total weed biomass (g/m^2)	WCE (%)
			Grassy weeds	Broad-leaf weeds	Sedge		
Bispyribac-sodium (TP)	15	1-3 leaf	3.61(38.11)	1.90(6.71)	2.67(13.67)	4.09 (58.49)	85.32
Bispyribac-sodium (TP)	20	1-3 leaf	3.17(23.11)	1.63(4.43)	2.55(6.23)	3.55 (33.77)	91.54
Bispyribac-sodium (TP)	25	1-3 leaf	2.65(13.73)	1.39(3.11)	2.38(4.90)	3.12 (21.74)	94.54
Bispyribac-sodium (TP)	15	4-6 leaf	5.15(73.30)	2.19(8.99)	3.47(18.85)	4.63 (101.14)	74.62
Bispyribac-sodium (TP)	20	4-6 leaf	5.00(36.27)	1.92(5.87)	3.07(11.50)	4.00 (53.64)	86.54
Bispyribac-sodium (TP)	25	4-6 leaf	3.25(25.2)	1.81(4.22)	2.60(7.40)	3.63 (36.82)	90.76
Bispyribac-sodium (SC)	20	4-6 leaf	5.0(37.50)	1.97(6.07)	2.97(12.34)	4.04 (55.91)	85.97
Weed free	-	-	0.0(00.00)	0.0(00.00)	0.0(00.00)	0.0 (0.00)	100.00
Weedy	-	-	5.72(306.93)	2.51(21.38)	4.25(70.30)	5.99 (398.61)	-
LSD (P=0.05)	-	-	0.25	0.33	0.20	0.47	

TP = Test product, SC = Standard check

Table 3. Effect of bispyribac-sodium on yield attributes and yield of direct seeded rice (mean data of 2011 and 2012)

Treatment	Dose (g/ha)	Application stage	Effective tillers/m^2	Grains/panicle	1000 grains weight (g)	Yield (t/ha)
Bispyribac-sodium (TP)	15	1-3 leaf	222.0	102.0	22.5	3.00
Bispyribac-sodium (TP)	20	1-3 leaf	248.3	106.3	22.7	3.80
Bispyribac-sodium (TP)	25	1-3 leaf	255.0	107.3	22.9	3.88
Bispyribac-sodium (TP)	15	4-6 leaf	200.0	100.0	21.3	2.30
Bispyribac-sodium (TP)	20	4-6 leaf	233.0	104.0	21.8	3.56
Bispyribac-sodium (TP)	25	4-6 leaf	241.0	104.7	22.2	3.72
Bispyribac-sodium (SC)	20	4-6 leaf	226.0	103.5	21.5	3.38
Weed free	-	-	260.7	110.7	23.2	4.03
Weedy	-	-	65.0	77.0	20.9	0.33
LSD (P=0.05)	-	-	20.1	4.5	NS	0.49

TP = Test product, SC = Standard check

On the basis of this study, it can be concluded that bispyribac-sodium 20 g/ha is optimum dose in rice for effective control of weeds and to attain higher grain yield of rice without any phyto-toxicity to rice or on lentil and mustard, which were planted as succeeding crops after harvesting of rice crop.

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Residual effect of sulfonylurea herbicides applied to wheat on succeeding maize

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ABSTRACT

The field experiment was conducted to assess the residual effects of sulfosulfuron (25, 37.5 and 50 g/ha) and mesosulfuron + iodosulfuron (12, 18 and 24 g/ha) herbicides applied to wheat on maize (*Zea mays* L.) grown in sequence at Ludhiana, Punjab (India). None of the sulfonylurea herbicides (sulfosulfuron and mesosulfuron + iodosulfuron) applied to wheat at different doses affected the emergence of maize crop during both the years. But the effect was evident on growth characters and yield during 2005 whereas in 2004, plant height and dry matter at all stages of maize was not affected significantly. This might be due to difference in rainfall received at different stages of the crop growth in both the years. The rainfall received from April to June (optimum sowing time) was 137 mm and 54.2 mm in 2004 and 2005, respectively, however, in July rainfall was more in 2005 but the earlier status of rainfall was more responsible for the residual effect in 2005 as the reduced rainfall presumably left the soil dry for long time and might have resulted in slow dissipation rate of the herbicides. Again in August, rainfall was more in 2004 (+45.7 mm departure from normal rainfall in 2004) than 2005 so this might have enhanced the movement of the herbicide to lower surface and thus no residual effect was observed on the crop. Hence, it is not safe to grow maize in rotation after application of these sulfonylurea herbicides on wheat, as significant effect on the growth and yield of maize was recorded during the years of less rainfall.

Key words: Herbicide, Maize, Mesosulfuron + iodosulfuron, Residual effect, Sulfosulfuron, Wheat

Wheat *(Triticum aestivum* L.) is one of the most extensively grown cereal crops of the world. The sole application of isoproturon over a period of 10-12 years posed the problem of its resistance in *Phalaris minor* as it started defying the killing potential of this herbicide even at its higher doses in Punjab state (Malik and Singh 1993, Walia *et al.* 1997). The use of new alternate herbicides including clodinafop, fenoxaprop-p-ethyl, sulfosulfuron, mesosulfuron + iodosulfuron were recommended which provided a great relief to wheat crop from the isoproturon resistant population of *Phalaris minor* (Malik and Singh 1995*)*.

The sulfonylurea herbicides though applied at very low rates but are known for their residue under varied type of environmental conditions because of less dissipation rates (Pandey and Singh 1994). Sulfonylurea herbicides have been commercialized for use under a wide variety of agronomic conditions in numerous crops (Brown and Cotterman 1994) as this group is having low mammalian toxicity and degrades to innocuous compounds after application. Sulfonylurea herbicides are highly active in the soil and some crops in rotation can be sensitive to even low soil residues (Walker and Brown 1982), additionally, excessive mobility and persistence of herbicides in soils may cause groundwater contamination and phytotoxic effects to sensitive crops grown in the following season. As the crops in which sulfonylurea herbicides find place are grown in varied agro ecosystems, it becomes imperative to investigate the persistence of sulfonylurea herbicides under different growing conditions so as to avoid any hazard, which may arise due to its continued use. These herbicides are known for their persistence in soil (Blair and Martin 1988) and thus have soil residual toxicity to some of the sensitive crops (Moyer 1995). Balyan (1998) also reported that with the exception of 0.4 mg glufosinate on mung bean and soyabean, the three herbicides (0.4 or 0.6 mg/litre sulfosulfuron, chlorsulfuron or glufosinate) were phytotoxic and decreased dry matter in all the crops *i.e.* mung bean, soyabean, pearl millet, maize and sorghum. Yadav *et al.* (2004) reported that the sulfosulfuron at 25 g/ha and pendimethalin at 1500 g/ha applied in wheat caused residual toxicity to maize but not to mung bean and cotton.

The application of mesosulfuron+ iodosulfuron at 15.0 + 3.0 and 30.0 + 6.0 g/ha applied in wheat had no residual effect on the succeeding crops of transplanted rice and urdbean (Singh *et al.* 2003). However, maize crop in succession was adversely affected due to these treatments.

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As the research regarding the residual effect of sulfonylurea herbicides on the succeeding crops is limited so the present work was carried out with the objective to assess the effect of doses of sulfonylurea herbicides on growth, development and yield of wheat and residual effects of sulfonylurea herbicides on following *Kharif* crops grown in sequence.

MATERIALS AND METHODS

The present investigation was carried out at Punjab Agricultural University, Ludhiana during the years 2003-04 and 2004-05. A pre-sowing irrigation to the field was given then ploughed twice with cultivator followed by cross planking to attain fine seedbed. One meter distance was maintained between the plots by having paths between them. All four sides of the plots were protected by soil boundaries (bunds) raised to a level of 40 cm height and 30 cm width. Wheat variety '*PBW 343*' was sown with seed rate of 100 kg/ha having spacing of 22.5 cm. The experiment was laid out in randomized block design for wheat crop with six different herbicide treatments and unsprayed control. The herbicide sulfosulfuron (1-(4,6-dimethoxypyrimidin-2-yl)-3-(2-ethylsulfony-limidazo [1,2-a]pyridin-3-ylsulfonyl) urea was applied at recommended dose (25 g/ha of sulfosulfuron 75% w/w WG formulation) as one treatment, second treatment was applied at 37.5 g/ha of sulfosulfuron 75% w/w WG formulation and last was double the recommended dose (50 g/ha). Similarly mesosulfuron (Methyl2-(3-(4,6-dimethoxypyrimidin-2-yl) ureidosul-fonyl)-4-methanesulfonamido-methyl benzoate) + iodosulfuron (Methyl 4-iodo-2-(3-(4-methoxy-6-methyl-1, 3, 5-triazin-2-yl) ureidosulfonyl benzoate) was applied as 12, 18 and 24 g/ha and the unsprayed control. Seven different plots each with a dimension of 7.25 x 5.00 m (net plot size) were prepared and these treatments were replicated four times. Both the herbicides were applied 35 days after sowing of wheat. After wheat harvest, the above-described dimensioned plots were sub-divided and the succeeding crop of maize was taken. All the data were collected from the center rows of each plot to minimize the border effects. All the weeds were removed manually from the succeeding *Kharif* crop of maize as no herbicide was applied to this crop. The sowing of maize was done in June.

The soil was loamy send with pH 7.4. However, it was high in available P_2O_5 (25.7 kg/ha) and medium in available K_2O_5 (222.3 kg/ha). The soil profile (0-90 cm) had 16.56 and 5.81 cm moisture content at 0.3 bar and 15 bar, respectively.

The experimental data were subjected to analysis using CPCS1, software developed by Cheema and Singh (1991). All the comparisons were made at 5% level of significance.

RESULTS AND DISCUSSION

Effect on maize crop

At harvest, the plant height (Table 1) was significantly more in unsprayed control than all other treatments applied to wheat. The plant height was significantly less at higher dose of both the herbicides than the lower dose. The per cent reduction in height was 2.91, 5.35 and 8.07 in sulfosulfuron applied doses of 25, 37.5 and 50 g/ha, respectively and 3.28, 4.75 and 7.13 in mesosulfuron + iodosulfuron 12, 18 and 24 g/ha, respectively over unsprayed control. All doses of mesosulfuron + iodosulfuron and sulfosulfuron were at par with each other. Though, maize crop has been reported very sensitive to sulfosulfuron (Singh and Walia 2005) but in a loamy sand soil, leaching of the herbicide to lower layers may also to some extent be able to nullify the adverse effect when the rainfall is frequent and more than the normal. The data indicated that higher dose of both the herbicides led to residual toxicity to the succeeding maize crop as the height was significantly reduced at all doses.

The dry matter accumulation (Table 1) was not significant at harvest in 2004 whereas it differed significantly in 2005. At harvest, dry matter accumulation was significantly more in unsprayed control than rest of the treatments. The per cent reduction in DMA was 4.03, 5.94 and 6.66 in sulfosulfuron at 25, 37.5 and 50 g/ha, respectively and 4.95, 4.04 and 3.72 in mesosulfuron + iodosulfuron at 12, 18 and 24 g/ha), respectively over unsprayed control.

The grain and straw yield (Table 1) was not significant during 2004. During 2005, the grain yield was significantly affected by different herbicide treatments applied to wheat. The significantly higher grain yield was obtained in unsprayed control than all other treatments. Significant reduction in grain yield was recorded where sulfosulfuron was applied at double dose 50 g/ha on wheat than 37.5 and 25 g/ha however, at later two doses, the grain yield was at par. The per cent reduction in grain yield was 11.45, 10.74 and 26.89 in sulfosulfuron at 25, 37.5 and 50 g/ha, respectively and 11.52, 16.0 and 15.01 in mesosulfuron + iodosulfuron applied at 12, 18 and 24 g/ha, respectively over unsprayed control. All the doses of mesosulfuron + iodosulfuron applied to wheat were at par with each other in case of maize grain yield but significantly less than unsprayed control. Similar trend was observed in straw yield during 2005.

The effect of herbicides applied to wheat on succeeding crop of maize was evident on growth characters and yield (Table 1) during 2005 whereas in 2004, plant height and dry matter at all stages of maize was not affected significantly. This might be due to differ-

Table 1. Residual effect of sulfonylurea herbicides applied to wheat on growth and yield of maize

Treatment	Emergence (m^2)		Plant height (cm) At harvest		Dry matter (g/plant) At harvest		Grain yield (t/ha)		Straw yield (t/ha)	
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
Sulfosulfuron 25 g/ha	7.65	7.28	188.6	155.2	175.8	156.2	4.75	3.64	5.69	4.44
Sulfosulfuron 37.5 g/ha	7.98	7.43	187.1	151.3	174.8	153.1	4.84	3.66	5.71	4.57
Sulfosulfuron 50 g/ha	7.52	7.27	185.7	147.0	176.0	151.9	4.69	3.00	5.92	4.12
Mesosulfuron + iodosulfuron 12 g/ha	7.18	7.46	186.3	154.6	178.2	154.7	4.54	3.63	5.71	4.64
Mesosulfuron + iodosulfuron 18 g/ha	7.65	7.38	185.3	152.3	175.2	156.1	4.48	3.45	5.75	4.60
Mesosulfuron + iodosulfuron 24 g/ha	7.50	7.43	186.4	148.5	175.5	156.7	4.43	3.49	5.55	4.56
Control (unsprayed)	6.89	7.55	189.8	159.9	174.7	162.7	4.79	4.11	5.84	5.12
LSD (P=0.05)	NS	NS	NS	4.61	NS	3.10	NS	0.32	NS	0.31

ence in rainfall received at different stages of the crop growth in both the years. The rainfall received from April to June was 137 mm and 54.2 mm in 2004 and 2005, respectively, however in July rainfall was more in 2005, but the earlier status of rainfall was more responsible for the residual effect in 2005 as the reduced rainfall presumably left the soil dry for long time and might have resulted in slow dissipation rate of the herbicides (Vicari *et al.* 1994). Again in August, rainfall was more in 2004 (+45.7 mm departure from normal rainfall in 2004) than 2005 so this might have enhanced the movement of the herbicide to lower surface (Junnila *et al.*1994) and thus no residual effect was observed on the crop. So the crop like maize can not be safely grown in rotation after wheat, as significant effect on the growth and yield was recorded.

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Effect of sowing time and weed management on performance of pigeonpea

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ABSTRACT

Field studies were conducted at Research Farm of CCS Haryana Agricultural University, Hisar, during *Kharif* 2006 and 2007 to find out the effect of sowing time (10th May, 25th May, 10th June and 25th June) and weed control measures consisted weedy, weed free, pendimethalin 1.0 kg/ha as pre-emergence (PE) *fb* HW at 60 DAS, trifluralin 1.0 kg/ha as pre-plant incorporation (PPI) *fb* HW at 60 DAS and HW at 30 and 60 DAS), in pigeonpea (*Cajanus cajan* L.). Results revealed that density and biomass of weeds increased with the corresponding advancement in crop growth and delay in sowing time from 10th May to 25th June. Pendimethalin 1.0 kg/ha as PE and trifluralin 1.0 kg/ha as PPI each followed by (*fb*) one hand weeding (HW) at 60 days after sowing (DAS) provided better weed control than HW up to 60 DAS but at 90 DAS, these three treatments were statistically at par. Trifluralin *fb* HW had an edge over pendimethalin *fb* HW up to 60 DAS. In general, yield and yield parameters of pigeonpea were superior when crop was sown on 10th and 25th May compared to delay in sowing (10th and 25th June) during both the years. Performance of crop was similar when sown on 10th and 25th May. Among weed control treatments, trifluralin 1.0 kg/ha (PPI) *fb* 1 HW at 60 DAS, being at par with 2 HW, had an edge over pendimethalin 1.0 kg/ha (PE) *fb* 1 HW at 60 DAS in respect of yield attributes and ultimately yield of pigeonpea.

Key words: Chemical control, Pigeonpea, Sowing time, Weed management, Yield

Pigeonpea (*Cajanus cajan* L. Millsp) is the most widely cultivated pulse crop of rainy season in India. It is generally sown in the month of May and June with pre-monsoon rains. The crop is grown in wider row spacing and takes 5 to 6 month duration to mature. It faces stiff competition from most aggressive weed like carpet weed (Kundra and Brar 1990). Other prominent weeds infesting this crop are *Digera arvensis, Digitaria sanguinalis* and *Cyperus rotundus* (Reddy *et al.* 1990). Sowing time of crop may influence the severity of weed infestation besides overall crop performance. Due to problem of labour scarcity and its increasing cost, chemical control of weeds either alone or integrated with manual weeding may prove more cost effective. In past, encouraging results have been obtained with herbicides like butachlor, oxyfluorfen, bentagran, thiobencarb, oxadiazon, pendimethalin and fluchloralin, (Kundra and Brar 1990, Mishra *et al.* 1990, Nagaraju and Kumar 2009, Singh *et al.* 2010). In the present study, efforts have been made to find out the effect of sowing time and different weed control measures on the performance of pigeonpea.

MATERIALS AND METHODS

To study the effect of sowing time and different weed control treatments on the performance of pigeonpea (*Cajanus cajan* L.), a field experiment was conducted during *Kharif* seasons of 2006 and 2007 at Research Farm of Department of Agronomy, CCS Haryana Agricultural University, Hisar. The soil of the experimental field was sandy loam in texture, low in available N (182.7 kg/ha), medium in available P_2O_5 (14.3 kg/ha) and high in K_2O (416.7 kg/ha) with slightly alkaline in reaction (pH 8.2). The experiment consisting four date of sowing (10th May, 25th May, 10th June and 25th June) in the main plots and five weed control treatments (weedy, weed free, pendimethalin 1.0 kg/ha as PE *fb* 1 HW at 60 days after seeding (DAS), trifluralin 1.0 kg/ha as PPI *fb* 1 hand weeding (HW) at 60 DAS and 2 HW at 30 and 60 DAS in the sub-plots was laid out in split plot design with three replications. Pigeonpea variety "*Manak*" was sown with a row to row spacing of 45 cm using a seed rate of 15 kg/ha (as per recommended package of practices for the state). The variety "*Manak*", also known as '*H77-216*', is of medium statured which mature in 120-130 days and it can fit into late sown conditions (even up to 1st fortnight of July). The plot size was 10.0 x 3.6 m accommodating 8 rows per plot. Herbicides were applied by a knapsack sprayer fitted with a flat fan nozzle with a volume rate of 500 liter/ha. The crop was raised with all other recommended package of practices for the state. Density and biomass of the total weeds were recorded at 30, 60 and 90 DAS dur-

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ing both the years. Yield and yield attributes were also recorded at harvest. Original data were analyzed by the method of analysis of variance (ANOVA) as described by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Effect on weeds

Density and biomass of weeds increased significantly with corresponding delay in each date of sowing (Table 1). The infestation of weeds was lowest when crop was sown on 10th May and was maximum when sown on 25th June during both the years. Early sown crop due to better growth and canopy cover suppressed weeds more effectively than late sown crop. Weed density during both the years was more at 30 DAS and it reduced with the advancement of crop stage at each sowing date, however, dry weight accumulation by weeds increased with corresponding increase in growth stage of crop from 30 to 90 DAS. Weed infestation as referred in terms of total weed density and biomass was maximum under untreated check and it was significantly reduced due to all weed control treatments (Table 1). Pendimethalin 1.0 kg/ha and trifluralin 1.0 kg/ha (60 DAS) were better than HW up to 60 DAS. However, these treatments were statistically at par at 90 DAS in terms of influencing density and biomass of weeds. During both the years, trifluralin 1.0 kg/ha *fb* HW clearly had an edge over pendimethalin 1.0 kg/ha *fb* HW up to 60 DAS up to 60 DAS. Trifluralin 1.0 kg/ha *fb* HW reduced the biomass of weeds to the extent of 83 and 94% at 30 and 90 DAS, respectively. Chauhan *et al.* (1995) have also reported satisfactory control of weeds in pigeonpea due to trifluralin 1.0 kg/ha (PPI) and pendimethalin 1.0 kg/ha (PE) each *fb* 1 HW at 60 DAS.

Effect on crop

Yield and yield attributes of pigeonpea being at par at first two date of sowing (10th May and 25th May) were superior to delayed two date of sowing (10th June and 25th June) during both the years (Table 2). It indicated that optimum sowing time for sowing of pigeonpea would be 10 - 25th May. Early sowing provided better vigor to crop and it also encountered less weed competition consequently resulting into higher productivity. Yield and yield attributes were lowest under weedy check and highest under weed free check (Table 2). Pendimethalin 1.0 kg/ha and trifluralin 1.0 kg/ha each *fb* HW at 60 DAS and HW (30 and 60 DAS) being at par were statistically similar to weed free check in terms of plant height and test weight during both the years. However, pendimethalin 1.0 kg/ha *fb* HW had lower plant height during 2007 and test weight during 2006 compared to weed free check. Trifluralin 1.0 kg/ha being at par with HW had an edge over pendimethalin 1.0 kg/ha in respect of yield attributes and ultimately yield of pigeonpea. These results were in conformity with earlier reports

Table 1. Effect of treatments on the population and dry weight of weeds in pigeonpea

Treatment	Time of application	Weed density (no./m²)						Biomass of weeds (g/m²)					
		30 DAS		60 DAS		90 DAS		30 DAS		60 DAS		90 DAS	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Date of sowing													
10 May	-	30.5	38.0	26.1	31.8	25.0	28.7	30.1	38.7	26.9	72.3	71.1	83.9
25 May	-	32.4	41.5	29.1	33.7	25.9	29.4	32.6	43.4	61.4	71.9	81.3	93.6
10 June	-	40.7	48.1	32.6	37.0	27.3	31.3	43.0	49.7	77.3	85.7	90.2	106.3
25 June	-	52.9	59.9	35.1	38.9	28.7	32.2	59.0	60.0	81.2	95.5	100.3	112.2
LSD (P= 0.05)		1.9	1.4	1.8	1.5	1.8	1.6	4.2	2.4	4.9	3.1	3.7	1.3
Weed control													
Pendimethalin 1 kg/ha + 1 HW	PE *fb* 60 DAS	17.3	19.9	24.3	27.9	8.1	8.8	17.0	22.7	67.8	93.2	20.3	25.2
Trifluralin 1 kg/ha + 1 HW	PPI *fb* 60 DAS	13.4	14.7	21.5	24.5	7.7	9.2	13.0	17.3	44.2	77.3	19.8	23.8
Two HW	PPI *fb* 30 and 60 DAS	82.4	99.7	7.6	7.7	7.5	8.8	90.2	100.1	104.8	34.9	19.8	25.0
Weedy	-	82.6	100.0	100.3	116.6	110.2	125.2	85.8	99.5	91.8	201.4	368.8	420.9
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
LSD (P= 0.05)		2.8	0.9	1.4	0.7	2.0	1.4	3.4	2.0	4.7	3.5	4.5	3.9

PE: Pre-emergence, PPI: Pre-plant incorporation, HW = hand weeding

Table 2. Yield and yield attributes of pigeonpea as influenced by date of sowing and weed control treatments

Treatment	Time of application	Plant height (cm)		Pods/plant (no.)		Seeds/plant (no.)		Test weight (g)		Grain yield (t/ha)	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Date of sowing											
10 May	-	180.2	181.0	189.3	180.8	3.97	3.94	101.7	100.7	1.62	1.70
25 May	-	179.8	179.7	187.4	179.1	3.94	3.94	101.0	100.2	1.60	1.68
10 June	-	177.1	175.6	181.2	163.5	3.88	3.95	97.7	98.2	1.51	1.29
25June	-	173.6	169.9	163.9	143.5	3.85	3.77	96.4	94.1	1.27	1.01
LSD (P=0.05)		2.2	2.3	3.6	4.0	0.05	0.04	0.9	2.1	0.08	0.08
Weed control											
Pendimethalin 1.0 kg/ha + 1 HW	PE *fb* 60 DAS	181.2	179.4	190.0	177.0	4.10	4.06	100.1	99.5	1.57	1.49
Trifluralin 1.0 kg/ha+ 1 HW	PPI *fb* 60 DAS	181.2	179.6	193.0	179.7	4.11	4.11	100.7	100.3	1.63	1.59
Two HW	PPI *fb*30 and 60	182.0	180.9	205.0	184.2	4.12	4.11	101.6	100.8	1.69	1.63
Weedy	-	161.2	161.2	112.3	103.2	3.07	3.04	91.5	89.0	0.89	0.67
Weed free	-	182.9	181.6	205.2	189.5	4.15	4.16	102.2	101.7	1.71	1.71
LSD (P=0.05)		2.7	2.0	3.0	4.0	0.03	0.04	1.4	2.3	0.11	0.09

PE= Pre-emergence, PPI= Pre-plant incorporation, HW = hand weeding

(Chauhan *et al.* 1995). Weeds allowed to grow throughout the crop season resulted in 47.8 and 60.8% reduction in grain yield of pigeonpea during 2006 and 2007, respectively (Table 2). Padmaja *et al.* (2013) also reported that uncontrolled weeds led to 79% loss in the seed yield of pigeonpea.

Based on the two year data, it was concluded that sowing time between 10 to 25th May and integrated use of trifluralin 1.0 kg/ha as pre-plant incorporation followed by one hand weeding at 60 days after sowing would be appropriate to achieve higher yield of pigeonpea with significantly lower density and dry weight of weeds.

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Promising early post-emergence herbicides for effective weed management in soybean

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ABSTRACT

A field experiment was conducted during *Kharif* season of years 2011 and 2012 at Norman E. Borlaug crop research centre of Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (U.S. Nagar), Uttarakhand. Fluazifop-p-butyl + fomesafen controlled grasses and non-grassy weeds effectively and recorded 29.3 weeds/m^2 in 500 g/ha against (171.17/m^2) in untreated check. However, the grain yield was highest (2.21 t/ha) in the treatment of weed free followed by fluazifop-p-butyl + fomesafen applied 313 g/ha as post-emergence (2-5 leaf stage of weeds). Biomass of weeds was also lowest in fluazifop-p-butyl + fomesafen 313 g/ha treated plots. However, total weed density was lowest in fluazifop-p-butyl + fomesafen 500 g/ha treated plot but this dose showed toxic effects on crop. Weed index was lowest (7.8%) in the treatment of fluazifop-p-butyl + fomesafen 313 g/ha and highest in untreated (63.5%).

Key words: Chemical control, Fluazifop-p-butyl + fomesafen, Soybean, Weed management

Soybean (*Glycine max* L. Merril) grown in *Kharif* season is heavily infested with weeds due to high moisture and temperature. Yield reduction due to uncontrolled weeds in soybean has been recorded to the tune of 30-80% depending upon type of weeds and duration of infestation, besides yield losses. Depletion of 26-65 kg N/ha, 3-11 kg P_2O_5 and 45-102 kg K_2O was also reported by Yaduraju (2002). Tewari and Trivedi (1985) suggested that soybean yield can be enhanced by almost 50% by adopting timely chemical weeding. Some weed species escape with the application of pre-emergence or pre-plant incorporated herbicides by one way or another. Malik *et al. (*2006) suggested that sequential application of herbicides may provide more consistent weed control than single application. Many times due to continuous rains, application of pre-emergence application of herbicides is not feasible. Keeping the facts in mind, an experiment was conducted to assess the efficacy of fluazifop-p-butyl + fomesafen (125 g +125 g) (Fusiflex 25% SL) (early post emergence applied at 2-5 leaf stage of weeds) in managing weeds in soybean.

MATERIALS AND METHODS

A field experiment was conducted at Norman E. Borlaug crop research centre of Govind Ballabh Pant University of Agriculture & Technology, Pantnagar (U.S. Nagar), Uttarakhand, India during *Kharif* season of 2011 and 2012. Pantnagar lies in the Tarai region to the South of foot hills of the Shivalik Himalayas at 29^{0}N latitude and 79.3^{0}E longitudeand at an altitude of 243.83 m above mean sea level. Fluazifop-p-butyl + fomesafen (25% SL) is a combination of flauzifop-p-butyl and fomesafen in which flauzifop-p-butyl control grassy and fomesafen control non-grasses in pulses particularly in soybean. Ten treatments, *viz*. control, fluazifop-p-butyl + fomesafen 200, 250, 313 and 500 g/ha, flauzifop-p-butyl 125 g/ha, fomesafen 250 g/ha, emazathapyr 100 g/ha, chlorimuron-ethyl 9.0 g/ha and weed free were replicated thrice in a randomized block design. Soybean seed (60 kg/ha) of variety '*PS-1042*' was sown on 8 July, 2011 and 10 July, 2012 at 45 cm row to row distance. Crop was nourished with 100 kg DAP/ha and was applied at the time of sowing as basal. Data on weeds (weed density, weed biomass) were transformed as log Crop was harvested on 5 November, 2011 and 10 November, 2012. All the herbicides were applied as post-emergence at 20-25 days after sowing of crop (2-5 leaf stage of weeds). Total rainfall received during crop season was 1799 mm during 2011 and 885.6 mm during 2012. Experimental soil was silty, rich inorganic carbon (1.05%) and medium in available P_2O_5 (49.0 kg/ha) and K_2O (240.4 kg/ha) with neutral reaction pH (7.3).

RESULTS AND DISCUSSION

Major weed species in soybean field were *Echinochloa colona* (36.2% during 2011 and 36.0% during 2012), *Eleusine indica* (76.6% during 2011 and 31.6% during 2012), *Dactyloctenium aegyptium* (16.8% during 2011 and 12.9% during 2012), *Digiteria*

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sanguinalis (19.5% during 2011 and 19.4% during 2012) among grasses. Among non-grasses, *Trianthma monogyna* (54.0% during 2011 and 47.0% during 2012), *Commelina benghalensis* (28.7% during 2011 and 25.8% during 2012) *Phyllanthus niruri* (17.4% in 2011 and 24.1 in 2012) were pre-dominant species before spraying. *Cyperus rotundus* (14.0% in 2011 and (15.0% in 2012) was the only sedges (Table 1).

Grasses were controlled effectively by fluazifop-p-butyl + fomesafen 313 g/ha (applied at 2-5 leaf stage of weeds). Fomesafen 250 g/ha and chlorimuron-ethyl 9.0 g/ha were effective control against broad-leaved weeds. Grasses were recorded in higher weedy (untreated plot) which was significantly higher over rest of the treatments except flauzifop-p-butyl applied 125 g/ha, fomesafen 250 g/ha and chlorimuron-ethyl 9.0 g/ha. Balyan *et al.* (2003) also reported that grassy weeds could not be controlled by fomesafen. Higher density (53.0 m^2) of non-grasses was recorded in weedy check which was significantly higher over rest of the treatments except chlorimuron-ethyl and fomesafen. *Cyperus rotundus* was controlled effectively by fluazifop-p-butyl + fomesafen 250 g/ha, 313 g/ha, 500 g/ha and chlorimuron-ethyl. Lowest weed density was recorded in the treatment of fluazilop-p-butil + fomesafen 313 g/ha.

Among grasses, all the grassy, weeds were controlled effectively by fluazifop-p-butyl + fomesafen. However, the rate of control was differential in different rates of application. Lowest density of *Echinichloa colona, Elusine indica, Dectyloctenium aegypticum* and *Digiteria sanguinalis* were controlled effectively at 500 g/ha treated plots. These grasses could not be controlled by fomesafen (250 g/ha), chlorimuron-ethyl (9.0 g/ha). Grasses were also controlled by imazathapyr (10% SL) applied 100 g/ha during both the years. Non-grasses, *viz. Commelina benghalensis, Trienthma monogyna* and *Phyllanthus niruri* were controlled completely in the fluazifop-p-butyl + fomesafen applied 500 g/ha during both the years. *Commelina benghalensis* was recorded highest in untreated plots which was significantly higher over rest of the treatments except flauzifop-p-butyl 125 g/ha during both the years. Weed biomass (g/m^2) at 60 days stage was highest in weedy check which was found significantly higher over rest of the treatments except fluazifop-p-butyl + fomesafen 200g/ha and chlorimuron-ethyl (Table 2). Biomass of weeds was reduced with the increase in rate of application of fluazifop-p-butyl + fomesafen 200 to 500 g/ha. Lowest weed biomass was recorded in the treatment of fluazifop-p-butyl + fomesafen 500 g/ha which was significantly lower over rest of the treatments. Among all the treatments, weed control efficiency was recorded highest in fluazifop-p-butyl + fomesafen 500 g/ha treated plots during both the years.

Lowest grain yield was recorded in untreated plots which were significantly lower than rest of the treatments during both the years. Highest grain yield was recorded in weed free plots which was significantly higher over rest of the treatments except the treatment of fluazifop-p-butyl+ fomesafen 313 g/ha during both the years. Reduction in grain yield due to uncontrolled weeds was recorded 61.82% during 2011 and 61.78% during 2012. The grain yield of soybean was increased as the rate of application of fluazifop-p-butyl + fomesafen was increased 200 g/ha to 313 g/ha and reduction in yield was recorded at 500 g/ha

Table 1. Weed density and biomass of weeds as influenced by fluazifop-p-butyl + fomesafen in soybean (average of two years)

Treatment	Total weed density at 60 DAS (no./m^2)				Weed biomass at 60 DAS (g/m^2)
	Grasses	Non-grasses	Sedges	Total	
Fluazifop-p-butyl+ fomesafen 200 g/ha	3.6(37.3)	3.3(26.7)	2.9(18.3)	3.4(100.4)	5.3(200.9)
Fluazifop-p-butyl+ fomesafen 250 g/ha	3.2(43.0)	2.4(10.7)	2.7(14.7)	3.1(66.7)	4.9(162.0)
Fluazifop-p-butyl+ fomesafen 313 g/ha	2.8(15.7)	1.7(5.0)	2.5(11.3)	2.8(49.7)	4.7(136.4)
Fluazifop-p-butyl+ fomesafen 500 g/ha	3.4(24.3)	3.3(28.0)	2.9(17.2)	2.2(29.3)	5.0(132.0)
Fluazifop-p-butyl 125 g/ha	3.7(43.0)	3.3(27.3)	2.8(17.0)	3.3(80.3)	5.1(166.5)
Fomesafen 250 g/ha	3.8(44.3)	3.5(34.7)	3.0(20.0)	3.5(105.0)	5.2(189.4)
Imazathapyr 100 g/ha	3.4(31.7)	3.1(23.3)	2.9(17.0)	3.2(78.0)	5.1(172.7)
Chlorimuron-ethyl 9.0 g/ha	4.0(58.3)	3.8(43.0)	3.2(25.0)	3.7(133.7)	5.3(219.9)
Weed free	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Untreated	4.3(76.0)	3.98(53.0)	3.2(25.3)	4.0(171.7)	5.6(274.8)
LSD (P=0.05)	0.6	0.6	0.4	0.3	0.3

Original data has been shown in parentheses; Data on weeds was transformed in log

Table 2. Yield and yield attributes influenced by various treatments (average of two years)

Treatment	No. of pods/ plant	No. of seeds/ pod	1000-seed weight	Seed yield (t/ha)	Weed index (%)	Oil content (%)	Protein content (%)
Fluazifop-p-butyl+ fomesafen 200 g/ha	60.2	2.4	121.9	1.63	26.1	20.10	39.46
Fluazifop-p-butyl+ fomesafen 250 g/ha	69.4	2.4	122.7	1.86	15.8	21.13	40.49
Fluazifop-p-butyl+ fomesafen 313 g/ha	72.9	2.4	123.0	2.03	7.8	21.14	40.72
Fluazifop-p-butyl+ fomesafen 500 g/ha	60.0	2.4	114.6	1.85	16.1	19.83	39.87
Fluazifop-p-butyl 125 g/ha	63.1	2.4	121.1	1.77	19.7	20.13	40.20
Fomesafen 250 g/ha	58.1	2.4	119.9	1.61	27.3	19.20	39.74
Imazathapyr 100 g/ha	68.1	2.4	121.4	1.85	15.9	20.50	39.66
Chlorimuron-ethyl 9.0 g/ha	58.4	2.4	118.9	1.52	31.2	19.63	38.18
Weed free	77.0	2.4	124.0	2.21	0.0	21.26	41.85
Untreated	45.9	2.2	118.0	0.81	63.5	18.26	37.97
LSD (P=0.05)	2.7	NS	3.54	0.18	8.0	0.49	NS

application of fluazifop-p-butil + fomesafen during both the years. The lower yield in fomesafen might be due to non controlling of grasses by this herbicide. Whereas flauzifop-p-butyl controlled grasses effectively which were more in number and biomass of total weeds was also higher in, fluazifop-p-butil + fomesafen treated plots during both the years. Numbers of pods/plant were highest in weed free plots and found significantly higher over rest of the treatments (Table 2). Number of pods/plant were increased as the application rate of fluazilop-p-butil + fomesafen was increased 200 to 313 g/ha, however, highest rate (500 g/ha) the number of pods/plant were reduced. Lowest pods/plant was recorded in weedy check. Though, number of seeds/plant was non-significant, weight of 1000 seeds was also higher in weed free which was significantly higher over rest of the treatments except the treatment chlorimuron-ethyl (9.0 g/ha), fomesafen 250 g/ ha, fluazilop-p-butil + fomesafen 500 g/ha and weedy check. Protein content was also recorded higher in weed free treatment. Oil content was lowest in untreated plots and was increased in the treatment of fluazifop-p-butyl + fomesafen applied at 200 g/ha to 313 g/ha and decreased in higher rate of fluazifop-p-butyl + fomesafen applied (500 g/ha). Highest oil content was recorded in weed free treatment which was found significantly higher over rest of the treatments except fluazifop-p-butyl + fomesafen 313 g/ha. Lowest oil content was recorded in untreated check (Table 2).

It may be concluded that fluazifop-p-butyl + fomesafen 313 g/ha is a broad spectrum herbicide to control weeds in soybean applied as an early post-emergence (2-5 leaf stage of weeds). Flauzifop-p-butyl controlled almost all the grasses whereas fomesafen controlled non-grasses effectively.

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Productivity of sunflower as influenced by tillage and weed management

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ABSTRACT

Field experiments were conducted during *Rabi* and *Kharif* season of 2012 and 2013 at northern block of Cotton Research Station, Veppantattai, Tamilnadu, to study the effect of tillage and weed management methods on weeds dynamics and yield of sunflower under irrigated conditions. The experiments were laid out in strip plot design with three replications. Main plot treatment consisted of three tillage methods, *viz*. conventional tillage, minimum tillage and zero tillage. Five weed management methods, *viz*. pre-emergence application of pendimenthalin 1.0 kg/ha followed by hand weeding on 40 DAS, pre-emergence application of pendimethalin 1.0 kg/ha followed by power weeding on 40 DAS, hand weeding twice on 20 and 40 DAS, power weeding on 20 and 40 DAS along with an unweeded check for both the crops were included in the sub-plot treatments. The sunflower hybrid seed '*Sunbred*' were sown on 60 x 30 cm spacing. The results revealed that conventional tillage combined with pre-emergence herbicide application of pendimethalin 1.0 kg/ha followed by hand weeding on 40 DAS recorded lower weed density, weed biomass and higher yield attributes and yield.

Key words: Productivity, Sunflower, Tillage, Weed management

Sunflower is an important oil seed crop of India, cultivated over an area of about 1.48 million ha with a production of 0.90 million tonnes and with a productivity of 576 kg/ha (Anonymous 2011a). The productivity of sunflower in India is quite low compared to that in other sunflower growing countries. This needs to be stepped up through improved cultivation practices. In Tamil Nadu, sunflower is grown in an area of 14,268 ha with a production of 18,975 tonnes and productivity of 1330 kg/ha (Anonymous 2011b). One of the causes for low yield is the weed growth which competing with the crop for nutrients, water, sunlight and space. Wide row spacing and slow initial growth of sunflower provide enough room for weeds to establish and to take advantage of slower initial growth of the crop. Uncontrolled growth of weeds cause enormous loss of nutrients, which in turn reduces the yield of sunflower up to 64% (Legha *et al*. 1992). Yield loses due to weeds varied from 28 to 93% depending on the type of weed flora and their intensity, stage, nature and duration of crop-weed competition (Sharma and Thakur 1998).

Costs on weed control are the largest variable cost in most crop cultivation. The combination of herbicides with mechanical weeding was effective in controlling major weeds. The herbicide controls weeds in rows whereas mechanical weeding removes weeds between the rows. Hence, a field experiment was conducted to develop information on weed population dynamics sunflower as influenced by tillage and weed management methods under irrigated conditions.

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MATERIALS AND METHODS

Field experiments were conducted during *Rabi* and *Kharif* season of 2012 and 2013 at Cotton Research Station, Veppantattai. The soil of the experimental farm is clay loam in texture. The soil was low in nitrogen, medium in phosphorus and potassium. The experiment was laid out in strip plot design with three replications. Main plot treatment consisted of three tillage methods, *viz.* conventional tillage, minimum tillage and zero tillage. Five weed management methods, *viz.* pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding on 40 days after seeding (DAS), pre-emergence application of pendimethalin 1.0 kg/ha by power weeding on 40 DAS, hand weeding twice on 20 and 40 DAS, power weeding on 20 and 40 DAS along with an unweeded check were included in the sub plot treatments. The sunflower hybrid seed '*Sunbred*' was sown on 60 x 30 cm. Conventional tillage made by one disc ploughing was given as the primary tillage operation followed by two cultivator operation as secondary tillage. One cultivator ploughing and ridger former operation only for minimum tillage. In zero tillage, the seeds were dibbled in the stubbles of the previous crop without any tillage or soil disturbance, except that which is necessary to place the seeds at the desired depth.

Weed management was done as per the treatment. For manual weeding treatments, two hand weeding were given at 20 and 40 DAS. Herbicide treated plots were applied with pendimethalin 1.0 kg/ha as pre-emergence spray on third day after sowing followed by a hand weeding on 40 DAS. For power weeded plots, two weeding were given on 20 and 40 DAS with power weeder in between rows and within the rows, weeds were removed manually.

RESULTS AND DISCUSSION

Weed flora

Weed flora of the experimental field during the cropping period primarily composed of grasses, sedge and broad-leaved weeds. The dominant weed species were *Dinebra retroflexa*, *Cynodon dactylon, Panicum repens*, *Chloris barbata*, *Cyperus rotundus*, *Trianthema portulacastrum*, *Parthenium hysterophorus* and *Digera arvensis* during first and second year of sunflower period, respectively. Dominant occurrence of *Trianthema portulacastrum, Digera arvensis, Parthenium hysterophorus, Cynodon dactylon,* and *Cyperus rotundus* weeds in sunflower on sandy clay loam soils has also been reported by Mynavathi *et al.* (2007).

Effect on weed density and weed biomass

Both tillage and weed management methods significantly influenced the weed density and biomass at 20 and 40 DAS (Table 1). Lower weed density and weed biomass were recorded in conventional tillage while in both the years, higher weed density and weed biomass were recorded in zero tillage due to deposition of weed seeds in the upper layer of the soil. Increase in perennial and some annual weed species due to reduced tillage was also reported by Hume *et al.* (1991).

Lower weed density and weed biomass were observed with pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding on 40 DAS during crop growth period. Application of herbicides at pre-germinated as well as at early establishment of weeds in crop was found to control poaceae weeds and broad-leaved weeds effectively (Khare and Jain 1995). Pre-emergence herbicides gave effective control of weeds by inhibiting the germination of the weed seeds and also killing the emerging weeds at the early stages (Vyas *et al.* 2000). Unweeded control resulted in higher grasses, sedge and broad-leaved weed population due to unchecked and increased weed growth at all the growth stages of crops

Effect on yield attributes and yield

Yield attributes and seed yield was significantly influenced by tillage and weed management methods (Table 2).Treatments received conventional tillage in-

Table 1. Effect of tillage and weed management practices on total weed density and weed biomass in sunflower

Treatment	Total weed density (no./m^2)				Total weed biomass (kg/ha)			
	2012		2013		2012		2013	
	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS	20 DAS	40 DAS
Tillage management								
Conventional tillage	15.6 (246.4)	13.0 (178.6)	8.1 (69.1)	5.0 (29.6)	15.6 (246.4)	13.0 (178.6)	16.0 (261.4)	13.6 (194.2)
Minimum tillage	17.0 (295.4)	14.5 (228.2)	9.5 (92.9)	5.9 (38.4)	17.0 (295.4)	14.5 (228.2)	17.2 (303.2)	14.8 (236.2)
Zero tillage	18.1 (333.4)	15.1 (252.6)	10.4 (111.9)	6.5 (47.3)	18.1 (333.4)	15.1 (252.6)	18.5 (347.6)	15.9 (277.2)
LSD (P=0.05)	0.27	0.34	0.23	0.17	0.27	0.34	0.23	0.45
Weed management								
Pendimethalin (PE) + one hand weeding at 40 DAS	15.7 (251.0)	11.1 (126.0)	7.7 (60.1)	4.0 (16.1)	15.7 (251.0)	11.1 (126.0)	15.8 (254.0)	11.6 (137.3)
Pendimethalin (PE) + one power weeding at 40 DAS	16.2 (265.6)	11.8 (140.6)	8.3 (71.2)	4.6 (21.8)	16.2 (265.6)	11.8 (140.6)	16.5 (265.6)	12.6 (160.6)
Hand weeding twice at 20 and 40 DAS	16.8 (287.3)	12.9 (169.6)	9.0 (83.0)	5.1 (27.0)	16.8 (287.3)	12.9 (169.6)	17.2 (299.3)	13.4 (181.6)
Power weeding at 20 and 40 DAS	17.4 (309.6)	13.8 (192.6)	9.8 (98.3)	5.7 (33.5)	17.4 (309.6)	13.8 (192.6)	17.8 (324.3)	14.4 (211.0)
Control	18.4 (345.0)	21.4 (470.0)	11.9 (143.9)	9.6 (93.6)	18.4 (345.0)	21.4 (470.0)	19.0 (367.0)	21.8 (488.6)
LSD (P=0.05)	0.35	0.58	0.48	0.58	0.35	0.58	0.46	0.82

Figures in parentheses are original values

Table 2. Effect of tillage and weed management practices on yield attributes and yield of sunflower

Treatment	Capituluam diameter (cm)		Capituluam weight(g)		No. of seeds/ capituluam		Seed yield (t/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013
Tillage management								
Conventional tillage	16.0	14.2	53.9	49.5	980.4	905.4	1.62	1.52
Minimum tillage	14.7	12.6	51.0	46.2	839.9	838.2	1.50	1.40
Zero tillage	14.2	12.1	45.3	44.5	772.2	767.1	1.28	1.21
LSD (P=0.05)	1.2	0.2	2.6	2.6	50.4	49.1	0.11	0.11
Weed management								
Pendimethalin (PE) + one hand weeding at 40 DAS	16.5	14.4	55.7	51.3	971.6	907.9	1.64	1.56
Pendimethalin (PE) + one power weeding on 40 DAS	15.7	13.6	52.8	49.0	905.6	870.7	1.54	1.38
Hand weeding twice at 20 and 40 DAS	15.1	12.8	50.3	46.6	860.3	841.0	1.45	1.44
Power weeding at 20 and 40 DAS	14.1	12.4	47.0	44.6	809.7	802.6	1.38	1.30
Control	13.5	11.8	44.3	42.0	774.2	762.2	1.33	1.24
LSD (P=0.05)	0.7	0.7	2.8	2.3	44.7	36.1	0.86	0.78

creased the yield attributes such as diameter and weight of the capitulum and number of seeds per capitulum of sunflower. This might be due to higher weed control efficiency and more amount of nutrient uptake consequently resulting in better related growth attributes. Yield attributes of sunflower were at lower range with zero tillage might be due to lesser weed control efficiency and higher weed density and biomass which might have reduced the nutrient availability and utilization by the crop.

Pre-emergence application of pendimethalin 1.0 kg/ha followed by one hand weeding on 40 DAS resulted in recording bigger capitulum with more seeds per capitulum and test weight of sunflower. This might be due to reduced weed density and biomass of all categories of weeds during critical period of crop weed competition thus resulting in better translocation of assimilates from source to sink during post anthesis period (Sumathi *et al.* 2010). The results are in line with the findings of Balyan (1993) and Jat and Giri (2000) who have obtained higher yield consequently recording higher yield contributing parameters with pre-emergence application of pendimethalin in sunflower due to better weed control efficiencies.

Basavarajappan (1992) reported that manual, mechanical and herbicidal weed control methods increased the capitulum diameter, number of seeds per capitulum compared to weedy check because of reduced competition from weeds. Unweeded control resulted in lower yield attributes due to stiff and continuous weed competition from the germination of crops throughout its growing period. Bedmar *et al.* (1989) and Nayak *et al.* (2000) obtained reduction in seed number per capitulum with unweeded control.

Conventional tillage recorded higher yield due to deep ploughing and pulverization of plough depth of soil layers which favoured the germination of current season weed seeds which were efficiently controlled by integrated weed management methods. The lower seed yield obtained with zero tillage was due to higher weed competition for nutrient, space and light offered by annual and perennial grasses.

Higher seed yield of sunflower obtained with pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding on 40 DAS was due to early application of broad spectrum selective herbicide which controlled the weeds and increased the growth, yield parameters and seed yield of sunflower (Jat and Giri 2000). Unchecked weed growth resulted in more total and dominant weed densities with higher weed biomass, which reduced the seed yield of sunflower drastically.

It was concluded that conventional tillage with disc plough followed by cultivator tillage twice and pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding at 40 DAS can keep the weed density and weed biomass below the economic threshold level and increase the productivity of sunflower under irrigated condition.

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Weed management in onion by pre-planting and post-emergence herbicides for seed production

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ABSTRACT

A field experiment was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India for two consecutive *Rabi* seasons 2011 and 2012 to find out most suitable and efficient combination of different pre-plant and post-emergence herbicides to control weeds in onion seed production crop. Experiment was conducted in randomized block design with 9 treatments and three replications consisting of pre-plant application of pendimethalin, post-emergence application of oxyfluorfen and quizalofop-ethyl and their different combinations. The pre-plant application of pendimethalin 0.750 kg/ha followed by post-emergence application of oxyfluorfen 0.250 kg/ha mixed with quizalofop-ethyl 0.050 kg/ha resulted in effective control of various broad-leaf and grassy-weeds and recorded lower weed density, weed biomass, weed index and higher weed control efficiency. This treatment also produced higher number of umbels per plant, plant dry matter, number of seeds per umbel, seed weight per umbel, 1000 seed weight and longer flowering stalk, and diameter of umbel. It also produced higher seed yield (439.30 kg/ha), gross return (` 329,475/ha), net return (` 192,450/ha) and B:C ratio (2.40) over all the other chemical weed control treatments.

Key words: Chemical control, Onion seed, Pre-emergence, Post-emergence, Weed management

Onion (*Allium cepa* L.) is an important vegetable crop which used in daily diet of people in the whole world. It becomes a major cash crop with higher market demand and price due to its culinary, dietary and medicinal values. In rainfed area, when protective irrigations are available, the onion crop performs better in monsoon season. It can generate more income than other annual or perennial cash crops within the short duration of 20 to 22 weeks when cultivated for seed production. Weed infestation is the important constraint in onion seed production, which causes reduction in bulb and seed yield to the tune of 40 to 80% (Channapagoudar and Biradar 2007). Onion grown for seed production is slow growing, shallow rooted crop with narrow upright leaves and non-branching habit. Due to this type of growing habit, it can not compete well with weeds. In addition to this, frequent irrigation and fertilizer application allows for successive flushes of weeds in onion. The conventional methods of weed control such as hoeing, weeding, *etc*. are laborious and very expensive. More over weeding during critical growth stages is very difficult due to increased cost of human labors and its scarce availability. Use of pre-plant and post-emergence herbicides may prove as the solution for over dependence on labors in onion weed control, but their proper combination, doses and time of application is more important for better results with low cost. Hence, present investigation was conducted to find out best suitable combination of pre-plant and post-emergence herbicides in seed production onion for effective control of weeds with higher seed yield.

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MATERIALS AND METHODS

A field experiment in randomized block design was conducted with 9 treatments and three replications at the Breeder Seed Production Farm of Mahatma Phule Krishi Vidyapeeth, Rahuri during two consecutive *Rabi* seasons (2011 and 2012). The experimental site was located at 19^0 47' N latitudes and 74^0 81' E longitudes. The average rainfall is 520 mm however, 421 mm and 445 mm was received as annual of 2011 and 2012, respectively. No rainfall received during the experimental period of *Rabi* season for both the years. The soil of experimental field was deep with silty clay loam in texture, slightly alkaline pH (8.7), medium in organic carbon (0.59%), available P_2O_5 (19.8 kg/ha), K_2O (277.8 kg/ha) and low in available N (252.5 kg/ha). Bulbs of onion variety *'Baswant- 780'* were planted at first fortnight of December for both the years on ridges and furrow of 60 cm wide with plant spacing of 30 cm with seed rate of 5 tone bulbs/ha. Recommended dose of fertilizers (120 kg N/ha + 60 kg P/ha + 60 kg K/ha) was applied as whole P and K at the time of sowing and N in two split doses as 50 per cent at the time of planting and remaining 50 per cent at 30 days after planting. Treatments consisted of: T_1- pendimethalin 0.750 kg/ha + oxyfluorfen 0.250 kg/ha + quizalofop-ethyl 0.050 kg/ha, T_2- oxyfluorfen 0.250 kg/ha + quizalofop-ethyl 0.050 kg/ha,T_3-pendimethalin 0.750 kg/ha + quizalofop-ethyl 0.050 kg/ha, T_4- pendimethalin 0.750 kg/ha+ oxyfluorfen 0.250 kg/ha, T_5- oxyfluorfen 0.250 kg/ha, T_6- quizalofop 0.050 kg/ha, T_7- pendimethalin 0.750 kg/ha and T_8- weedy check (three hand weeding at 20, 40 and 60 days after planting and one manual uprooting of weeds at 90 days after planting), T_9- weed free check. Crop was infested with blight and anthracnose diseases for both the years which were controlled by alternately spraying of fungicides mancozeb 0.750 kg/ha + carbendezim 0.750 kg/ha, propineb 0.350 kg/ha and tebuconezole 0.200 kg/ha. Three sprayings of insecticides for controlling aphids and thrips were also followed as- first spray of diamethoate 0.150 kg/ha, second spray of acephate 0.600 kg/ha and third spray of imidacloprid 0.040 kg/ha. Regular irrigations were provided to crop generally at 12 to 15 days interval up to 110 days after planting. Regular biometric observations were recorded at specific time intervals by selecting randomly five plants in each treatment. Mature umbels were harvested in three pickings from 125 to 140 days after planting for both the years and yield observations were recorded from net plots. Weed density (no./m^2) and biomass of weeds (g/m^2) were recorded by putting a quadrate of 1 m^2 at two random spots in each plot. Weed control efficiency and weed index was calculated by standard formula.

For economic study, prevailing market prices were used for different outputs and inputs. The trend of observations was same for both the years, hence data were subjected to pooled analysis for interpreting the results.

RESULTS AND DISCUSSION

Effect on weed

The dominant grassy weed species observed in experimental field were *Cynodon dactylon, Dinebra retroflexa, Setaria italica, Digitaria sanguinalis, Echinochloa crusgalli, Cyperus rotundus, Acrachne racemosa* and *Dactyloctenium aegyptium.* The broad-leaved weeds were *Boerhaavia diffusa, Parthenium hysterophorus, Digera arvensis, Alternanthera echinata, Amaranthus viridis, Legascea mollis, Phyllanthus maderaspatensis, Euphorbia* spp. and *Portulaca oleracea*. Different weed parameters in onion seed production crop were significantly affected by application of various pre-plant and post-emergence herbicides (Table 1). Combination of pre-planting application of pendimethalin 0.750 kg/ha with mixed use of oxyfluorfen 0.250 kg/ha and quizalofop-ethyl 0.050 kg/ha as post-emergence recorded lower density of grassy and broad-leaved weeds, weed biomass and weed index and higher weed control efficiency as compared to all the other herbicidal treatments. This might be due to the combined action of pre-planting and post-emergence herbicides used in onion. The primary mode of action of pendimethalin is to inhibit microtubule formation in cells of susceptible monocot and dicot weeds which are an important part of the cell division process. As a result of restricted cell division, growth of the emerging weed seedling is prevented, eventuating in death due to lack of food reserves. Similar results of application of pendimethalin in onion were also reported by Hussain *et al.* (2008). The broad-leaf and grassy-weeds were escaped from action of pendimethalin were controlled up to maximum amount by application of oxyfluorfen and quizalofop-ethyl, respectively at 25 days after planting, when these weeds were at 3-4 leaf stage. Oxyfluorfen disturbs the chlorophyll synthesis pathway of susceptible weeds by inhibiting the enzyme called 'protoporhirinogen oxidase'. It also causes break down the cell membrane of leaf by which weed dies. Ghosheh (2004) has also discussed the effects of post-emergence application of oxyfluorfen for weed control in onion crop. Quizalofop-ethyl inhibit the activity of the acetyl-CoA carboxylase enzyme, which is necessary for fatty acid synthesis in grassy weeds. These effects of quizalofop for controlling weeds in onion are in confirmation with the earlier results reported by Yumnam *et al.* (2009). Highest number of grassy and broad-leaf weeds, weed biomass and weed index and lowest weed control efficiency were observed in control treatment.

Effect on growth and yield

Maximum number of umbels per plant, length of flowering stalk, plant dry matter, number of seeds per umbel, diameter of umbel and seed weight per umbel were recorded in treatment weed free check (Table 2). Considering the chemical treatments, combined application of pre-plant pendimethalin 0.750 kg/ha with post- emergence application of oxyfluorfen 0.250 kg/ha mixed with quizalofop-ethyl 0.050 kg/ha was proved more dominant in respect of these growth and yield attributing characters. However, it was at par with post-emergence mixed application of oxyfluorfen and quizalofop-ethyl in respect of number of umbels per plant. This might be due to the decreased competition of weed with crop for space, water, air, nutrients and sunlight because of their effective control as a result of application of different pre- and post-emergence herbicides. It provides better environment and other resources in sufficient quantity for the proper growth and development of crop. Kalhapure *et al.* (2013) also reported that the application of pendimethalin as pre- emergence and oxyfluorfen as post-emergence was responsible for better growth and development of onion crop due to the weed free environment. The effect of application of different pre- and post-emergence herbicides was found to be non significant in respect of 1000 seed weight of onion. All the growth and yield attributing characters were found lower in control treatment.

Effect on yield and economics

Significantly highest seed yield of onion (573.60 kg/ha), gross returns (` 4,30,200/ha), net returns (` 2,80,350/ha) and B:C ratio (2.87) were recorded in treatment weed free check as compared to all other treatments. Among weedicide treatments, pre-plant application of pendimethalin 0.750 kg/ha along with post-emergence application of oxyfluorfen 0.250 kg/ha mixed with quizalofop-ethyl 0.050 kg/ha produced significantly higher onion seed yield (439.30 kg/ha), gross returns (` 3,29,475/ha), net returns (` 1,92,450/ha) and B:C ratio (2.40) in pooled analysis as compare to all other treatments (Table 3). Lowest seed yield of onion was recorded in control which was 59.03 kg/ha. Kalhapure and Shete (2013) reported the improvement in yield and economical parameters from combined use of pendimethalin as pre plant and oxyfluorfen as post-emergence in onion.

Table 1. Effect of different treatments on various weed parameters in onion at harvest (pooled data of two years)

Treatment	Weed density/m^2 Grassy weeds	Weed density/m^2 Broad-leaved weeds	Weed biomass (g)	Weed control efficiency (%)	Weed index (%)
T_1- Pendimethalin 0.750 kg/ha + oxyfluorfen 0.250 kg/ha+ quizalofop-ethyl 0.050 kg/ha	16.26	8.65	37.74	86.10	23.41
T_2- Oxyfluorfen 0.250 kg/ha+ quizalofop-ethyl 0.050 kg/ha	27.69	12.65	68.52	74.76	36.57
T_3- Pendimethalin 0.750 kg/ha+ quizalofop-ethyl 0.050 kg/ha	19.25	26.15	85.91	68.36	50.32
T_4- Pendimethalin 0.750 kg/ha+ oxyfluorfen 0.250 kg/ha	41.65	16.38	98.34	63.79	50.60
T_5- Oxyfluorfen 0.250 kg/ha	56.61	32.61	131.66	51.52	57.19
T_6- Quizalofop 0.050 kg/ha	28.64	43.98	114.15	57.97	60.37
T_7- Pendimethalin 0.750 kg/ha	72.98	34.63	151.28	44.29	73.41
T_8- Weedy check	97.93	68.27	271.56	00	89.71
T_9- Weed free check	11.65	7.36	19.12	92.96	-
LSD (P=0.05)	3.99	2.17	5.64	-	-

Table 2. Effect of different treatments on various growth and yield attributing characters in onion seed crop (pooled data of two years)

Treatment	Number of umbels per plant at 90 DAP	Length of flowering stalk at 90 DAP (cm)	Plant dry matter at harvest (g)	Number of seeds per umbel at harvest	Diameter of umbel at harvest (cm)	Seed weight per umbel (g)	1000 seed weight (g)
T_1	4.14	79.67	37.59	484.78	7.04	1.91	3.94
T_2	3.68	73.50	33.75	455.24	6.48	1.78	3.91
T_3	3.09	70.63	30.38	442.67	5.96	1.66	3.75
T_4	3.11	68.72	28.77	421.60	5.82	1.64	3.89
T_5	2.78	62.51	25.13	439.22	4.88	1.59	3.62
T_6	2.64	60.44	24.28	417.78	4.64	1.55	3.71
T_7	1.92	54.26	21.90	400.56	4.15	1.43	3.57
T_8	1.25	39.86	16.96	247.82	3.67	0.85	3.43
T_9	4.63	83.39	42.06	553.35	7.52	2.23	4.03
LSD (P=0.05)	0.51	2.72	3.24	12.44	0.42	0.11	NS

(DAP- Days After Planting)

Table 3. Effect of weed control treatments on onion seed yield and economics

Treatment	Seed yield (kg/ha)			Gross returns (x10^3 `/ha)			Net returns (x10^3 `/ha)			Cost of cultivation (x10^3 `/ha)			B:C ratio		
	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Pooled	2011	2012	Mean
T_1	411.4	467.2	439.3	308.5	350.4	329.5	173.0	211.9	192.4	135.5	138.5	137.0	2.28	2.53	2.4
T_2	336.6	391.2	363.9	252.5	293.4	272.9	117.8	155.7	136.8	134.6	137.6	136.1	1.87	2.13	2
T_3	271.5	298.4	285.0	203.6	223.8	213.7	70.1	87.2	78.6	133.6	136.6	135.0	1.52	1.64	1.58
T_4	261.2	305.5	283.3	195.9	229.1	212.5	62.2	92.4	77.3	133.7	136.7	135.2	1.47	1.68	1.57
T_5	224.7	266.5	245.6	168.5	199.8	184.2	35.8	64.1	50.0	132.7	135.7	134.2	1.27	1.47	1.37
T_6	202.4	252.3	227.3	151.8	189.2	170.5	19.0	53.4	36.2	132.8	135.8	134.3	1.14	1.39	1.27
T_7	136.4	168.6	152.5	102.3	126.5	114.4	-28.9	-7.7	-18.3	131.2	134.2	132.7	0.78	0.94	0.86
T_8	51.3	66.7	59.0	38.5	50.0	44.3	-91.8	-83.3	-87.6	130.3	133.3	131.8	0.30	0.38	0.34
T_9	521.4	625.8	573.6	391.1	469.3	430.2	242.7	318.0	280.3	148.3	151.3	149.8	2.64	3.1	2.87
LSD (P=0.05)	24.4	26.6	23.4	14.5	15.7	12.7	10.6	12.6	8.9	6.2	8.2	5.9	-	-	-

Combined application of pre-plant pendimethalin 0.750 kg/ha with post-emergence application of oxyfluorfen 0.250 kg/ha mixed with quizalofop-ethyl 0.050 kg/ha is the best efficient chemical weed management method for controlling important grassy and broad-leaf weeds in seed production onion with higher yield and monetary return.

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Chemical weed management in garlic

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ABSTRACT

A field experiment was conducted to study the influence of various herbicidal treatments on the growth and productivity of garlic (*Allium sativum* L.) during 2012-13 and 2013-14 on sandy loam soils of SKUAST, Chatha. The experiment involved two genotypes of garlic replicated thrice in factorial randomized block design. The weed density, weed dry matter accumulation and weed control efficiency varied significantly with the stage of the crop showing a declining trend, being highest at 60 days after sowing and lowest at the time of harvesting. Significantly lower weed density, weed dry matter accumulation, weed index and relatively higher weed control efficiency were recorded in large segmented cultivar (*SJKG-01*) with weed free plots followed by treatment with pre-emergence application of oxadiargyl 90 g/ha *fb* post-emergence application of quizalofop-ethyl 50 g/ha, at 2-3 leaf stage of weeds. The average bulb weight (26.73 g), bulb diameter (3.96 cm.) and bulb yield (4.83 t/ha) were also more in large segemented than the smaller one (*SJKG-02*). Among herbicidal treatments, the weed free plots in both the cultivars produced plants with more average bulb weight, bulb diameter and bulb yield followed by the plots with pre-emergence application of oxadiargyl *fb* post-emergence application of quizalofop-ethyl, applied at 2-3 leaf stage of the weeds. From economics point of view, the weed free plots resulted in higher cost of cultivation and net returns followed by the treatment combination of oxadiargyl 90 g/ha pre-emergence *fb* quizalofop-ethyl as post-emergence 50 g/ha applied at 2-3 leaf stage of weeds yielding a B: C ratio of 5.70 in small segmented and 6.73 in large segmented garlic respectively.

Key words: Chemical control, Garlic, Herbicides, Quizalofop-ethyl, Weed management

Garlic (*Allium sativum* L.) belonging to family amaryllidaceae, is the second most widely cultivated crop in the family after onion. It consists of an underground bulb and above ground vegetative part, which also comprises of a flat as well as slender leaves. It has fibrous root system and is frost hardy. India is second largest producer of garlic in the world next to China. Madhya Pradesh is front runner in its production followed by Gujrat. Jammu & Kashmir occupied an area of 0.28 thousand hectare with a production of 0.30 thousand MT (Anonymous, 2011). In Jammu division, it is a prominent crop of the districts of Poonch, Kathua, Udhampur, Reasi and Doda. But its productivity in the state is quite less as compared to the national average due to a number of factors but the main limiting factor is the weed infestation that competes for nutrients, soil, moisture, space and light considerably reducing the yield, quality and value through increased production and harvesting costs (Hussain 1983). The garlic is closely planted crop with very small canopy. Due to smaller leaf size it can not compete with the weeds. Their competition with the plants starts at very early growth stage because immediately after planting the cloves, the weed emergence occurs that competes with the tender seedlings. Under Jammu and Kashmir conditions, weeds are mostly managed manually, which is tedious and expensive operation and often damages the crop,

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Sometimes due to shortage of labour and unexpected rains, hand weeding and mechanical operations are more often either delayed or all left together. In such situations, the herbicidal weed management practices becomes much more important. Therefore, the studies were conducted to test old and new herbicides used either alone or in combination at different times to provide good results of weed control, and garlic yield.

MATERIALS AND METHODS

Field experiment was conducted during *Rabi* 2012-13 and 2013-14 at Chatha, Jammu (32-40^0 N latitude, 74-53^0 E longitude and 300 m. above mean sea level). The soil of the experimental site was silty loam in texture, slightly alkaline in reaction (pH 7.72), medium in available N (240 kg/ha) and P_2O_5 (12.1 kg/ha) and low in available K_2O (134 kg/ha). Twelve treatments comprised of pre-plant, pre-emergence (2 DAS) and post- emergence (30 DAS) application of oxyflourofen 0.15 kg/ha, pre-emergence application of pendimethalin 1.0 kg/ha, alachlor 1.5 kg/ha and butachlor 1.0 kg/ha, early-post (10 DAS) application of oxadiargyl 120 g/ha, pre-emergence application of oxadiargyl 90 g/ha *fb* post-emergence (2-3 leaf stage of weeds) application of ouizalofop-ethyl 50 g/ha, pre-emergence application of pendimethalin 0.75 kg/ha *fb* post-emergence application quizalofop-ethyl 50 g/ha, two hand weedings (40 and 60 DAS), weedy check and weed free, respectively.

A basal dose of farm yard manures 20 t/ha was incorporated in the soil at the time of field preparation. In addition to this 100 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare were applied through urea, single super phosphate and muriate of potash, respectively. The full dose of phosphorus, potash and 1/3 of nitrogen was applied at the time of sowing and the remaining nitrogen was applied 40 and 60 days after planting. Both large segmented (*SJKG-1*) and small segmented (*SJKG-2*) were dibbled at a spacing of 15 x 10 cm and 5-7.5 cm deep using a seed rate of 600 kg/ha. The herbicides were sprayed to each treatment plot using knapsack sprayer with a spray volume of 600 L water/ha. Rest of the management practices were in accordance with the recommended package of practices.

The survey of weed flora of the experimental plot was done at 60 days after planting and at the time of harvesting. For recording the observations, five plants were randomly selected in each plot and tagged. The observations were recorded from time to time. The data obtained on various parameters were analyzed as per fisher's method (Cochran and Cox 1957). The treatment differences were tested for significance by 'F' test for the data in which the treatment effects were significant, the appropriate standard error of mean and critical differences were worked out at 5% level of significance.

RESULTS AND DISCUSSION

Weed flora

Garlic crop was infested with a large number of weeds owing to longer duration, slow initial growth, non tillering/branching habit and sparce canopy development besides frequent irrigation and high fertilizer application. Prominent weed species recorded were *Chenopodium album*, *Chenopodium murale*, *Amaranthus viridis*, *Anagallis arvensis*, *Convolvulus arvensis*, *Parthenium hysterophorus*, *Spergula arvensis*, *Digera arvensis*, *Cyprus rotundus*, *Euphorbia hirta* and *Cynodon dactylon*. The pooled data of two years indicated that both the varieties varied significantly for the weed density, recorded a 60 DAS and at harvest. Large segmented cultivar (*SJKG-1*) possessed less weed density (51.36 and 46.44/m^2) than the smaller one (53.06 and 48.06) during both the years under study (Table 1). Wider leaf blade and drooping habit of *SJKG-1* might havesuppressed the weed infestation during whole crop cycle.

In both cultivars, weed free plots possessed no weed density followed by treatment plots with pre-emergence application of oxadiargyl 90 g/ha+ post-emergence application of quizalofop-ethyl 50 g/ha. The treatments oxyflurofen 0.15 kg/ha (PE) was statistically at par with oxyflurofen 0.15 kg/ha (pre-plant) and pendimethalin 1.0 kg/ha (PE) recorded 60 DAS. Weed dry matter accumulation was least in weed free plots followed by treatment plots with pre-emergence application of oxadiargyl 90 g/ha + post-emergence application of quizalofop-ethyl 50 g/ha recorded at 60 DAS and at harvesting, during both the years. However, dry matter accumulation 60 DAS in treatment with post emergence application of oxyflurofen, early post application of oxadiargyl and two hand weeding at 40 and 60 DAS was at par (Table 1). Weed control efficiency denotes the magnitude of increase in yield due to weed control. Both cultivars (*SJKG-1* and *SJKG-2*) varied in terms of weed control efficiency both at 60 DAS and at harvesting.

Larger segmented yielded more WCE (66.16% and 59.28%) than the smaller one (64.25% and 58.65%). The weed free plots with 100% WCE were followed by plots having treatment with pre-emergence application of oxadiargyl 90 g/ha + post-emergence application of quizalofop-ethyl 50 g/ha and plots receiving 2 hand weedings (40 and 60 DAS). Lowest WCE was recorded in weedy check plots. Both types of garlic responded variably towards the weed index, during both the years (Table 2). Large segmented recorded significantly lower weed index (27.14) then the smaller one (30.44). Herbicides were also significant in influencing the weed index and lower weed index (9.83%) was recorded with pre-emergence application of oxadiargyl 90 g/ha + post-emergence application of quizalofop-ethyl 50 g/ha applied at 2-3 leaf stage of weeds followed by two hand weedings (40 and 60 DAS). Treatments comprising of pre-emergence and post–emergence application of oxyflurofen 0.15 kg/ha were at par to each other during both the years. This parameter was maximum in weedy check plots due to prominent weed-crop competition, suppression of crop plants by the emerging weeds and more utilization of nutrients and moisture by the weed canopy. Similarly, maximum weed index was recorded by Rahman *et al.* (2012) in garlic, Hussain *et al.* (2008) and Patel *et al.* (2011) in onion. The chemical weed control in garlic is a better practice supplemented to

Table 1. Effect of herbicidal treatments on weed density, weed dry matter accumulation and weed control efficiency (pooled data of two years)

Treatment	Weed density (no./m^2)				Weed dry matter accumulation (%)				WCE (%)			
	60 DAS		At harvest		60 DAS		At harvest		60 DAS		At harvesting	
	SJKG-1	*SJKG-2*	*SJKG-1*	*SJKG-2*	*SJKG-1*	*SJKG-2*	*SJKG-1*	*SJKG-2*	*SJKG-1*	*SJKG-2*	*SJKG-1*	*SJKG-2*
Oxyflurofen 0.15 kg/ha PP	50.0	53.0	42.0	47.0	69.7	82.6	30.7	34.1	73.3	75.0	66.7	64.8
Oxyflurofen 0.15kg/ha PE (2 DAS)	41.7	59.0	33.7	53.0	75.5	80.3	42.5	35.4	66.9	66.2	54.8	56.5
Oxyflurofen 0.15kg/ha POE (30 DAS)	38.0	39.7	30.0	31.7	52.5	74.8	28.4	31.5	68.0	67.3	56.2	60.1
Pendimethalin 1.0 kg/ha PE	54.0	50.3	46.0	44.3	71.6	80.5	34.7	37.9	54.4	53.7	55.6	53.6
Alachlor 1.5kg/ha PE	51.0	78.0	47.0	74.0	78.4	84.0	41.3	39.4	52.6	48.3	45.9	49.7
Butachlor 1.0 kg/ha PE	68.0	75.0	64.0	71.0	73.0	82.2	30.1	36.7	48.6	40.8	43.1	46.9
Oxadiargyl 120g/ha E- Post (10 DAS)	65.0	58.0	54.0	50.0	69.6	75.3	28.2	30.6	79.6	78.0	71.5	68.8
Oxadiargyl 90 g/ha PE *fb* quizalofop-ethyl 50 g/ha POE	34.3	31.0	28.3	25.0	39.3	59.3	25.5	27.0	87.6	88.7	76.6	73.9
Pendimethalin 0.75kg/ha PE *fb* quizalofop-ethyl 50 g/ha POE	69.7	64.0	63.7	56.0	47.0	67.2	32.8	35.1	68.1	68.5	67.4	60.1
Two HW 40 and 60 DAS	59.7	53.3	53.7	45.3	50.6	76.9	26.2	29.7	83.8	84.4	73.5	69.1
Weedy check	85.0	75.3	90.0	79.3	85.6	84.6	53.7	49.7	0.00	0.0	0.00	0.0
Weed free	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	100.0	100.0	100.0
Pooled Mean	51.4	53.1	46.4	48.1	59.4	70.6	31.2	32.3	66.2	64.2	59.3	58.6
LSD (P=0.05) Varietie	1.24		1.24		5.15		0.88		0.49		0.52	
Herbicide	3.03		3.03		12.61		2.15		1.19		1.28	
Varieties x herbicide	4.30		4.29		17.83		3.04		1.69		1.81	

Table 2. Effect of herbicidal treatments on weed index, average bulb weight, bulb diameter, bulb yield/plot and total bulb yield (pooled data for two years)

Treatment	Weed index		Avg. Bulb weight (g)		Bulb diameter (cm)		Bulb yield/plot (g)		Total bulb yield (t/ha)	
	SJKG-1	*SJKG-2*	*SJKG-1*	*SJKG-2*	*SJKG-1*	*SJKG-2*	*SJKG-1*	*SJKG-2*	*SJKG-1*	*SJKG-2*
Oxyflurofen 0.15 kg/ha PP	23.9	28.3	25.9	21.8	4.01	3.42	2269.6	1911.3	5.04	4.25
Oxyflurofen 0.15kg/ha PE (2 DAS)	38.5	40.7	20.3	21.7	3.75	3.27	1852.3	1580.9	4.12	3.51
Oxyflurofen 0.15kg/ha POE (30 DAS)	37.3	42.1	26.4	18.1	3.86	3.78	1869.0	1542.5	4.15	3.43
Pendimethalin 1.0 kg/ha PE	28.5	34.6	22.9	20.5	3.60	3.31	2130.2	1744.9	4.73	3.88
Alachlor 1.5kg/ha PE	42.6	44.9	24.8	16.7	3.69	3.44	1711.0	1468.4	3.80	3.26
Butachlor 1.0 kg/ha PE	41.2	46.5	28.5	17.1	3.80	3.48	1752.0	1426.2	3.89	3.17
Oxadiargyl 120g/ha E- Post (10 DAS)	22.0	24.6	31.6	22.3	4.02	3.64	2324.5	2010.2	5.17	4.47
Oxadiargyl 90 g/ha PE *fb* quizalofop-ethyl 50 g/ha POE	8.4	11.2	31.7	26.0	4.41	3.87	2729.4	2367.7	6.06	5.26
Pendimethalin 0.75kg/ha PE *fb* quizalofop-ethyl 50 g/ha POE	15.2	18.8	30.1	24.2	4.09	3.29	2526.7	2165.1	5.61	4.81
Two HW 40 and 60 DAS	12.4	14.5	29.4	25.0	4.29	3.70	2611.4	2279.0	5.80	5.06
Weedy check	55.5	58.7	15.0	13.9	3.29	3.05	1326.4	1100.7	2.95	2.45
Weed free	0.0	0.0	33.7	28.4	4.75	3.98	2981.2	2667.1	6.62	5.93
Pooled Mean	27.1	30.4	26.7	21.3	3.96	3.49	2173.2	1855.3	4.83	4.12
LSD (P=0.05) Varieties:	0.4	0.1	1.1	0.4	0.07	0.02	11.9	4.2	0.03	0.009
Herbicides:	1.0	0.4	2.9	1.0	0.17	0.06	29.3	10.3	0.06	0.023
Varieties x Herbicides:	1.5	0.5	4.1	1.4	0.23	0.08	41.5	14.5	0.092	0.032

PP= pre plant, PE= pre-emergence, POE=post-emergence conventional methods and forms an integral part of the modern crop production practices in this crop. The use of herbicides is one of the options left with the farmers to eliminate crop weed competition at the early growth stages of the crop.

The oxadiargyl acts as contact herbicide whereas the quizalofop-ethyl functions systemically, get translocated into the plant system thus restricting the weed growth and yielding significant weed control efficiency after weed free treatment. The interaction between the varieties also showed similar trend owing to less weed-crop competition, more clean cropped area and interfering with the metabolic pathways of the weeds. The results were in conformity with the findings of Channappagouder and Biradar (2007). Moreover, Ramani and Khanpare (2010), Ramalingam *et al.* (2013) advocated that these herbicides had no residual effects on the succeeding crops of groundnut, green gram and pearl millet.

Yield studies

Both the cultivars (*'SJKG-1'* and *'SJKG-2'*) varied significantly for the yield attributes, *viz.* average bulb weight, bulb diameter, bulb yield per plot and total bulb yield as evident from the pooled data recorded in two years. (Table 2). All these attributes were significantly higher in large segmented (*'SJKG-1'*) than the smaller one (*'SJKG-2'*). Higher bulb weight (26.73 g), bulb diameter (3.96 cm.), bulb yield per plot (2173.21 g) and total bulb yield (4.83 t/ha) in larger segmented cultivar as compared to smaller one (21.34 g, 3.49 cm., 1855.37 g and 4.12 t/ha) owes to more surface area of the leaves and spreading habit that resulted in more absorption of sunlight and more dry matter accumulation and ultimately the total yield. Tindal (1986) also emphasized the importance of capture of space and sunlight for better foliage development leading to more total yields. The herbicidal treatments also significantly influenced these yield parameters being more recorded in weed free plots followed by pre-emergence application of oxadiargyl 90 g/ha *fb* post-emergence application of quizalofop-ethyl 50 g/ha and minimum being recorded in weedy check (Table 2). More yields in weed free plots seems to be due to favourable environment created by clean crop culture resulting in more absorption of solar radiation and plant nutrients resulting in more photosynthetic rates and more dry matter accumulation in the cloves following the cultural practices in weed free plots . The positive herbicidal effects of oxadiargyl and quizalofop-ethyl were disruption of cell division and ionic balance ultimately leading to death of weeds thus created favourable conditions for better crop growth and yield. The weedy check recorded minimum yield attributes owing to low chlorophyll content and photosynthetic rates due to unchecked weed growth thereby reducing the availability of moisture, light and nutrients to the crop and resulted in loss of yield in unweeded control (Channappagouder and Biradar 2007).

Economic studies

Significantly higher gross returns (` 3,64,369) and net returns (` 3,00,436) was realized in large segmented garlic with weed free plots (Table 3), followed by pre-emergence application of oxadiargyl 90 g/ha *fb* post-emergence application of quizalofop-ethyl 50 g/ha applied at 2-3 leaf stage of weeds. This was due

Table 3. Effect of herbicidal treatments on economics of garlic

Treatment	Cost of cultivation (x10^{3} ` /ha)	Gross returns (x10^{3} `/ha)		Net returns (x10^{3} `/ha)		B:C Ratio	
		SJKG-1	*SJKG-2*	*SJKG-1*	*SJKG-2*	*SJKG-1*	*SJKG-2*
Oxyflurofen 0.15 kg/ha PP	44.2	277.4	233.6	233.1	189.3	5.2	4.2
Oxyflurofen 0.15kg/ha PE(2 DAS)	44.2	226.4	193.2	182.1	148.9	4.1	3.3
Oxyflurofen 0.15kg/ha POE (30 DAS)	44.2	226.4	193.2	182.1	148.9	4.1	3.3
Pendimethalin 1.0 kg/ha PE	44.2	260.3	213.2	216.1	169.0	4.8	3.8
Alachlor 1.5kg/ha PE	44.1	209.1	179.4	165.0	135.3	3.7	3.0
Butachlor 1.0 kg/ha PE	42.9	214.1	174.3	171.1	131.3	3.9	3.0
Oxadiargyl 120g/ha ethyl-post (10 DAS)	43.0	284.1	245.6	241.0	202.6	5.6	4.7
Oxadiargyl 90 g/ha PE *fb* quizalofop-ethyl 50 g/ha POE	43.1	333.6	289.3	290.4	246.2	6.7	5.7
Pendimethalin 0.75kg/ha PE *fb* quizalofop-ethyl 50 g/ha POE	44.0	308.8	264.6	264.7	220.5	6.0	5.0
2 HW 40 and 60 DAS	48.9	319.1	278.5	270.2	229.6	5.5	4.7
Weedy check	41.4	162.1	134.5	120.7	931.3	2.9	2.2
Weed free	63.9	364.3	325.9	300.4	262.0	4.7	4.1

to better control of weeds in these treatments. But B: C ratio was significantly higher (6.73) in pre-emergence application of oxadiargyl *fb* post-emergence application of quizalofop-ethyl followed by pre-emergence application of pendimethlin *fb* post-emergence application of quizalofop-ethyl (6.01). This could be attributed to lower cost of cultivation in these treatments as compared to weed free plots. In weed free plots the cost of cultivation increased remarkably due to regular weeding operations followed for clean cultivation. It increased the cost of manual weeding thus corresponding towards total output cost. Moreover, unweeded control recorded significantly lesser B: C ratio (2.92) due to lower bulb yield owing to more crop weed competition. Similar findings were also recorded by Prakash *et al.* (2000) and Vermani *et al.* (2001).

The weed free plots resulted in higher cost of cultivation and net returns followed by the treatment combination of oxadiargyl 90 g/ha (PE) *fb* quizalofop-ethyl (POE) 50 g/ha applied at 2-3 leaf stage of weeds yielding a B: C ratio of 5.70 in small segmented and 6.73 in large segmented garlic respectively.

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A new cost-effective method for quantification of seed bank of *Orobanche* in soil

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ABSTRACT

A simple technique to germinate *Orobanche* in the presence of live host seedlings under controlled conditions was developed. Surface sterilized seeds were preconditioned separately in Petriplates and were transferred on a bed made of sterilized sand, cotton and filter paper kept on a 1000 ml beaker. Host plant (mustard and tomato) seeds were germinated in Petriplates and transferred to the beaker containing the preconditioned *Orobanche* seeds. The beakers were then incubated at room temperature for 10 days and observed under stereo binocular microscope. This technique may be useful in many ways including quantification of the weed seed bank in the infested fields, screening of contaminated seed lots from infested areas for the purpose of quarantine and seed certification. Use of live host seedlings instead of synthetic stimulants, both reduced the cost and made it possible to use this technique.

Key words: Parasitic plant, *Orobanche*, Seed bank, Vegetable crops, Weed biology

Parasitism in higher plants is evolved as a result of competition for limited resources, primarily in the arid and nutrient-deficient habitats leading to the development of special adaptations like the production of haustoria, to derive nutrition from the neighboring plants (Atsatt 1973). *Orobanche* (broomrape) is an obligate root parasitic angiosperm, parasitizing several economically important plants world over. *Orobanche* spp. has a wide host range including agriculturally important crops such as tomato, tobacco, potato, brinjal, several legumes, sunflower and mustard (Parker and Riches 1993). The most common species in India are *O. cernua, O. crenata, O. ramosa* and *O. aegyptiaca,* causing a loss of about 20-80% in the tomato and tobacco and about 30-35% in brinjal and mustard (Ramachandraprasad *et al.* 2008). Life cycle of *Orobanche* has the following distinct stages, *viz.* seed germination, haustorial initiation, attachment, penetration and establishment in the host and emergence of the flowering stalk above soil (Graves 1995). Minute size of their seeds permits only few hours of life after germination and therefore must quickly attach to a host root before their resources are exhausted. However the seeds can remain dormant in the soil for about 20 years. The parasite attacks the host root and dev elops underground for about 25-40 days, after which depending upon conditions outside, produce the flowering stalks above ground. Thus by the time the parasite becomes visible above ground, sufficient damage had already been caused by development of the parasite at the cost of the host plant. Host crops infected with *Orobanche* are often contaminated with the minute seeds of *Orobanche,* which are difficult to clean and as such requires time consuming and laborious microscopic examination or costly germination tests to find the admixtures for the purpose of clean seed certification and quarantine. The management strategies would be more efficient if it is possible to determine the *Orobanche* seed bank in the soil with rapid and easy technique for germination method. This paper presents the findings of such work.

MATERIALS AND METHODS

Collection of seeds and viability test of *Orobanche*

Seeds were collected from fully matured flowers of *Orobanche* growing on tomato and mustard crops from the farmer's field in Gwalior district (Latitude: 26°17'N, Longitude: 78°13'E, Elevation: 617.0 ft) Madhya Pradesh, India, during March 2011. The seeds were sun dried and stored in plastic containers at room temperature (25±2^{0}C). Seed viability was assayed using 2, 3.5-triphenyl-tetrazolium chloride (TTC) staining (Granados and Torres 1999), where the seeds were placed in 1% solution of TTC, incubated for 72 h at 35 ^{0}C in the dark. The seeds were then observed microscopically and red or orange seeds were considered viable, while white seeds were considered dead.

Germination under controlled conditions

Surface sterilized seeds, about 100 in numbers were placed on autoclaved moist filter paper of size

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Whatman No.1 in Petriplates of diameter 9 cm. The plates were covered with black polythene sheets and wrapped in aluminum foil to provide complete darkness and then incubated at 25±2 ^{0}C for 10 days for conditioning (Plakhine *et al*. 2009). The preconditioned seeds with filter paper were aseptically transferred on a bed made of sterilized sand, cotton and filter paper kept on a 1000 ml beaker. While sand was used for maintaining moisture for longer period, cotton and filter paper were used to keep the fine sand particles separate from the seeds.

In a parallel setup, surface sterilized seeds of mustard and tomato were placed in separate Petriplate with moistened blotting papers for germination. After germination, about 10 seedlings were surface sterilized and transferred to the beaker containing the preconditioned *Orobanche* seeds. The beakers provided sufficient vertical space for the growth of host plant seedlings. A mild fungicide such as bavistin was sprayed to avoid fungal contamination. *Orobanche* seeds without host plant were maintained for the purpose of comparison. About 30 beakers with similar sets of *Orobanche* seeds and host plant seedlings were maintained. The beakers were then incubated at room temperature for 10 days after which, the filter paper with *Orobanche* seeds and host plant were removed gently for observation under stereo binocular microscope. The experimental set up was tested several times for confirmation of the credibility of the technique.

Screening of contaminated soils and quantification of seed bank

To quantify the seed load of *Orobanche* in the infested soil, about 1 g of infested soil was suspended in clean sterile distilled water, filtered to remove large soil particles and then transferred to the beaker with standard germination paper for conditioning of *Orobanche* seeds. The procedure described above was followed to estimate the number of seeds germinated. Analysis of soil samples was done collected from 10 farmer's fields in and around Gwalior district of Madhya Pradesh. Soils samples were collected on the basis of farmer's report of *Orobanche* infestation. Soil samples collected from the farmer's fields in Bahadurpur 1 and 2, Khokapura 1 and 2, Murena 1 and 2, Seetapur, Daulpur road, Billua 1 and 2, near Gwalior were used for quantification of weed seed bank and 5 replications were maintained for each location.

RESULTS AND DISCUSSION

Collection and identification of *Orobanche species*

Seeds were dark brown in colour, oblong to ovoid with surface reticulations. Size of stalk was 30-40 cm, inflorescence dense with pentamerous flowers, bluish violet colour at the top and white at base, corollas were strongly curved and lobed with bluish violet calyx 4 in number, 9- 12 mm in length, single pistil of length 16 mm, 5 corollas of 15-18 mm in length, the bract was dark in colour with hairy surface, stamens were 4 in number (8-12 mm length) and 10 mm style. Based on the above characters as also described by Foley (2004) and Plaza *et al.* (2004), the species under study was identified as *O. cernua*

Germination under controlled conditions

Seed viability was tested for the seeds collected from all different locations. Maximum viability of 67.8% was observed for the seeds collected from Murena 2 while a minimum of 44.4% from Seetapur location (Table 1). Periodical observation of the seeds of *Orobanche* indicated an overall germination percentage of about 70% on mustard and about 63% on tomato in a period of 20 days. Using the germination setup as described in methodology, we could germinate fresh seeds of *Orobanche* similar to the report of Abbes and Kharrat (2006), while according to Perez-de-Luque *et al.* (2004), under natural conditions preconditioning of seeds in soil is required for germination of *Orobanche*. Microscopic observation of the germinating seeds indicated the following important events in that sequence (i) seeds swell after absorbing moisture during the conditioning period (ii) color of the seed coat changes from light brown to dark brown on 2nd to 4th day upon exposure to the host seedlings. (iii) The proximal end of the imbibed seeds became more pointed and protruded from the base, (iv) the testa ruptured and (v) germ-tube elongates to reach the host root and attaches to the root surface by production of haustoria to enter the root tissues. After successful establishment of haustoria inside the host root, a globular tubercle is formed. The tubercle is densely surrounded by brown root meristem, growing into a flowering stalk of *Orobanche* which emerges above the ground to produce flowers.

Table 1. Viability of *Orobanche* seeds collected from the soils of different villages around Gwalior and tested by TTC staining method

Sample	Host crop	% Viability of *Orobanche* seeds
Bahadurpur 1	Mustard	65.8
Seetapur	Brinjal	44.4
Billua 1	Tomato	50.2
Khokapura 1	Mustard	49.2
Daulpur road	Brinjal	48.8
Billua 2	Tomato	55.6
Murena 1	Brinjal	44.8
Murena 2	Mustard	67.8
Bahadurpur 2	Mustard	56.6
Khokapura -2	Tomato	54.8

Table 2. Comparison of some popular methods for weed seed bank estimation

Objective of the technique	Advantages	Disadvantages	Reference
In vitro germination of parasitic weed seeds	• Can provide valid information about the seed bank load of the parasitic weeds	• Root leachate collection and tissue culture involves costly facilities, expertise and time	Batchvarova *et al.* (1998)
Weed seed bank analysis	• Can provide weed seed density of non-parasitic seeds	• A general technique and not suitable for parasitic seeds	Espeland *et al.* (2010)
Sandwich model of *Orobanche* germination	• Can provide a general information about presence of *Orobanche* seeds	• Does not give complete information, time consuming and the glass-fiber may cause respiratory problems for the personnel involved	Losner-Goshen *et al.* (1998)
Petridish method using synthetic germination stimulants like GR24, Nijmegen-1 etc.,	• Widely used technique for the study of *Orobanche* seed germination • Gives better germination than any other technique under controlled conditions	• Germination stimulants are costly and not readily available in the market • No information about complete life cycle, only germ tube development can be observed but tubercle development and attachment cannot, because of absence of host root	Mangus *et al.* (1992)
1. Seed germination by using live host seedlings under laboratory conditions 2. Quantification of soil seed bank 3. Screening of crop seed samples from infested fields	• Germination of the parasitic weed seed, interaction between the host plant and weed and stages of development of the parasitic weeds can be studied in relatively less time • Uses locally available standard laboratory wares and thus very cheap and easy to setup when compared with other methods • Can be used to quantify the soil seed bank load of parasitic weed seeds which is not possible by other methods • Depending upon the sample size and representativeness, can give accurate prediction of the seed load in the soil • Screening of crop seed lots is less laborious and reliable than other methods	• Host plant may become week because of lack of food sources • Takes about 20-25 days including the preconditioning and germination period in the case of soil seed bank screening.	Our proposed technique

Batchvarova *et al.* (1998) demonstrated the *in vitro* germination of *Orobanche,* where the host root extract was used as stimulant for the development of the callus. This method requires the production of callus cultures which requires more technical facilities. Likewise in the "sandwich method" (Losner-Goshen *et al.* 1998), *Orobanche* seeds were placed between two layers of glass-fibre paper and the sandwich was buried in autoclaved sand in small pots as a modification of the method given Parker and Dixon (1983). This method uses glass-fibre which is not eco-friendly in their production and use. Similarly the use of Petri dish for the germination of *Orobanche* seeds was described by Sauerborn *et al.* (1987). However these methods were either costly or required some special skills or could not give an insight into the different stages of germination of the *Orobanche* seeds and for conducting the studies. In contrast (Table 2), the current method described in the study provides a very simple and effective technique to check the germination, quantify the viable seeds in a given lot and thereby estimate the weed seed bank load in the given quantity of infested soil and to study the stages in germination and development of *Orobanche* in the host. The germinated host plant seedling provides the essentially required host signals in a concentrated manner right near the pre-imbibed *Orobanche* seeds, thereby providing a perfect condition for the germination and growth of *Orobanche* seeds.

Quantification of soil seed bank

Results indicate that the quantity of viable *Orobanche* seeds varied from a maximum of 69.6 seeds per gram of soil in Bahadurpur region where mustard was host crop while minimum germination of about 6.8 seeds per gram of soil of *Orobanche* from the fields with brinjal in Seetapur regions. Bar chart (Fig. 1) showing the number of viable seeds of *Orobanche* per gram of soil indicates that host crop and the soil type influences the variations in the weed seed bank of the soil which may help to determine the severity of the infection in the succeeding cropping season and device management strategies accordingly. Quantification of weed seed bank is an important criteria in the management of weeds and it helps in predicting the weed dynamics (Allen and Nowak 2008) and intensity of crop weed competition for using appropriate management strategies (Creech *et al.* 2008). Understanding the factors behind germination of *Orobanche* and their actual seed load in the soil is crucial for the development of management strategies to deplete the soil seed bank of *Orobanche* (Joel 2000). Several tech-

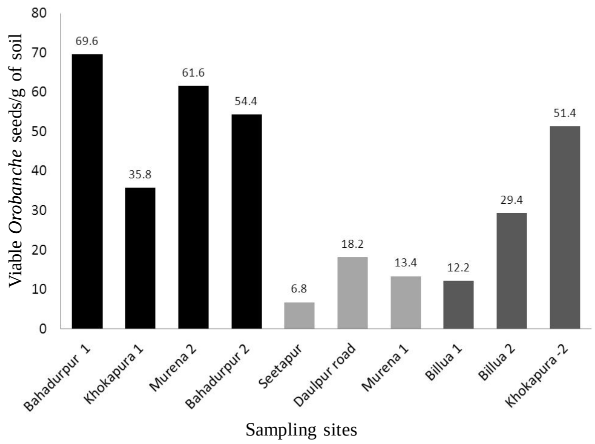

Fig. 1. *Orobanche* infestation in farmers fields in and around Gwalior district of Madhya Pradesh

niques have been proposed for estimation of non-parasitic weeds (Espeland *et al*. 2010). The general extraction and emergence method of germination used for non-parasitic weeds cannot be used for the parasitic weeds, especially *Orobanche*, because of their very minute size and obligate dependence on the host stimulants for germination. Further their similarity with other seeds of parasitic plants like *Striga* spp. and *Phelipanche* sp. poses difficulty in their identification. Germination of *Orobanche* is generally erratic (Batchvarova *et al*. 1998) and have the following stringent criteria *i.e.*, soil moisture and temperature during the preconditioning period, availability and reception of host signals as root exudates and finally the viability of seeds (Plakhine and Joel 2010). Thus the estimation of *Orobanche* has always been very tricky and not much work has been done on this earlier. The germination technique using live host plant seedlings described above has been demonstrated to fairly estimate the number of viable seeds present in a defined quantity of soil.

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Mycobiota associated with *Parthenium hysterophorus* isolated from North India

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ABSTRACT

Parthenium hysterophorus, one of the "worst weeds", is an erect and much branched annual or ephermeral herb causing colossal loss in terms of economic, environmental, animal and human health hazards. A survey on occurrence of the natural enemies of *P. hysterophorus* L. was conducted in Kurukshetra and its adjoining areas, Haryana, India. The *Parthenium* population at different places during different seasons were found to have various diseases. The native pathogens of *Parthenium hysterophorus* were studied and compared on the basis of pathogenicity by Koch's postulates. A total of twenty six pathogenic fungi, P1-P26 were isolated from different diseased *Parthenium* plants. All the isolates were preliminarily identified on the basis of cultural and morphological characteristics and it was observed that all of them belongs to the fungi imperfecti except isolates P19, P20 which belongs to Ascomycota. On the basis of pathogenicity, the isolates P2, P5, P7, P9, P12, P17 and P23 were selected and the effect of different media on the growth and sporulation of selected pathogens was tested. This study will help to develop mycoherbicides by using these fungal pathogens in combination or single.

Key words: Ascomycota, Ephermeral, Fungi imperfecti, Mycoherbicide, *Parthenium hysterophorus*

White top (*Parthenium hysterophorus* L.) is an annual herb of Asteraceae family, originating from tropical Americas and now a weed of global significance in many countries around the world. It was reported that the seeds of this weed came to India with grains imported from U.S.A. under the USA PL 480 scheme and spread alarmingly like a wild blaze to almost all the states in India and established as a naturalized weed. In India, the weed was first reported in Poona (Maharashtra) by Prof. Paranjape in 1955, as stray plants on rubbish heaps and was reported by Rao in 1956, as a new record for the country but the earliest record of this species in India goes back to 1814 by William Roxburgh, 'the father of Indian Botany', in his book *Hortus Bengalensis* (Rao 1956, Rouxburg 1814). It was estimated to spread in 35 million hactare of land in India representing wasteland including pastures, cropland and forestland (Sushilkumar and Varshney 2010).

With the ever increasing population of the weed in both urban and rural localities, the associated problems like crop production, animal husbandry, human health and biodiversity are also phenomenally growing day by day. To the weed scientist, *Parthenium* has proved a challenge because conventional methods have failed to suppress its growth and prevent its unchecked spread throughout the world, and still efforts are being made to control this weed by all possible means. In this context, biological control with plant pathogens is an effective, safe, selective and practical means of weed management. Since 1979, considerable progress has been made towards practical use of plant pathogens as safe and selective agents of weed management (Charudattan and Walker 1982, Aneja *et al.* 2013, Kour 2014). The biological control of this weed using fungal pathogens under the mycoherbicidal strategy has been suggested as one of the most efficient method, owing to its long lasting, less costly and eco-friendly nature. The objective of the present study was to search for fungal pathogens naturally occurring on *Parthenium* weed in Northern India that could be used for reducing *Parthenium* population to economic levels.

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MATERIALS AND METHODS

Isolation of the pathogens

Surveys were conducted during 2013-14 in Kurukshetra and adjoining area to search pathogens associated with *Parthenium*. Leaf surfaces were washed with distilled and sterilized water in order to remove epiphytic fungi and adherent soil particles**.** The infected portions of the leaves were cut into 1.0-1.5 cm fragments, surface sterilized with 70% ethanol for 1-2 minutes and then rinsed in sterile distilled water 3 to 4 times. These fragments were transferred on to the potato dextrose agar (PDA) medium (potato: 200g, agar-agar: 20 g, dextrose: 20 g, distilled water: 1000 ml) Petriplates supplemented with streptomycin sulphate and were incubated at 25 °C (Aneja *et al.* 2014)

Identification

5 mm diameter discs from 7 day old PDA cultures, taken from the advancing mycelial margins with a cork borer, were placed at the centre of PDA and maintained at 25±2 under continuous darkness. Seven days later, the colony appearance and their diameters on PDA were determined. The morphological characteristics of the mycelium, conidia and perithecia of pathogens were observed and preliminarily identified by consulting monograms (Ellis 1971, 1976, Bilgrami 1991).

Screening of the major pathogens

All the isolates were preceded for the pathogenicity tests and the pathogenicity was determined *in vitro* conditions. *In vitro* pathogenicity test healthy leaves of *Parthenium* were used for inoculation. The leaves were washed with sterile distilled water and wiped with a cotton swab dipped in 70% alcohol. Some of the leaves before inoculation were injured on adaxial surface by pricking with a flamed needle. Mycelial discs, taken from 5 days old colony, were placed on injured and uninjured portions and covered with sterile moist cotton. The inoculated leaves were kept in sterilized moist chambers and incubated at 25 °C. Regular observations for the appearance of symptoms were made after 3 days of incubation. (Aneja *et al.* 2000)

Effect of different media on growth and sporulation

To see the effect of different media, on the growth and sporulation of fungal pathogens, seven media namely potato sucrose agar (PSA), potato dextrose agar (PDA), potato dextrose yeast agar (PDAY), *Parthenium* dextrose agar (PeDA), *Parthenium* dextrose yeast agar (PeDAY), maltose extract agar (MEA) and nutrient agar (NA) were used. Inoculated plates were incubated at 25 °C for ten days. Three replicates were run per medium per condition for all the test fungi. Fungal growth was determined by measuring the diameter of the colony at two places at right angle to each other and an average of the cross diameter was considered as growth of the fungus.

Conidial concentration of different pathogens on different media was measured by scraping the mycelial growth from the plate with distilled water and then homogenized on magnetic stirrer for 5 minutes, placed 1-2 drops of suspension on the hemocytometer slide and calculated the conidial concentration using microscope (Tuite 1969).

RESULTS AND DISCUSSION

During surveys conducted between 2013-14 in Kurukshetra and its adjoining area, over 47 diseased specimens were collected and examined for the fungal pathogens (Table 1). A total of twenty six fungal pathogens namely *Alternaria* sp. (four different species), *Cladosporium* sp. (three different species), *Curvularia* sp. (two different species), *Colletotrichum* sp. (two different species), *Drechslera* sp., *Fusarium* sp. (four different species), *Chaetomium* sp. (two different species), *Acremonium* sp., *Trichoconiellia padwickii*, *Pestalotia* sp., *Epicoccum* sp., *Nigrospora* sp., *Scedosporium* sp. and *Torula* sp. were identified. On the basis of sporulating structures produced on the live *Parthenium* leaves, one pathogens namely *Cercospora* sp., was identified.

Out of these twenty six pathogens, seven were selected on the basis of pathogenicity for evaluation of biocontrol potential and were tested for the growth and sporulation on different media. Species of *Alternaria*, *Fusarium* and *Curvularia* were already reported from *Parthenium hysterophorus* but *Torula* sp. and *Trichoconiellia padwickii* has been reported first time on this weed during the survey.

***Alternaria alternata* agg**

The symptoms appeared as small, central and marginal brown or black spots scattered on leaves. The spots became irregular in shape. When their size increased they turned brown to black in colour. Several such lesions may coalesce resulting in leaf drying. Culture grey green in colour with white margins and becoming black at maturity. Conidiophores light brown to golden brown, simple, branched, septate, straight or curved, smooth walled. Conidia light brown to olivaceous, borne long acropetal chains, ovoid or obclavate with a long or short beak, or ellipsoidal and without beak, smooth to echinulate, muriform with transverse and longitudinal septa. The beak, when present, is always smaller and lighter in colour than the conidial body (Fig. 1, A1-A4). Diseased specimens and culture have been deposited at CAB International Mycological Institute, UK with reference No. 502784 and IIBC, Ascot, UK.

***Alternaria* sp.**

The colony on PDA is green with white margins. The mycelium is branched and septate and the aerial hyphae are undeveloped. On living leaves of *Parthenium* symptoms are characterized as dark brown, irregular marginal spots. Conidiophores are solitary rarely in groups (1-3 in number), septate, light brown and straight to geniculate with 1-4 scars. Conidia mostly solitary, rarely in chains of 2-4, dark brown, smooth,

Table 1. Characteristic and percentage frequency of various fungal pathogens

Isolates	Symptoms	Preliminary identification	Colony characteristics	Pathogenicity	Frequency (%)
P1	Leaf spot	*Pestalotia* sp.	Yellowish white with black sclerotia	++	1.92
P2	Leaf spot	*Alternaria* sp.	Green with white margin	+++	9.62
P3	Leaf spot	*Alternaria* sp.	Grey with green margin	++	2.56
P4	Leaf spot	*Alternaria* sp.	Light grey	++	3.85
P5	Leaf blight	*Torula* sp.	White green	+++	5.13
P6	Leaf spot	*Fusarium* sp.	Whitish yellow	++	1.28
P7	Leaf blight	*Fusarium* sp.	Reddish white	+++	3.85
P8	Leaf spot	*Fusarium* sp.	White orange	+	6.41
P9	Leaf blight	*Fusarium solani*	Pale green	+++	5.13
P10	Leaf spot	*Cladosporium* sp.	Grey	+	5.77
P11	Leaf spot	*Cladosporium* sp.	purple-brown	+	4.49
P12	Leaf spot	*Alternaria alternata* agg.	Grey-green	+++	10.26
P13	Leaf spot	*Acremonium* sp.	White	+	1.92
P14	Anthracnose	*Colletotrichum* sp.	White to brown	+	4.49
P15	Anthracnose	*Colletotrichum* sp.	Dark brow with black sclerotia	++	5.77
P16	Leaf spot	*Nigrospora* sp.	Grey to black	+	3.85
P17	Leaf blight	*Trichoconiellia padwickii*	Brown to grey with orange exudates	+++	1.28
P18	Leaf spot	*Cladosporium* sp.	Grey green	+	1.92
P19	Leaf spot	*Cercospora**	-	-	-
P20	Leaf spot	*Chaetomium* sp.	Olive green	+	1.28
P21	Leaf spot	*Chaetomium* sp.	Olive to dark green	+	3.21
P22	Leaf spot, tip drying	*Dreschlera* sp.	Grey	++	2.56
P23	Leaf spot	*Curvularia* sp.	Grey	+++	4.79
P24	Leaf spot	*Cuvularia* sp.	Green to black	++	3.85
P25	Leaf spot	*Epicoccum* sp.	Orange to brown	+	3.85
P26	Leaf spot	*Scedosporium* sp.	Orange white	+	1.28

+ - low; ++ - moderate; +++ - high; * - Uncultured

with 3-5 transverse and 2-3 longitudinal septa, short beaked which sometimes swollen at the apex or ellipsoidal and without beak. Light brown to dark brown coloured chlamydospores present solitary or in chains (Fig. 1, B1-B4).

***Curvularia* sp.**

Symptoms appeared on leaves are brown to black leaf spots scattered all over the leaf. *Curvularia* sp. appears as shiny velvety-grey, fluffy growth on the colony surface with septate, dematia-ceous hyphae producing brown, geniculate conidiophores. Conidiophores arise in tufts of 4-6 from subcuticular stromata; erect, inflated at the base, dark brown, septate, nodulose with spiral conidial scars. Conidia olive brown, usually curved, ellipsoid 3 septate, rounded at the base, 2 central cells, larger and darker than the two nearly hyaline end cells (Fig. 1, C1-C4).

Fusarium solani

Symptoms are characterised as, dark brown, irregular, marginal and central spots. Culture pale to green in reverse; aerial culture pale. Hyphae are septate and hyaline. Conidiophores are simple (non-branched) or branched monophialides (phialides with a single opening). Macroconidia are moderately curved, stout, thick-walled, usually 3-5 septate, measure 4-6 x up to 65 µm long, and are borne on short conidiophores that soon form sporodochia. Microconidia are borne from long monophialides, are one to three-celled, 2-5 x 8-16 µm long, and occur in false heads only (in clusters of conidia at the tip of the phialide). Chlamydoconidia are present (sometimes profuse) and occur both singly and in pairs (Fig. 1, D1-D4). The identification of pathogen has been confirmed at CABI International Mycological Institute, UK with reference No. 503548.

***Fusarium* sp.**

The symptoms appeared as water soaked brown spots scattered on the leaf surface. These spots coalesced and formed larger brown spots. Culture whitish cream to deep rose red to burgundy in reverse with floccose texture; aerial culture white, becoming somewhat compressed by the formation of orange sporodochia due to the presence of conidial mass. Microconidia produced on polyphialidic conidiophores, usually looking like rabbit ears or X- shaped, straight, obovoid and 0-1 septate. Macroconidia scarce, sickle shaped, 3-5 septate. Chlamydospores present abundantly, in chains or cluster (Fig. 1, E1-E4).

***Torula* sp.**

Symptoms are characterized by the presence of black marginal necrotic spots on the leaves of *Parthenium*. Colonies are whitish green, effuse to

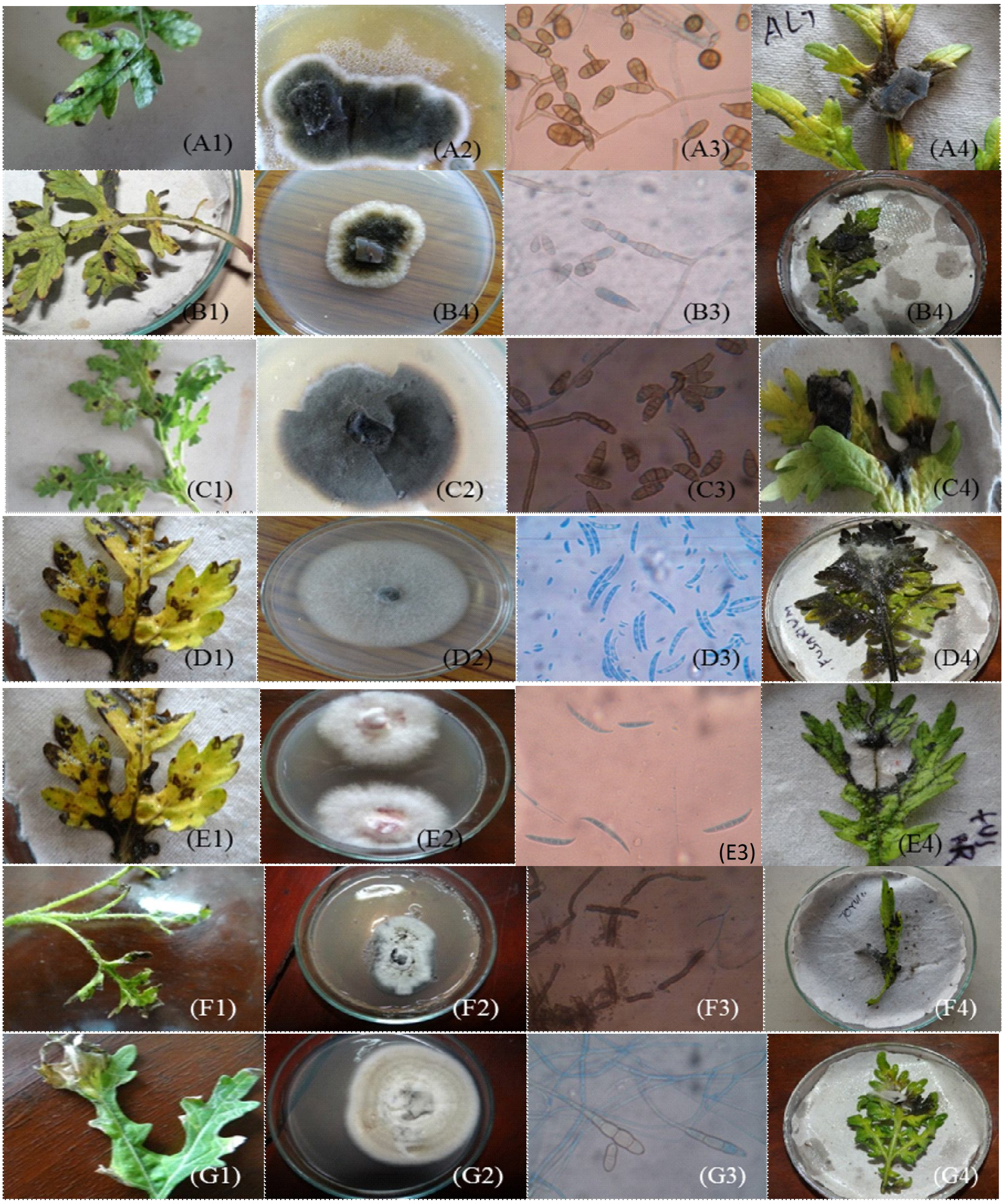

Figure 1. Symptoms, colony characteristic, microscopic view and pathogenicity test of fungal pathogen reported on *Parthenium* weed. *A. alternata* agg.(A1-A4); *Alternaria* sp.(B1-B4); *Curvularia* sp.(C1-C4); *Fusarium solani* (D1-D4); *Fusarium* sp. (E1-E4); *Torula* sp. (F1-F4); *Trichoconeilla padwickii* (G1-G4)

crusted-like with pronounced vertical streaking, becoming markedly thickened and friable in age. Conidia are dark brown phragmoconidia, typically roughened, borne in unbranched moniliform, acropetal chains. The wall of the distal conidial cell is characteristically thinner and lighter in pigmentation than the rest of the conidium (Fig. 1, F1-F4).

Trichoconeillia padwickii

Symptoms on living leaves of *Parthenium*, are characterized as dark brown to black, irregular marginal spots. Colonies are whitish brown and black from reverse on PSA. Conidiophores are brown, straight to geniculate with 1-4 scars, up to 190 µm long, 5.7-9.5 µm thick. Conidia mostly solitary, rarely in chains of

Table 2. Colony diameter of different pathogens on different media

Pathogens	Colony diameter on different media (cm)						
	PDA	PDAY	PeDAY	PeDA	MEA	PSA	NA
Alternaria alternata agg.	6.72±0.21	7.95±0.18	6.84±0.03	6.59±0.45	7.68±0.08	6.97±0.28	6.11±0.17
Alternaria sp.	5.63±0.07	5.12±0.47	4.95±0.43	4.95±0.04	5.15±0.25	6.32±0.43	4.81±0.41
Curvularia sp.	5.85±0.25	6.55±0.32	5.4±0.42	5.29±0.67	5.31±0.41	6.39±0.35	5.25±0.62
Fusarium solani	5.88±0.08	6.95±0.22	6.39±0.34	6.45±0.51	6.87±0.63	7.15±0.55	4.95±0.16
Fusarium sp.	6.51±0.16	6.95±0.04	7.1±0.45	6.95±0.34	6.79±0.06	7.81±0.23	5.86±0.39
Torula sp.	4.35±0.51	4.53±0.31	4.14±0.58	4.05±0.53	4.36±0.24	4.79±0.71	4.20±0.11
Trichoconeilla padwickii	5.55±0.28	5.16±0.25	5.24±0.36	5.47±0.08	4.85±0.34	6.85±0.12	3.60±0.08

Table 3. Effect of different media on the sporulation of pathogens

Pathogens	Average spore count/ml (x10^5) on different media						
	PDA	PDAY	PeDAY	PeDA	MEA	PSA	NA
Alternaria alternata agg.	19.00±0.46	11.95±0.81	16.84±0.53	14.59±0.45	17.68±0.68	14.97±0.28	1.11±0.17
Fusarium solani	24.88±0.56	27.95±0.43	24.39±0.04	23.45±0.39	22.87±0.26	18.15±0.58	9.95±0.68
Fusarium sp.	16.51±0.16	18.95±0.04	10.1±0.44	12.95±0.61	16.79±0.38	15.81±0.22	8.86±0.33
Curvularia sp.	17.85±0.25	19.55±0.32	15.4±0.82	13.29±0.38	19.31±0.42	18.39±0.42	14.25±0.13
Trichoconeilla padwickii	5.55±0.27	7.16±0.25	4.24±0.16	4.47±0.23	6.85±0.34	6.85±0.21	2.60±0.02
Alternaria sp.	25.63±0.53	23.12±0.42	21.95±0.53	22.95±0.47	27.15±0.41	23.32±0.63	18.81±0.41

2, obclavte, rostrate, pale to golden brown, smooth to minutely verruculose, with 5-9 transverse and rarely seen longitudinal septa, body 72-106 × 17.1-26.6 µm, beak hyaline, filiform, septate, straight to geniculate sometimes swollen at the apex, often much longer than the body of the spore, 55-165 µm long and 1.9-3.8 µm thick. Diseased specimens and culture have been deposited at CABI, International Mycological Institute, UK (reference no. 502783)(Fig. 1, G1-G4).

Growth and sporulation on different media

Of the seven media tested for the growth and sporulation, *A. alternata* and *Curvularia* sp. showed excellent growth and sporulation on PDAY, its growth and sporulation was good on PDA, MEA, PSA, PeDA, PeDAY and poor on NA. *Alternaria* sp. showed best growth and sporulation on MEA media and was poor on NA. Growth of *Fusarium* sp. was best observed on PSA and it sporulate well on all the media but best on PDAY. Best growth and sporulation of *Fusarium solani* and *Trichoconeilla padwickii* were observed on PSA and PDAY respectively. The growth of *Torula* sp. was best on PSA but its spore count could not be performed because the conidia of this pathogen were indistinct.

Literature search revealed that a great deal of work has been done by the scientists to control this weed by fungal pathogens. Saxena and Kumar (2007) worked on the mycoherbicidal potential of *Alternaria alternata* ITCC (LC#508) in Northern India to control *Parthenium* weed, and reported 50% damage of plants *in vitro* detached leaf and whole plant bioassay at 96 hours post-treatment at a concentration of 1×10^6 spores/ml. *Sclerotium rolfsii* (teleomorph: *Athelia rolfsii*), incites a severe collar rot disease on *Parthenium* (Pandey *et al.* 1998, Shukla and Pandey 2006). Although, the pathogen is responsible for severe damage to weed, but the wide host range of the species creates doubt about its suitability as mycoherbicides. *Cladosporium* sp. (MCPL-461), a floral leaf pathogen of *Parthenium*, produces symptoms on the flowers, buds, and inflorescences, and causes sterility and reduces seed viability. The severity of pathogen to the reproductive organs led to serious damages of the *Parthenium* plants and may be used as a potential mycoherbicide against this weed (Kumar *et al.* 2009). Satyaprasad and Usharani (1981) reported powdery mildew causing *Oidium parthenii* on *Parthenium* at Hyderabad. The fungus appears as small, circular, white powdery spots on the surface of leaves, and spreads over the entire lamina on both the surfaces giving a powdery appearance to the plant. Severe infection leads to defoliation. Kauraw *et al.* (1997) reported *Fusarium pallidoroseum,* on *Parthenium* from Jabalpur. It was found to reduce seed germination, seedling vigour, height of plant, number of branches and number of flowers and reported as a potential biocontrol agent for *Parthenium* management.

But these pathogens suffered from one or the other disadvantages, so our work in this area aims for searching a potential pathogen which should be the host specific and emerges as an effective mycoherbicide against this weed.

A total of twenty nine fungal pathogens have been reported on *P. hysterophorus* weed from various parts of the globe. During our study on fungal pathogens, we have reported 26 pathogens on this weed. Out of these, *Torula* sp. and *Trichoconeilla padwickii* were reported first time on *Parthenium hysterophorus.* Looking into the severity of the disease and damage caused to the *Parthenium* weed during surveys in North India, the pathogens P2, P5, P7, P9, P12, P17, P23 seem to offer great potential for development and exploitation as effective biocontrol agents for checking *Parthenium* growth. Further work on its host specificity and evaluation as biocontrol agents is in progress in our lab, which may leave to recognize the potential of these pathogens.

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Impact of invasive alien siam weed and congress grass on native flora

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ABSTRACT

Study was done on impact of invasive alien weeds *Chromolaena odorata* and *Parthenium hysterophorus* on native naturalized flora of few selected sites in Mysore, Karnataka. Total six sites were selected for the study. Of which, at 3 sites *C. odorata* and *P. hysterophorus* were present (sites 1, 2 and 3) while at other 3 sites *C. odorata* and *P. hysterophorus* were absent (sites 4, 5 and 6). At sites 1, 2 and 3, frequency, density and abundance of the native flora were low than the sites 4, 5 and 6. There was 30, 24 and 12% reduction of native flora at sites 1, 2, and 3, respectively. There was a constant fear of losing many medicinally and economically important plants due to invasion of these weeds.

Key words: *Chromolaena odorata,* Invasive weeds, Impact assessment, Native flora, *Parthenium*

Many alien weeds have been established on Indian soil ever since the late 15th century, following Portuguese settlement in the country. While the vast majority of these have become naturalized and seem to be the permanent denizens of our flora. A few aliens particularly those that have established in the last century or so have proved to be invasive that have rapidly spread like wild fire in all biogeographic sites and have not only taken a heavy toll of native biodiversity but also have affected human health.

Most of invasive weeds originated from Mexico and the tropical American region, have established themselves in vast areas in India. Although extinction of local populations due to spread of alien weeds was recognized as early as 1872 by Darwin (1872), but now the problem of biological invasions has received considerable attention (Rao and Kavitha 2012). Although elimination of native species due to invasion of alien species is well known (Dogra *et al*. 2009, Booth *et al*. 2003, Hulme 2003), quantitative assessments of the loss of native species is not well studied. While it is important to obtain baseline data on their correct taxonomic identification and distribution, it is also equally important to know the impact of invasive weeds on the local flora/native biodiversity in weed invaded and non-invaded areas. The Convention on Biological Diversity held in 1992 in Rio de Janeiro (Article 8h) also emphasized the serious threat to native flora from exotic invasive weeds and urges the scientific community to take steps for their control and eradication (Rao and Kavitha 2012).

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Chromolaena odorata (L.) King and Robinson (‘bitter bush’, ‘jack in the bush’, ‘triffid weed). is a native of South and Central America, found very extensively in forests, forest cleared areas, agricultural lands, plantations, throughout Western Ghats from plains to ascending to *c.a.* 1000 m. Often forms pure patches as undergrowth of forests. It has emerged one of the 12 worst invasive weeds in Western Ghats. There are also reports on adverse effects of invasion of *C. odorata* responsible for the poor regeneration of trees in degraded forest areas.

Parthenium hysterophorus L. (‘Santa Maria, fever few’, ‘congress grass’, ‘ragweed, *Parthenium*’, ‘white top weed’) is a native of tropical America and Mexico. In India, it is naturalized throughout Western Ghats, lower Himalayas, North East India, grows in agricultural areas, range/grasslands, disturbed areas, suburb/shrublands, and urban areas. This is one of the worst weeds of Western Ghats which colonizes almost in pure population, vast areas along railway lines, roadsides, fallows, forest cleared areas and even in protected areas and the weeds has the capacity to fragment the native species to extinction. The species also causes health hazards to both human and cattle population (Nagarajachari 2005, Sushilkumar 2011).

Many agriculture fields associated with many important medicinal flora were observed to be infested heavily with *C. odorata* and *P. hysterophorus* which prompted us to take up a detail investigation on the impact of the invasive species on the quantitative loss of medicinal and other native species in those localities. Impact of *C. odorata* and *P. hysterophorus* is poorly studied in Mysore district of Karnataka state.

MATERIALS AND METHODS

Study area

Mysore district (Karnataka state) with an area of 4,126.45 km^2 forms the third richest in forest wealth in Karnataka. The district lies between 11^0 30' N to 12^0 50' N latitudes and 75^0 45' E to 77^0 45' E longitudes. Total 6 ecologically and topographically similar sites were selected. Site-1 experienced the infestation of *C. odorata* (Elachipalya near Chennapatna of Mysore district) and site-2 (foothills of Chamundi temple, Mysore) and site-3 (Shambhudevanapura near Malavalli, Mysore district) wa heavily invaded by *P. hysterophorus*. The remaining 3 sites selected in the adjacent localities were not infested with these alein weeds (site 4, 5, and 6). The study was carried out for one year from March 2012 to February 2013. In each of these areas, 30 quadrates were laid by random quadrate method. All the plant species encountered were collected in flowering and fruiting conditions and herbarium specimens were prepared following the standard procedure of Rao and Jain (1977). The specimens were correctly identified using the local floras.

The vegetation data collected for abundance, frequency and density were calculated using the following ecological method of Curtis and Mclntosh (1950) and with following formulae:

$$\text{Frequency (\%)} = \frac{\text{Total No. of quadrates in which the species occur}}{\text{Total number of quadrates studied}} \times 100$$

$$\text{Density} = \frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates in which the species occurred}}$$

Frequency formulae for non infested sites is $A>B>C>D>E$ and in infested sites frequency formulae is $A<B<C<D<E$.

RESULTS AND DISCUSSION

A total of 79 plant species were encountered in both weeds infested and non infested sites, of which 34 species were found in sites 1, 2 and 3 infested by *C. odorata* and *P. hysterophorus* and 45 species belonging to different families at non infested sites 4, 5, and 6. The flora present in all the sites differed with respect to density, abundance and frequency.

Phytosociological attributes of native or naturalized flora in localities infested by invasive alien weeds:

Site 1 (*C. odorata* invaded site)

Sida acuta and *Croton bonplandianum* were found to appear with highest frequency of 66.7% each, followed by *Hyptis suaveolens* (50%), *Calotropis procera* and *Leucas aspera* (33.3%), *Cassia auriculata*, *Lettsomia eliptica* (30%) and *Argyreia nervosa* (23.3%) and least frequent was *Achyrathus aspera* and *Celosia argentea* (16.7%) (Table 1).

More abundant species was *Calotropis procera* (9) followed by *Hyptis suaveolens* (also invasive species) (6.78), *Sida acuta* (6.28), *Achyranthes aspera* (6.10), *Leucas aspera* (5.37). Remaining species were least present with respect to their abundance.

Croton bonplandianum, *Hyptis suaveolens* and *Celosia argentea* were present with highest density 3.70, 3.63 and 3.0 respectively. Least was *Cipadessa baccifera* (0.16), *P. hysterophorus* (0.60) followed by *Calotropis procera* (0.50). Density of other species was average (Table 1).

Site 2 (*P. hysterophorus* invaded site)

Analysis of frequency in this site revealed frequency of *Mollugo cerviana* (20%), *Acalypha indica* and *Amaranthus spinosus* (16.7%) each. Similar frequency was exhibited by *Euphorbia hirta*, *E. prostrata*, *Alternanthera echinata*, *Tribulus terrestris* and *Zornia gibbosa* (13.3%). Least frequent was *Indigofera linifolia* (1%).

Most abundant species was *Alternanthera echinata* (20.70) followed by *Euphorbia prostrata* (14.3), *Amaranthus spinosus* (13.4), *Zornia gibbosa* (8.75). *Amaranthus speciosa* was least abundant (2.53). Remaining species shared average abundance.

Tribulus terrestris (2.93) and *Euphorbia hirta* (2.63) were found to be highly dense followed by *Portulacca olaracea* (2.03).

Site 3 (*Parthenium hysterophorus* invaded site)

Melochia corchorifolia and *Amaranthus spinosus* were the species found with high frequency of 66.7% and 50%, respectively followed by *Canthium parviflorum* (36.7%), *Abutilon indicum*, *Cassia tora* and *Flacourtia indica* (33.3%) each. Other species were found to be of average frequency.

Most abundant species was *Chenopodium album* (7.84) followed by *Canthium parviflorum* (6.50), *Sida acutangula* (6.33), *Cassia tora* (6.30). Least abundant was *Portulacca olaracea* (1.3) (Table 1).

Cassia tora (5.27) and *Chenopodium album* (4.03) exhibited high density values followed by *Canthium parviflorum* (2.7), *Abutilon indicum* (2.6), *Sida rhomboideae* and *Sida acutangula* (2.57).

Highly abundant species was *Chenopodium prostratum* (12.06) followed by *Cassia tora* (10.27), *Sida rhomboideae* (9.08), *Canthium parviflorum* (8.64), *Amaranthus spinosus* (8.8) *etc*, *Polycarpea corymbosa* was less abundant (4.1).

Cassia tora was most densely populated species (7.53) followed by *Chenopodium album* (6.03), *Abutilon indicum* and *Sida acutangula* (3.7), *Sida rhomboideae* (3.63) *etc*. Very less dense population of *Chenopodium prostratum* (2.07) was also observed (Table 1).

Site 4 (*C. odorata* absence *site*)

Croton bonplandianum (86.7%), *Sida acuta* (83.3%) were more frequent followed by *Hyptis suaveolens* (66.7%), *P. hysterophorus* (63.3%), *Phyllanthus* spp., (60%), *Boerhaavia diffusa* (56.7%), *Achyranthes aspera* and *Argyreia nervosa* (53.3%), *Cipadessa buccifera* (50%), *Calotropis procera* (43.3%), *Cassia auriculata* and *Rungia* spp., (33.3%) each. Less frequent species were *Aristida* spp., and *Solanum xanthocarpum* (17.7%) (Table 2).

Highest abundance value was observed in *Leucas aspera* (6.7) followed by *Sida acuta* (6.53), *C. bonplandianum* and *Rungia* sp., (5). Least was *Cipadessa baccifera* (1). Remaining species were abundant on an average scale.

Sida acuta population was found to be dense (5.7) followed by *C. bonplandianum* (5), *Celosia argentea* and *Hyptis suaveolens* (4) each. *Cipadessa baccifera* was least dense (0.33) in the locality. (Table 2).

Site 5 (site where *P. hysterophorus* was absent)

Alternanthera echinata, *Mollugo cerviana*, *Mollugo monophylla* and *Sida acuta* showed high frequency (80%) followed by *Acalypha indica, Euphorbia hirta, Amaranthus spinosus* (70%). Less frequency was seen for *Solanum nigrum* (30%) (Table 2).

The analyses of abundance shows that *Alternanthera echinata* was most abundant (17.75) followed by *Amaranthus speciosus* (11.75), *Indigofera linifolia* (10.8), *Desmodium triflorum* (10.75), *Mollugo monophylla* (10.57). *Trianthema portulacastrum* was least abundant (2.94). More densely populated plant species were *Sida acuta* (5.27) followed by *Phyllanthus amurus* (3.93), *Tribulus terrestris* (3.87), *Euphorbia hirta* (3.07), *Mollugo monophylla* (2.47), *Alternanthera echinata* (2.37) *etc.* Least densely populated species was *Portulacca olaracea* (0.7).

Table 1. Phytosociological attributes of native flora infested invasive alien weeds

Plants species	F (%)	A	D
Site 1: *C. odorata* infested area			
Achyranthus aspera	16.70	6.10	1.73
Argyreia nervosa	23.33	2.75	01.40
Calotropis procera	33.33	9.00	0.50
Cassia auriculata	23.33	3.57	1.03
Celosia argentea	16.70	5.91	3.00
Cipadessa buccifera	26.70	2.00	0.16
Croton bonplandianum	66.70	3.24	3.70
Hyptis suaveolens	50.00	6.78	3.63
Lettsomia sp.,	30.00	0.83	0.40
Leucas aspera	33.33	5.37	2.60
Parthenium hysterophorus	50.00	4.17	0.60
Sida acuta	66.70	6.28	2.70
Site 2: *P. hysterophorus* infested area			
Acalypha indica	16.70	5.60	0.70
Alternanthera echinata	13.33	20.70	2.03
Amaranthus speciosa	12.00	2.53	1.17
Amaranthus spinosus	16.70	13.40	0.73
Euphorbia hirta	13.33	8.10	2.63
Euphorbia prostrata	13.33	14.33	0.60
Indigofera linifolia	1.00	3.14	1.40
Mollugo cerviana	20.00	2.60	0.90
Phyllanthus amurus	10.00	5.00	2.60
Portulacca olaracea	10.00	7.00	0.40
Solanum nigrum	10.00	6.00	1.20
Tribulus terrestris	13.33	5.00	2.93
Zornia gibbosa	13.33	8.75	0.87
Site 3: *P. hysterophorus* infested area			
Abutilon indicum	33.33	5.35	2.60
Amaranthus spinosus	50.00	3.64	1.57
Argyreia pomacea	16.70	2.80	1.70
Canthium parviflorum	36.70	6.50	2.77
Cassia tora	33.33	6.30	5.27
Chenopodium album	26.70	7.84	4.03
Flacourtia indica	33.33	3.23	1.87
Melochia corchorifolia	66.70	5.80	1.40
Polycarpon prostratum	16.70	3.60	1.20
Portulaca olaracea	26.70	1.33	0.53
Sida acutangula	23.33	6.33	2.57
Sida rhomboideae	30.00	6.21	2.27
Tribulus terrestris	23.33	3.85	1.93
Trichodesma indicum	23.33	4.20	2.10

F= Frequency, A= Abundance, D=Density

Site 6 (site where *P. hysterophorus* was absent)

Highest frequency was exhibited by *Melochia corchorifolia* (83.3%) followed by *Amaranthus spinosus* (73.3%), *Canthium parviflorum, Cassia tora, Flacourtia indica* (66.7%). *Argyreia pomacea* (23.3%) was least frequent.

From the results it was evident that in non infested sites, most of the native flora fall under A-D (Site 4), A (Site 5), A-D (Site 6) frequency classes, hence the vegetation of local flora was semi heterogeneous. In infested sites, the native flora fall under A, B, C, D, E, hence was flora was categories as heterogeneous (Table 3 and 4).

Indian region has been at the receiving end of many exotic weeds ever-since the Portuguese settlement in India. While a vast majority of these have naturalized and appear to be the permanent denizens of native flora, yet a few have acquired invasive characters and have overtaken the native flora either completely killing these or drastically altering the native ecosystems in different biogeographic sites (Rao and Kavitha 2010).

On comparison of native plant species between infested and non infested sites, most of the medicinally important species like *Aristida* spp., *Boerhaavia diffusa, Phyllanthus* spp., *Solanum xanthocarpum* and *Rungia* spp. were not found in *C. odorata* invaded site 1.

Similarly at site 2 invaded by *P. hysterophorus*, disappearance of *Trianthema portulacastrum*, *Amaranthus speciosa, A. spinosus, Sida acuta, Mollugo monophylla* and *Desmodium triflorum* reflected the negative impact of *P. hysterophorus* on the survival of the native flora. Same was the case in site 3 infested with *P. hysterophorus* where *Chenopodium prostratum* and *Polycarpea corymbosa* were not found in all the three seasons. This clearly shows that approximately 30, 24 and 12% of the native vegetation was lost at site 1, 2 and 3, respectively. *C. odorata* and *P. hysterophorus* have interfered the growth and survival of native plant community which are highly medicinal in nature.

The invasiveness of *C. odorata* is attributed to the production of large quantities of propagules and also its capability to suppress the native vegetation through competative ability. Dominance of *P. hysterophorus* over other native flora throughout the year is due to its wide ecological amplitude. Ecological conditions in the study area like high soil moisture content, temperature around 25-30 °C and high humidity also supported the germination and growth of *P. hysterophorus. Parthenium* has been *reported* a C_3 type of plant, which has tendency to become a C_4 (Hegde and Patil 1982, Patil and Hegde 1983).

The plant species in both the sites (weed infested and non infested) differed in the frequency, abundance and density. This indicated that they have been severely affected by *C. odorata* and *P. hysterophorus*

Table 2. Phytosociological attributes of native flora in absence of invasive alien weeds

Plants species	F (%)	A	D
Site 4: Absence of *C. odorata*			
Achyranthus aspera	53.33	3.95	2.63
Argyreia nervosa	53.33	2.38	1.7
Aristida spp.,	16.7	1.2	1
Boerhaavia diffusa	56.7	2.7	1.33
Calotropis procera	43.33	5	0.83
Cassia auriculata	33.33	4.1	1.37
Celosia argentea	26.7	4.8	4
Cipadessa buccifera	50	1	0.33
Croton bonplandianum	86.7	5	5
Hyptis suaveolens	66.7	4	4
Lettsomia eliptica	40	1.33	0.7
Leucas aspera	46.7	6.7	6.7
Parthenium hysterophorus	63.33	3.33	1
Phyllanthus spp.	60	3.57	0.83
Rungia spp.,	33.33	5	1.33
Sida acuta	83.33	6.53	5.7
Solanum xanthocarpum	16.7	8	1.33
Site5: Absence of *P. hysterophorus*			
Acalypha indica	70	8	1.33
Alternanthera echinata	80	17.75	2.37
Amaranthus speciosa	40	11.75	1.57
Amaranthus spinosus	70	5.55	1.7
Desmodium triflorum	40	10.75	1.43
Euphorbia hirta	70	9.2	3.07
Euphorbia prostrata	60	8.33	0.83
Indigofera linifolia	50	10.8	1.8
Mollugo cerviana	80	4.75	1.27
Mollugo monophylla	80	10.57	2.47
Phyllanthus amurus	50	7.87	3.93
Portulacca olaracea	40	6.7	0.7
Sida acuta	80	6.7	5.27
Solanum nigrum	30	4.28	2.33
Trianthema portulacastrum	50	2.94	1.83
Tribulus terrestris	60	4.85	3.87
Zornia gibbosa	60	6.4	1.07
Site 6: Absence of *P. hysterophorus*			
Abutilon indicum	50	4.18	3.77
Amaranthus spinosus	73.33	8.8	2.93
Argyreia pomacea	23.33	5.91	2.37
Canthium parviflorum	66.7	8.64	4.03
Cassia tora	66.7	10.27	7.53
Chenopodium album	53.33	12.06	6.03
Chenopodium prostratum	60	4.76	2.07
Flacourtia indica	66.7	5.42	2.53
Melochia corchorifolia	83.33	5.7	2.47
Polycarpea corymbosa	20	4.1	2.73
Polycarpon prostratum	23.33	2.7	2.13
Portulaca olaracea	33.3	1.55	0.93
Sida acutangula	50	5.94	3.77
Sida rhomboidea	60	9.08	3.63
Tribulus terrestris	33.33	5.07	2.37
Trichodesma indicum	33.33	4.70	2.7

Table 3. Frequency classes of native flora in area infested with alien weeds

Site 1: *C. odorata* infested area		Site 2: *P. hysterophorus* infested area		Site 3: *P. hysterophorus* infested area	
Frequency classes	No. of species	Frequency classes	No. of species	Frequency classes	No. of species
1-20 A	2	1-20 A	13	1-20	2
21-40 B	6	21-40 B	0	21-40	10
41-60 C	2	41-60 C	0	41-60	1
61-80 D	2	61-80 D	0	61-80	1
81-100 E	0	81-100 E	0	81-100 E	0

Table 4. Frequency classes of native flora in the absence of invasive alien weeds

Site 4: Absence of *C. odorata*		Site 5: Absence of *P. hysterophorus*		Site 6: Absence of *P. hysterophorus*	
Frequency classes	No. of species	Frequency classes	No. of species	Frequency classes	No. of species
1-20	2	1-20	0	1-20	1
21-40	3	21-40	4	21-40	6
41-60	8	41-60	6	41-60	5
61-80	2	61-80	6	61-80	3
81-100	2	81-100	1	81-100	1

with regards to their growth and survival. Elimination of native flora is an indication that if these two invasive alien weeds are not checked at the earliest, there is a fear of losing many medicinally important plants from the area.

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Short communication

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Integrated weed management and crop establishment method for higher yield in direct-seeded rice

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In recent years, there has been a shift from transplanted rice to direct-seeded rice (DSR) cultivation in several countries of South East Asia (Pandey and Velasco 2002). At present, 23% of rice is direct-seeded globally (Rao *et al.* 2007). Heavy weed infestation is one of the major constraints in DSR causing severe yield losses which is the major bottleneck in DSR cultivation especially in dry field conditions (Harada *et al.* 1996, Rao*et al.* 2007). Yield losses due to weeds varied from 40-100% in direct-seeded rice (Choubey *et al.* 2001). Rice establishment methods plays an important role in influencing weed and crop growth and productivity. Mahajan and Chauhan (2011) observed that paired row planting pattern (15-30-15-cm row spacing) in DSR had a great influence on weeds as compared to normal row planting system (23-cm row spacing). Paired row planting greatly facilitates weed suppression by maintaining rice plant's dominant position over weeds through modification in canopy structure. At the same time Roy *et al.*(2009) reported that the yield of direct seeding of rice can be enhanced with square planting (20 x 20 cm) of rice.

Most of the herbicides recommended for DSR are applied as pre-emergence to control weeds during initial period, however, a combination of herbicides may be more effective to control various flushes of weed in DSR. In DSR, use of butachlor (1.5 kg/ha), pendime-thalin (1.2 kg/ha) and anilophos (0.4 kg/ha) as pre-emergence are recommended for the control of grassy weeds (Gogoi and Sharma 1993). Mehta *et al.* (2010) reported good control of *Echinochloa crusgalli* with application of bispyribac-Na 30 g/ha. Azimsulfuron 17.5 g/ha is effective in controlling broad-leaf weeds and sedges including *Cyperus rotundus*. Therefore, for mixed type of weed flora, it can be tank mixed with other herbicide to target broad spectrum weed control. Keeping above facts in view, an experiment was conducted to study the effect of rice establishment and integrated weed management practices on weeds and the crop growth in direct-seeded rice.

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A field trial was conducted at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India) during *Kharif* 2012. The Agricultural Research Farm, is located in at $25^0$18'N latitude and $88^0$36'E latitude at an altitude of 129 metres above the mean sea level in the Northern Gangetic alluvial plains. Climatologically, Varanasi district has a subtropical climate and is subjected to extremes of weather conditions *i.e.*, extremely hot summer and cold winter. The area also receives some winter showers due to western disturbances during December to February. The maximum temperature usually fluctuates between 22 °C and 40.7 °C while minimum temperature varies from 8.6-29.9 °C. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction (pH 7.56) with low organic carbon content (0.43%), low available nitrogen (183.63 kg/ha), phosphorus (18.64kg/ha) and potassium (218.86 kg/ha) in which rice cultivar '*MTU 7029*' was dry direct seeded and the experiments were laid out in split plot design on 28^{th} June 2012 with 20 treatment combinations replicated thrice.

Main plot consisted five rice establishment treatments, *viz.* i) Conventional tillage normal spacing (R × R -18 cm); ii) Conventional tillage square planting (R × R-20 cm, P × P-20 cm); iii) Conventional tillage paired row (9-27-9 cm); iv) Reduced tillage paired row (9-27-9 cm); v) Reduced tillage square planting (R × R -20 cm, P×P-20 cm) and sub-plot consisted of four weed management treatments, *viz.* weedy, two hand weeding, pendimethalin 1 kg/ha *fb* azimsulfuron 17.5 g/ha *fb* bispyribac 25 g/ha (tank mixed) at 15 DAS *fb* 1 HW, oxadiagryl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha at 20 DAS *fb* 1 HW. All the standard practices were adopted to raise the crop. Biometric observations on weed growth parameters, crop growth attributes and yield were recorded to ascertain significant results.

The minimum weed density and weed biomass at 60 days stage was recorded under reduced till square

Table 1. Effect of rice establishment method and weed management on weed growth at 60 DAS, yield attributes, and yield of direct-seeded rice

Treatment	Weed density (no./m²)**	Weed biomass (g/m²)	Plant height (cm)	Number of tillers/m²	Dry matter accumulation (g/running m)	Panicle length (cm)	No. of panicle/ m²	Number of grains /panicle	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Rice establishment method											
CT-Normal spacing	7.1(67.7)	16.6(371)	51.0	223.6	48.1	24.9	413.7	115.0	23.5	5.84	8.40
CT-Square planting	7.2(66.2)	15.8(333)	50.1	217.8	38.3	25.2	427.7	116.9	23.3	5.72	7.77
CT-Paired row	7.6(70.5)	14.7(286)	50.7	244.8	47.8	24.7	481.0	115.8	24.2	5.91	9.07
RT-Paired Row	6.9(62.7)	13.7(249)	49.9	244.0	33.0	24.9	382.3	109.8	22.2	5.72	8.43
RT-Square planting	6.3(49.0)	13.0(226)	49.6	207.3	34.9	25.0	350.3	119.0	22.4	5.11	6.51
LSD (P=0.05)	0.50	0.34	NS	9.90	1.14	NS	17.81	3.90	0.61	0.467	1.59
Weed management											
Weedy	12.3(151)	23.9(575)	47.7	159.9	29.5	25.0	315.2	89.5	22.3	2.80	6.92
Two hand weeding	5.7(33.1)	14.3(205)	53.1	287.1	53.4	25.2	474.4	131.9	25.0	7.20	8.74
Pendimethalin *fb* azimsulfuron + bispyribac 15 DAS *fb*1HW	6.5(42.4)	15.6(245)	51.1	235.4	43.5	25.1	446.7	125.1	23.2	6.59	8.37
Oxadiagryl *fb* metsulfuron-methyl + chlorimuron-ethyl 20 DAS *fb* 1HW	7.4(55.3)	18.0(293)	49.2	227.5	35.3	24.5	407.7	114.7	22.0	6.05	8.12
LSD (P=0.05)	0.28	0.29	0.75	9.71	1.99	0.44	13.54	3.60	0.55	0.38	1.13

*CT = Conventional tillage, RT = Reduced tillage, HW = Hand weeding, *fb*= followed by, DAS = Days after seeding

**values given in parentheses are original means

planting which was found significantly lesser than rest of rice establishment methods (Table 1). Whereas amongst weed management practices, pendimethalin 1 kg/ha *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ ha 15 DAS *fb* 1HW significantly reduced weed density and weed biomass in comparison to oxadiagryl 50 g/ha *fb* metsulfuron-methyl 2 g/ha+ chlorimuron-ethyl 2 g/ha 20 DAS *fb* 1 HW**.** Two hand weeding significantly reduced weed density and weed biomass as compared to rest of the weed management treatments.

Variations in plant height were non-significant due to rice establishment methods. However, conventional till paired row planting and reduced till paired row had comparable number of tillers/m² and both these treatments were found significantly better than square planting under reduced and conventional till method of rice establishment. In case of dry matter (g/plant) accumulation, conventional till normal spacing and CT paired row had significantly more dry matter accumulation than square planting method of rice sowing under both conventional till (CT) and reduced till (RT). All the weed management treatments recorded significantly taller plants. Two hand weeding recorded significant higher values of plant height, number of tillers/m², dry matter accumulation followed by azimsulfuron 17.5 g/ ha + bispyribac 25 g/ha *fb* 1 HW and metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha *fb* 1 HW.

Observations on panicle length data were non-significant as influenced by rice establishment methods. CT paired row recorded the maximum number of panicles/m² and test weight and it was found significantly better than all the rice establishment methods. RT square planting, CT paired row and CT square planting recorded statistically comparable number of grains/panicle and it was significantly superior than RT paired row, where as in case of grain and straw yield, CT paired row was statistically at par with CT normal spacing, CT square planting and RT paired row. The maximum gain and straw yields were recorded under weed free which was found significantly better than all the weed management treatments. Amongst weed management practices, pendimethalin 1 kg/ha *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha *fb* 1 HW recorded higher values of yield attributing characters and yield, *viz.* number of panicles/m², number of grains/panicle, test weight and grain yield and it was found significantly better than oxadiagryl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ha *fb* 1 HW, however, in case of panicle length it was at par with all the weed management treatments.

SUMMARY

A field trial was conducted during *Kharif* 2012 at Agricultural Research Farm, Institute of Agricultural sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India) to study effect of rice establishment

and integrated weed management practices on weed growth and grain yield. Pendimethalin 1.0 kg/ha *fb* azimsulfuron 17.5 g/ha + bispyribac 25 g/ha 15 DAS *fb* 1 HW significantly reduced weed density and weed biomass in comparison to oxadiagryl 50 g/ha *fb* metsulfuron-methyl 2 g/ha + chlorimuron-ethyl 2 g/ ha 20 DAS *fb* 1 HW. Rice grain yield in CT paired row was statistically at par with CT normal spacing, CT square planting and RT paired row. It was significantly higher as compared to RT square planting. Amongst weed management practices, pendimethalin 1 kg/ha *fb* azimsulfuron 17.5 g/ha + bispyribac 25g/ha *fb* 1HW recorded higher rice grain yield attributing characters *viz*. number of panicles/m^2, number of grains/panicle, test weight and grain yield and it was found significantly better than oxadiagryl 50 g/ha *fb* metsulfuron methyl 2g/ha+ chlorimuron-ethyl 2g/ha *fb* 1 HW.

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Short communication

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Weed control in wet-seeded rice by post-emergence herbicides

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Crop-weed competition is one of the prime yield limiting biotic constraints resulting in yield reduction in rice. Among the various systems of cultivation of rice, direct- seeding of sprouted seeds in puddled soil (wet-seeded rice) offers a good alternative stand establishment practice to transplanting system. It reduces labour cost and give yield similar to transplanting, making it more economical. But weed problems are more critical in direct seeding (Moorthy and Saha 2002) contributing to a yield loss of 40 to 100% (Choubey *et al.* 2001). Among the various weed control measures, use of chemical herbicides is the most common practice as it is easier, time and labour saving, and economical compared to hand weeding (Rekha *et al.* 2003). For controlling mixed flora of weeds emerging during the early stages of crop growth, application of herbicides are needed. Hence a viable recommendation would be a single application of a broad spectrum herbicide or a herbicide combination. Continuous use of same herbicide may lead to herbicide resistance in weeds and so the rotational use of different herbicides are essential for effective weed control. Therefor, the present study was conducted to evaluate the efficacy of various new post-emergence herbicides and herbicide combinations for weed control in wet-seeded rice, to find out the most effective herbicide or herbicide combination for cost effective weed control and to assess the response of rice and its major weeds to new herbicides.

A field experiment was conducted during *Mundakan* season (2011 to 2012) in a farmer's field at Alappad in the Kole lands (10^0 31' N latitude and $76^0$13' E longitude and 1m below mean Sea level) of Thrissur district using the rice variety *'Jyothi'*. The soil was clayey with pH 5.5, organic content 2.1%, available P and K 26 and 281 kg/ha, respectively. The experiment comprised of 13 treatments, *viz.* post-emergence spray of metamifop, metamifop with a follow up spray of carfentrazone ethyl, metamifop with a follow up spray of chlorimuron-ethyl +metsulfuron methyl, cyhalofop-butyl, cyhalofop-butyl with a follow up spray of chlorimuron-ethyl + metsulfuron-methyl, fenoxaprop-p-ethyl, fenoxaprop-p-ethyl with a follow up spray of chlorimuron-ethyl + metsulfuron-methyl, fenoxaprop-p-ethyl with a follow up spray of ethoxysulfuron, bispyribac-sodium, penoxsulam, azimsulfuron, unweeded control and hand weeded checks. The trial was laid out in randomized block design with three replications.

All herbicides were sprayed at 20 days after sowing (DAS) with follow up spray on next day using knapsack sprayer. Data on weed biomass and N, P and K content of weeds (at 30 DAS, 60 DAS and harvest) and yield attributes were recorded. Weed control efficiency (WCE), weed index (WI) and economics of production were also calculated. Data on weed biomass, which showed wide variation, was subjected to square root transformation ($\sqrt{x + 0.5}$) to make the analysis of variance valid (Gomez and Gomez, 1984). Multiple comparisons among treatment means, where the F-test was significant (at 5% level) were done with Duncan's Multiple Range Test (DMRT).

Major weed species found in experimental plot were grasses which comprised of *Echinochloa colona, Echinochloa crusgalli, Echinochloa stagnina* and *Leptochloa chinensis. Ludwigia perennis, Lindernia crustacea, Monochoria vaginalis, Sphaeranthes indicus* and *Alternanthera* sp. were the broad-leaved weeds and *Fimbristylis mileacea, Cyperus iria* and *Cyperus difformis* were the sedges present.

A weed biomass of 33-38 kg/ha was registered in plots sprayed with fenoxaprop p-ethyl, metamifop and cyhalofop-butyl at 30 DAS. The highest weed biomass of 350 kg/ha was recorded in unweeded control. By 60 DAS, weed biomass quadrupled in unweeded control with 1300 kg/ha and the lowest weed biomass (43 kg/ha) was noticed in hand weeded plots followed by bispyribac -sodium (129 kg/ha) (Table 1). There was an increase in dry weight from 1300 to 2280 kg/ha in unweeded plot.

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Very low N uptake of 1.5 kg/ha was noticed in bispyribac-sodium sprayed plots at 60 DAS which was only one-twelfth of the uptake registered in unweeded control. A maximum uptake of 41 kg/ha was observed in unweeded control at the harvesting stage of the crop which was double compared to uptake at 60 DAS. Minimum uptake of 0.6 kg/ha was noticed in hand weeded plot followed by 1.6 kg/ha in bispyribac-sodium.

At 30 DAS, the highest number of tillers was in hand weeded plot which was at par with penoxsulam, fenoxaprop p-ethyl + chlorimuron-ethyl+ metsulfuron methyl, cyhalofop-butyl, fenoxaprop-p-ethyl + ethoxysulfuron and metamifop + carfentrazone-ethyl. However at 60 DAS, tiller count in hand weeded control (592/m^2) was significantly superior to all other treatments (Table 2).

The maximum number of productive tillers was also recorded in hand weeded treatment (215/m^2) and minimum was noticed in unweeded control with 156/m^2. Maximum grains/panicle of 112 was recorded in hand weeded treatment as well as in cyhalofop-butyl + chlorimuron-ethyl + metsulfuron-methyl (Table 2). There was no significant difference between treatments for 1000 grain weight (test weight) of grains.

The highest grain yield of 6.13 t/ha was recorded in hand weeded plot which was at par with cyhalofop-butyl + chlorimuron-ethyl + metsulfuron-methyl and fenoxaprop + chlorimuron-ethyl + metsulfuron-methyl (5.8 t/ha) and lowest yield of 4.03 t/ha was obtained in unweeded control (Table 2). Abraham *et al.* (2012) also reported about the efficacy of fenoxaprop in direct-seeded rice. In the case of straw, the highest yield was obtained in hand weeding with 5.83 t/ha and lowest in unweeded control with 4.37 t/ha.

Regarding economics of production, among different treatments, maximum B: C ratio of 1.8 was obtained in cyhalofop-butyl + chlorimuron-ethyl+ metsulfuron-methyl, fenoxaprop-p-ethyl + chlorimuron-ethyl + metsulfuron-methyl, bispyribac-sodium and fenoxaprop-p-ethyl alone. Although hand weeded treatment resulted in a net profit of ` 63,075/ha, but B:C ratio was reduced to 1.4 due to high cost of cultivation (` 45,825/ha) and the least B:C ratio of 1.2 was noted in unweeded control.

The treatment bispyribac-sodium showed highest weed index of 6.1 compared to other treatments followed by cyhalofop-butyl + chlorimuron-ethyl + metsulfuron-methyl and fenoxaprop-p-ethyl +

Table 1. Effect of various post-emergence herbicides on weed biomass and nutrient uptake (kg/ha) by weeds

Treatment	Weed biomas			N uptake			P uptake			K uptake		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
Metamifop	*6.09^{b} (36.67)	17.94^{d} (321.33)	18.22^{d} (332.00)	*1.19^{bc} (0.93)	2.02^{d} (3.59)	2.21^{fg} (4.43)	*0.76^{c} (0.09)	1.20^{b} (0.96)	1.22^{e} (1.0)	*1.30^{b} (1.19)	2.28^{de} (4.71)	2.19^{g} (4.30)
Metamifop + carfentrazone-ethyl	0.71^{c} (0)	18.35^{cd} (336.33)	21.44^{c} (459.33)	0.71^{d} (0)	2.17^{bc} (4.24)	2.57^{cd} (6.15)	0.71^{c} (0)	1.14^{d} (0.80)	1.35^{c} (1.33)	0.71^{c} (0)	2.42^{bc} (5.37)	2.79^{de} (7.30)
Metamifop + chlorimuron ethyl+ metsulfuron methyl	0.71^{c} (0)	18.59^{c} (345.00)	21.11^{c} (445.33)	0.71^{d} (0)	1.93^{e} (3.23)	2.67^{bc} (6.68)	0.71^{c} (0)	1.08^{f} (0.67)	1.35^{c} (1.33)	0.71^{c} (0)	2.22^{e} (4.45)	2.67^{e} (6.67)
Cyhalofop-butyl	6.25^{b} (38.67)	18.59^{c} (345.00)	19.24^{d} (370.00)	1.21^{b} (0.97)	2.16^{c} (4.17)	2.35^{cf} (5.05)	0.92^{b} (0.38)	1.10^{e} (0.72)	1.27^{d} (1.13)	1.32^{b} (1.23)	2.45^{b} (5.51)	2.67^{e} (6.64)
Cyhalofop-butyl + chlorimuron ethyl+ metsulfuron-methyl	0.71^{c} (0)	13.24^{f} (175.00)	16.5^{e} (272.00)	0.71^{d} (0)	1.76^{f} (2.62)	1.98^{h} (3.45)	0.71^{c} (0)	0.85^{j} (0.22)	1.14^{f} (0.81)	0.71^{c} (0)	1.61^{g} (2.09)	2.50^{f} (5.77)
Fenoxaprop p-ethyl	5.81^{b} (33.33)	15.38^{e} (236.00)	18.22^{d} (332.00)	1.11^{c} (0.74)	1.75^{f} (2.58)	2.12^{gh} (4.0)	0.77^{c} (0.10)	0.98^{g} (0.47)	1.21^{e} (0.93)	1.27^{b} (1.12)	1.85^{f} (2.93)	2.46^{f} (5.60)
Fenoxaprop-p-ethyl + chlorimuron-ethyl + metsulfuron-methyl	0.71^{c} (0)	12.46^{g} (155.00)	15.08^{f} (227.33)	0.71^{d} (0)	1.58^{g} (2.0)	1.94^{h} (3.27)	0.71^{c} (0)	0.90^{h} (0.31)	1.07^{g} (0.65)	0.71^{c} (0)	1.51^{h} (1.81)	2.28^{g} (4.73)
Fenoxaprop-p-ethyl + ethoxysulfuron	0.71^{c} (0)	19.56^{b} (382.00)	21.73^{c} (472.00)	0.71^{d} (0)	2.25^{b} (4.58)	2.48^{de} (5.66)	0.71^{c} (0)	1.17^{c} (0.87)	1.39^{c} (1.43)	0.71^{c} (0)	2.41^{bc} (5.33)	2.91^{cd} (8.0)
Bispyribac-sodium	0.71^{c} (0)	11.39^{h} (129.33)	12.07^{g} (146.00)	0.71^{d} (0)	1.40^{h} (1.48)	1.46^{i} (1.66)	0.71^{c} (0)	0.87^{i} (0.26)	0.94^{h} (0.40)	0.71^{c} (0)	1.45^{h} (1.63)	1.53^{h} (1.86)
Penoxsulam	0.71^{c} (0)	19.56^{b} (382.00)	23.23^{b} (539.33)	0.71^{d} (0)	2.25^{b} (4.58)	2.74^{bc} (7.03)	0.71^{c} (0)	1.12^{e} (0.76)	1.44^{b} (1.60)	0.71^{c} (0)	2.24^{e} (4.55)	2.93^{c} (8.10)
Azimsulfuron	0.71^{c} (0)	18.31^{cd} (335.00)	23.35^{b} (544.67)	0.71^{d} (0)	2.20^{bc} (4.37)	2.84^{b} (7.60)	0.71^{c} (0)	1.15^{d} (0.83)	1.46^{b} (1.63)	0.71^{c} (0)	2.34^{cd} (5.01)	3.11^{b} (9.23)
Unweeded control	18.71^{a} (350.00)	36.06^{a} (1300.00)	47.75^{a} (2280.00)	2.99^{a} (8.50)	4.32^{a} (18.20)	6.44^{a} (41.04)	1.09^{a} (0.70)	1.93^{a} (3.25)	2.70^{a} (6.84)	2.96^{a} (8.23)	4.17^{a} (16.90)	6.62^{a} (43.33)
Handweeded control	0.71^{c} (0)	6.59^{i} (43.00)	8.11^{h} (65.33)	0.71^{d} (0)	0.98^{i} (0.47)	1.05^{j} (0.61)	0.71^{c} (0)	0.76^{k} (0.08)	0.78^{i} (0.11)	0.71^{c} (0)	1.00^{i} (0.51)	1.08^{i} (0.68)

* $\sqrt{x + 0.5}$ transformed values, Original values in parentheses. In a column, means followed by common letters do not differ significantly at 5% level by DMRT. DAS – Days after sowing

Table 2. Effect of various post-emergence herbicides treatments on tiller count, yield attributes, yield, economics of cultivation, weed index (WI) and weed control efficiency (WCE)

Treatment	Tiller count 60 DAS (no./m^2)	Panicles (no./m^2)	Filled grains/ panicle (no.)	Grain yield (t/ha)	Straw yield (t/ha)	Total cost (x10^3 `/ha)	Net profit (x10^3 `/ha)	B:C ratio	WI	WCE (%)
Metamifop	530.0^{de}	187.00^{de}	102.00^{abc}	5.13^{ef}	5.60^{abcd}	36.15	57.15	1.6	16.3^{bc}	85.4^{e}
Metamifop+ carfentrazone ethyl	541.7^{cd}	187.33^{de}	109.00^{ab}	5.20^{def}	5.37^{def}	37.89	56.31	1.5	15^{bcd}	79.8^{f}
Metamifop + chlorimuron-ethyl + metsulfuron-methyl	554.0^{bc}	189.00^{d}	102.00^{abc}	5.50^{bcd}	5.20^{ef}	37.47	60.62	1.6	9.9^{def}	80.5^{f}
Cyhalofop-butyl	524.7^{de}	191.33^{cd}	101.67^{bc}	5.37^{cde}	5.47^{cde}	35.68	61.81	1.7	12.3^{cde}	83.8^{e}
Cyhalofop-butyl +chlorimuron-ethyl + metsulfuron-methyl	556.0^{bc}	196.33^{bc}	112.00^{a}	5.80^{ab}	5.67^{abc}	37.01	67.09	1.8	5.2^{fg}	88^{d}
Fenoxaprop p-ethyl	527.0^{de}	191.00^{cd}	105.00^{abc}	5.60^{bc}	5.17^{f}	35.35	64.25	1.8	8.4^{ef}	85.4^{e}
Fenoxaprop p-ethyl + chlorimuron-ethyl + metsulfuron-methyl	554.7^{bc}	198.33^{b}	110.00^{ab}	5.80^{ab}	5.10^{f}	36.67	65.63	1.8	5.2^{fg}	90^{c}
Fenoxaprop-p-ethyl + ethoxysulfuron	509.7^{e}	182.33^{e}	96.00^{cd}	5.10^{ef}	5.80^{ab}	36.91	56.99	1.5	16.6^{bc}	79.3^{f}
Bispyribac-sodium	564.3^{b}	191.00^{cd}	105.67^{abc}	5.73^{b}	5.37^{def}	36.14	65.56	1.8	6.1^{f}	93.6^{b}
Penoxsulam	554.3^{bc}	190.67^{cd}	100.00^{bcd}	5.33^{cde}	5.50^{cd}	35.89	60.10	1.7	12.9^{cde}	76.3^{g}
Azimsulfuron	517.3^{e}	175.33^{f}	100.33^{bcd}	4.90^{f}	5.53^{bcd}	35.07	54.92	1.6	19.9^{b}	76.1^{g}
Unweeded control	394.0^{f}	156.67^{g}	91.00^{d}	4.03^{g}	4.37^{g}	32.82	40.37	1.2	33.8^{a}	-
Handweeded control	592.0^{a}	215.00^{a}	112.00^{a}	6.13^{a}	5.83^{a}	45.82	63.07	1.4	-	97.1^{a}

In a column, means followed by common letters do not differ significantly at 5% level by DMRT

chlorimuron-ethyl + metsulfuron-methyl (5.2). Maximum weed control efficiency of 97.1% was obtained in hand weeded plots followed by bispyribac-sodium (93.6%) and fenoxaprop p-ethyl + chlorimuron ethyl+ metsulfuron-methyl (90%). Ramachandiran and Balasubramanian (2012) also reported about the higher weed control efficiency of fenoxaprop-p-ethyl + chlorimuron-ethyl + metsulfuron-methyl in aerobic rice.

SUMMARY

An experiment was conducted at Kole lands in Thrissur district, Kerala to study the efficacy of various post-emergence herbicides in wet-seeded rice. The results showed that cyhalofop-butyl + chlorimuron-ethyl+ metsulfuron-methyl, fenoxaprop-p-ethyl + chlorimuron-ethyl+ metsulfuron-methyl and bispyribac-sodium were best treatments with a lower weed biomass as well as high grain yield and B:C ratio. Maximum weed control efficiency of 97.1% was obtained in hand weeded plots followed by bispyribac-sodium (93.6%). The highest grain yield of 6.13 t/ha was recorded in hand weeded plot which was at par with cyhalofop-butyl + chlorimuron-ethyl + metsulfuron-methyl and fenoxaprop + chlorimuron ethyl+ metsulfuron-methyl (5.8 t/ha). From this study it can be concluded that, cyhalofop-butyl with a follow up spray of chlorimuron-ethyl + metsulfuron-methyl or fenoxaprop-p-ethyl with a follow up spray of chlorimuron-ethyl + metsulfuron methyl or bispyribac sodium alone can be recommended for effective post emergence weed control and higher yield in wet seeded rice. If grasses are the predominant weeds, cyhalofop-butyl or fenoxaprop-p-ethyl alone without follow up spray of chlorimuron-ethyl + metsulfuron-methyl can also be recommended.

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Short communication

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Integrated weed management in dry-seeded rice

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Rice is the major *Kharif* crop of India covering 42.8 million ha area and amounting to 85.7 million tonnes of production (Anonymous 2012). The conventional system of rice production *i.e*. transplanting under puddled conditions (CT-TPR) is mainly followed by farmers. However, it is water, labour, and energy intensive, besides adversely affecting the environment. Therefore, to assure sustainability of rice production, more resource efficient alternative methods of rice cultivation are needed. For this reason, dry-seeded rice (DSR) technology being water, labour, energy efficient, and having eco-friendly characteristics, received much attention, and is emerging as a potential alternative to CT-TPR (Kumar and Ladha 2011). However, weed control is major limitation for the success of DSR (Chauhan and Yadav 2013). Aerobic systems are sub ject to much higher weed pressure than CT-TPR (Rao *et al.* 2007) in which weeds are suppressed by standing water, and transplanted rice seedlings, which have a''head start'' over germinating weed seedlings. Therefore, the present investigation was undertaken to find out suitable weed management practices in DSR. The hypothesis was that sequential application of pre-emergence (PRE) herbicides and post-emergence (POE) herbicides followed by (*fb*) handweeding (HW) will provide a season long weed control in DSR.

A field experiment was conducted during the *Kharif* season of 2011 at Chaudhary Charan Singh Haryana Agricultural University, Regional Research Station, Karnal, India. The soil of experimental plot was clay loam in texture, with slight alkaline reaction (pH 8.2), medium organic carbon (0.40%), low available nitrogen (115 kg/ha), and medium available phosphorus (9 kg P/ha), and potassium (112 kg K/ha). The experiment was laid out in split-plot design with three replications. The treatments comprised of four seed rates,*viz*.10, 17.5, 25 and 32.5 kg/ha which were assigned to main plots,and five weed control methods,*viz*. weedy check (W_1), weed free (W_2), pendimethalin 1.0 kg/ha as pre-emergence (PE) *fb* bispyribac-sodium 25 g/ha +ready-mixchlorimuron +metsulfuron 4 g/ha as post-emergence (POE) at 30 days after sowing (DAS) *fb* one HW 60 DAS (W_3), pendimethalin 1.0 kg/ha PE *fb* cyhalofop 200 g/ha POE 30 DAS *fb* ready-mix chlorimuron + metsulfuron 4 g/ha 35 DAS *fb* one HW 60 DAS (W_4) and pendimethalin 1.0 kg/ha PE *fb* fenoxaprop 60 g/ha POE 30 DAS *fb* ready-mixchlorimuron + metsulfuron 4 g/ha 35 DAS *fb* one HW 60 DAS (W_5) were allotted to sub-plots. Basmati rice variety *'CSR –30'* was seeded on 10th June 2011 under dry condition in rows 20 cm apart using limit-plot seed drill. The herbicides were sprayed uniformly with Knapsack sprayer fitted with flat fan nozzle calibrated to deliver 500 l/ha water volume. Species-wise weed density (no./m^2) and weed biomass (g/m^2) were recorded by putting a quadrat (0.25 m^2) at three random spots in each plot at 30, 60, 90 and 120 DAS. Data on weed density and biomass of weeds were transformed using square-root transformation ($\sqrt{x+0.5}$) before statistical analysis and weed control efficiency (WCE) was calculated on the basis of weed biomass.

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Effect on weeds

The weed flora observed in the experimental field included *Echinochloa colona, E. glabrescens, Leptochloa chinensis, Dactyloctenium aegyptium, Cyperus iria, C. difformis, Fimbristylis miliacea, Eclipta alba, Ammania baccifera, Digera arvensis, Lindernia crustacean,* and *Mazus pumilus.* All the weed control treatments significantly reduced the weed density and biomass over weedy check. Among the weed control methods, W_3 (PE application of pendimethalin 1.0 kg/ha *fb* bispyribac 25 g/ha + ready-mix chlorimuron + metsulfuron 4 g/ha at 30 DAS *fb* one HW at 60 DAS), recorded significantly lower weed density, weed biomass and higher WCE of 82% at 60 DAS compared to other treatments (Table 1). Pre-emergence application of pendimethalin controlled only grasses, few broad-leaf weeds but not sedges, as also reported by Yaduraju and Mishra (2004). Whereas POE of bispyribac-sodium 25 g/ha 30 DAS effectively controlled all three types of weeds *i.e*., grasses, broad-leaved and sedges. These findings are in conformity with Brar and Bhullar (2012).

Table 1. Effect of treatments on total weed density, weed biomass, WCE and rice grain yield at different stages of rice crop growth

Treatment	Stages of rice crop growth (DAS)				Weed control efficiency (WCE)	Grain yield (t/ha)
	Weed density (no./m^2)		Weed biomass (g/m^2)			
	60	120	60	120	60	
Seed rate (kg/ha)						
S_1	15.14 (317.8)	7.30 (109.2)	13.90(293)	8.70(178)	66.5	1.57
S_2	13.70 (258.1)	6.23 (77.3)	12.30 (218)	7.20 (116)	66.3	2.14
S_3	12.32 (208.0)	5.50 (58.2)	11.10 (184)	6.30 (85)	65.8	2.24
S_4	11.30 (174.9)	4.73 (42.3)	10.00 (148)	5.40 (61)	66.2	2.27
LSD (P=0.05)	0.14	0.12	0.19	0.09	NS	0.16
Weed control						
W_1	26.50 (711.0)	17.70 (321.1)	26.90 (734)	22 (507)	0	0.28
W_2	1.00 (0.0)	1.00 (0.0)	1.00 (0)	1.00 (0)	100.0	2.73
W_3	11.31 (130.1)	3.60 (12.0)	9.10 (85.00)	3.70 (13)	81.9	2.63
W_4	13.10 (147.1)	3.60 (12.1)	10.80 (108)	3.80 (14)	75.6	2.48
W_5	13.61 (185.4)	3.70 (13.6)	11.30 (128)	3.90 (15)	73.4	2.16
LSD (P=0.05)	0.12	0.18	0.22	0.38	0.4	0.14

*Original values are in parentheses and before statistical analysis were subjected to square root transformation $(\sqrt{x+1})$

The increase in seed rate also resulted in a significant decrease in the total weed density and total weed biomass at all the stages of crop growth (Table 1). With increase in seed rate the number of crop plants per unit area was higher, giving them competitive advantage over existing weeds. These findings are in agreement with the reports of Gill (2008). The treatment combinations of W_3 with all the seed rates resulted in highest WCE compared to all other treatment combinations and highest WCE was recorded with W_3S_4.

Effect on rice

All weed control treatments resulted in significantly higher rice grain yield than weedy check. Rice crop growth and yield contributing characters were affected adversely due to weedy condition which resulted in 90% loss of rice grain yield. The rice grain yield produced with pendimethalin 1.0 kg/ha pre-emergence (PE) *fb* bispyribac-sodium 25 g/ha + ready-mix chlorimuron + metsulfuron 4 g/ha post-emergence (POE) at 30 DAS *fb* one hand weeding (HW) 60 DAS treatment was statistically at par with that of weed free treatment. Among treatment combinations, pendimethalin 1.0 kg/ha pre-emergence (PE) *fb* bispyribac-sodium 25 g/ha + ready-mix chlorimuron + metsulfuron 4 g/ha post-emergence (POE) at 30 DAS *fb* one hand weeding (HW) 60 DAS with all rice seed rates (10, 17.5, 25 and 32.5 kg/ha) produced more grain yield as compared to other treatment combinations. However, with increment in seed rate beyond 17.5 kg/ha with all weed control methods did not increase the grain yield significantly. The increase in rice grain yield over weedy check due to different treatments was attributed to the reduced density and biomass of weeds at all stages of crop growth, which resulted in increased dry matter production of rice, number of panicles per square metre, number of grains per panicle and 1000 grain weight.

SUMMARY

The present study revealed that weeds cause a rice yield loss of about 90% in dry-seeded rice and the integrated approach to control weeds based on PE application of pendimethalin 1.0 kg/ha *fb* POE bispyribac-sodium 25 g/ha + ready-mix chlorimuron + metsulfuron 4 g/ha 30 DAS *fb* one HW 60 DAS was found to be best with WCE of 82%. Increase in rice seed rate from 10 to 32.5 kg/ha resulted in decrease in weed density and weed biomass but the rice yield increase beyond 17.5 kg/ha seed rate was non-significant. Therefore, rice seed rate of 17.5 kg/ha was found optimum for DSR, however it needs further investigation and confirmation.

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Short communication

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Yield performance of zero-till wheat with herbicides in rice-wheat cropping system

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Key words: Chemical control, Herbicide, Rice-wheat cropping system, Weeds, Zero tillage

Rice-wheat is the most predominant cropping system of India with an area of 13.0 m ha. Twenty five per cent of the rice area of country is grown in rotation-involving wheat, whereas 40% of the wheat is grown in rotation with rice. The productivity of this system is stagnating or declining, which is causing concern about sustainability of rice–wheat production system. The major constraints for wheat are poor crop stand, late planting, poor soil condition due to puddling, imbalance use of fertilizer, problem of weeds specially *Phalaris minor, Avena ludoviciana*, high cost of production due to excess tillage *etc*. Sowing of wheat crop under conventional tillage gets delayed by 10 to 12 days, affecting the yield adversely. The reduction in wheat yield due to delay in sowing has been recorded as one per cent of total yield/ha/day (Pal *et al*. 1996). Zero till drill machine is able to sow the wheat crop after the harvest of transplanted rice in standing rice stubbles.

It has been observed that zero tillage technique not only avoids the problem of delayed sowing but also reduces the incidence of *P. minor* and *A. ludoviciana*, which are most obnoxious weeds of wheat. Zero tillage has certain other advantages like improving soil health and reducing the cost of production. Sulfosulfuron + metsulfuron (MSM) and fenoxaprop-p-ethyl have been mostly used for control of weeds in conventional tillage system of wheat, whether its performance remain same or not in canal command areas under zero tillage, needs confirmation. Therefore, on-farm trials were carried out to evaluate the efficiency of herbicides and to observe the performance and profitability of zero tillage under clay loam soils in wheat at farmers' fields.

Ten on-farm trials were conducted for the two consecutive years during *Rabi* season 2007-08 and 2008-09 at randomly selected locations which come preferably under canal command area (village- Sikraur and Khemaupur of district Azamgarh, UP). The soils of experimental sites were clay loam with normal in reaction and available nitrogen and phosphorus were at lower side while potash represents its richness. The zero tillage (ZT) consisted of direct drilling of wheat seed (100 kg/ha) and di-ammonium phosphate (125 kg/ha) by zero till seed-cum-ferti drill machine without any field preparation in presence of excessive moisture condition and anchored rice residues. However, conventional tillage (CT) consisted of four to five ploughing and more than two planking for fine tilth. A set of two tillage practices like conventional tillage and zero tillage were evaluated with sulfosulfuron 75% + MSM 5% WG (40 g/ha) and fenoxaprop-p-ethyl (10 EC) 1000 ml/ha applied at 25 days after sowing (DAS) with flat fan nozzle using 500 litre water/ha. The prevailing sale rate of wheat produce at ` 900/q was used for economic calculations of treatments and net returns *etc*.

The dominant weeds at trial sites were *Phalaris minor, Chenopodium album, Avena ludoviciana, Melilotus alba, M. indica, Vicia sativa, Cynodon dactylon, Cyperus rotundus, Anagallis arvensis, Convolvulus arvensis, Rumex* species *etc*. Weed density was substantially quite low in zero tillage system at each and every site of trials. This observation is in confirmation to the findings of Singh, (2008). Foliar application of company mixed herbicides at 25 DAS effectively controlled both broad and grassy weeds as compared to weedy check. The weed control efficiency (WCE) of sulfosulfuron + MSM was higher and equally effective in both system of wheat sowing in comparison to fenoxaprop-p-ethyl (Table 1). Similar results of maximum reduction in weed density and weed biomass were obtained with application of broad spectrum herbicides by Singh *et al*. (2002).

Results also revealed that zero tillage system of wheat sowing registered maximum effective tillers ($412/m^2$) and grain yield (4.16 t/ha) over conventional tillage by increasing 50.2% higher production (Table 2). The benefits due to herbicidal treatment (` 12,510/

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Table 1. Effect of zero tillage and herbicides on weeds in wheat at farmers' field

Treatment	Dose g/ha (Product)	Mean of 2007-08 and 2008-09					
		Weed density at 25 DAS (no./m^2)		Weed biomass at 45 DAS (g/m^2)		Weed control efficiency (%)	
		ZT	CT	ZT	CT	ZT	CT
Sulfosulfuron + MSM	40	72	169	2.2	1.7	97.2	98.3
Fenoxaprop-p-ethyl	1000	80	193	8.7	14.5	89.0	85.8
Weedy check	-	83	257	78.9	102.3	-	-

Table 2. Effect of zero tillage and herbicides on wheat and economics at farmers' field

Treatment	Dose g/ha (Product)	Mean data of 2007-08 and 2008-09								Benefit: Cost Ratio	
		Effective tillers (no./m^2)		Grain yield (t/ha)		Yield increase (%)		Benefit due to herbicide treatment (x10^3 `/ha)			
		ZT	CT	ZT	CT	ZT	CT	ZT	CT	ZT	CT
Sulfosulfuron + MSM	40	412	386	4.16	3.98	50.2	49.9	12.51	11.92	2.24	1.89
Fenoxaprop-p-ethyl	1000	392	364	3.95	3.91	42.6	47.3	10.62	11.29	2.14	1.86
Weedy check	-	328	262	2.77	2.65	-	-	-	-	1.65	1.39

ha) were obtained with the use of sulfosulfuron + MSM. The present findings are corroborated with the results of Punia *et al*. (2008) as they obtained best yield advantage with application of sulfosulfuron + MSM at 32+2 g/ha. However, there were not much difference in yield of both tillage practices with fenoxaprop-p-ethyl and it also recorded more benefits (` 11,295/ ha) than weed control under zero tillage system (` 10,620/ha). Similarly, the profitability of farmers' were more with zero till sown wheat when combined with herbicidal weed control treatments over conventional system of wheat production as well as weedy check. Application of post-emergence herbicides proved to be more effective as compared to without spray in both practice (Chauhan *et al*. 2001). In addition to this, zero tillage also saved cost of production around ` 2,200 – 2,400/ha, and facilitated placement of major fertilizer (DAP) below the seeding zone, light irrigation at every crop growth stages resulting no yellowing, maximum exposure of leaves towards radiation and at least one week advancement in sowing during winter season of eastern Uttar Pradesh.

SUMMARY

Ten on-farm trials (OFTs) were carried out at farmers' fields in participatory mode during the *Rabi* season of 2007-08 to 2008-09 in selected adjoining villages to the Krishi Vigyan Kendra, Azamgarh of eastern Uttar Pradesh. The main objectives of activities were to evaluate the performance and profitability of zero tillage and herbicides on weed control and productivity of wheat crop under rice-wheat cropping system. Zero till sown wheat was found much effective in suppression of weed density and population of *Phalaris minor* in comparison to conventional tillage. A drastic reduction in weed density was obtained with the application of sulfosulfuron + metsulfuron methyl 75 WG at 40 g/ha ready-mix under both method of wheat sowing. The higher average grain yield and monitory returns were also achieved under zero tillage sown wheat combined with sulfosulfuron + metsulfuron methyl as post emergence. However, grain yield obtained under zero tillage was almost comparable to conventional tillage with fenoxaprop-p-ethyl 10 EC at 1000 ml/ha.

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Short communication

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Integrated weed management in transplanted rice

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Rice (*Oryza sativa* L.) is the principal crop of India cultivated in an area of 44 million ha annually with a production of 103 mt, with an average productivity of 2.3 t/ha (Parthipan *et al.* 2013). Out of 44 mha of rice grown in India, about 57% (25 mha) is grown under irrigated condition (Government of India 2010). A major hindrance in successful cultivation of transplanted rice is heavy infestation of weeds causing drastic reduction in yield. Uncontrolled weeds growth caused 33-45% reduction in rice grain yield (Singh *et al.* 2007, Manhas *et al.* 2012). Therefore, proper weed management is essential for enhancing rice production. Removal of weeds during the critical period of crop-weed competition is essential to minimize crop-weed competition and maximize yield. Sometime, after transplanting the crop faces the moisture stress situation as farmers are unable to maintain the water in the field which leads to heavy infestation of weeds. In this type of situation no single weed management practice. Integration of different methods of weed management resulted in effective control of weeds and enhanced the productivity of transplanted rice (Brar and Walia 2001).Therefore, the present study was undertaken to assess the effect of different weed control treatments either applied alone or in combination on weed infestation and grain yield of transplanted rice.

A field experiment was conducted at G.B.Pant University of Agriculture and Technology, Pantnagar during 2012. The soil of the experimental site was silty loam having a pH of 7.3 and EC 1.16 (mS/cm). The organic carbon and available N, P and K were 0.86%, 226.2 kg/ha, 22.8 kg/ha, 145.4 kg/ha, respectively. The experiment was laid out in a randomized block design and replicated thrice with twelve treatments (Table 1). Rice variety '*Sarjoo 52*' was transplanted on 6th July 2012 at spacing of 20 x 10 cm. All the plots (5 x 3m) were fertilized with 120 kg N, 60 kg P, 40 kg K /ha through NPK mixture, urea, murate of potash and 20 kg $ZnSO_4$ per hectare. Full dose of P and K and half dose of N were applied uniformly as basal at the time of transplanting. Remaining half dose of N was top dressed in two equal splits *i.e.* one-fourth at active tillering [30-35 days after transplanting (DAT)] and one-fourth at panicle initiation (60-65 DAT) stage of the crop. After treatment execution, the water application was uniform for all the treatments to keep the soil near saturation. Rice crop was harvested manually with help of sickle at height of 10-15 cm from ground level on 3 November 2012. Species-wise weed density and biomass were recorded at 60 DAT by placing a quadrate of 50 x 50 cm from the marked sampling area of 1.0 m^2 in each plot. The cost of cultivation was calculated by taking into account the prevailing market price of inputs and operational cost from the farmer's field. The returns were calculated by using minimum support price of rice (` 1250/100 kg) for 2011-12. The significant differences between treatments were compared by critical difference at 5% level of probability.

All the weed control treatments significantly reduced the weed density compared to weedy check (Table 1). Grassy and broad-leaf weeds were found pre-dominant at 60 DAT. Pre-emergence application of pretilachlor 750 g/ha without water stagnation in field up to one week along with post-emergence application of bispyribac-Na 20 g/ha were found to be very effective in reducing the weed density as compared to other treatments. The better performance of these herbicides could be attributed to its effectiveness against *Echinochloa* sp. which was dominant weed species among the diverse weed flora. This treatment was also found superior over rest of the treatments as it provided complete control of grassy and non-grassy weeds. Water stress for one week led to uniform emergence of weeds which were then controlled by post-emergence application of bispyribac-Na in this treatment

Different weed control treatments significantly reduced the biomass of different weed species over the weedy check (Table 2). Pre-emergence application of pretilachlor 750 g/ha without water stagnation

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in field up to one week *fb* post-emergence application of bispyribac-Na 20 g/ha caused significant reduction in biomass of grassy weeds, *viz. E. colona, E. crus-galli, L. chinensis* and *I. rugosum* than other integrated treatments. The better performance of this treatment could be attributed to the reduced weed competition in the initial stage and suppression of late emerged weeds by sequential application of bispyribac-Na. Among the treatments where herbicides were applied alone, bispyribac-Na 20 g/ha was found superior than other herbicides in reducing the biomass of different weed species.

Table 1.Effect of different weed control treatments on weed density at 60 days after transplanting (DAT)

Treatment	Dose (g/ha)	Weed density (no./m^2)							
		Grasses				Broad-leaved weeds			Sedges
		E. colona	*E. crusgalli*	*L. chinensis*	*I. rugosum*	*C. axillaris*	*A. baccifera*	*A. sessilis*	*C. difformis*
Penoxsulam	20.0	3.1(21.3)	2.4 (10.7)	3.0(18.7)	2.8(16.0)	2.3(9.3)	3.2(22.7)	2.2(8.0)	0.0(0.0)
Penoxsulam	22.5	2.7(13.3)	1.6(4.0)	2.7(13.3)	2.6(12.0)	2.0(6.7)	3.0(20.0)	2.0(6.7)	0.0(0.0)
Penoxsulam	25.0	1.8(5.3)	0.0(0.0)	1.6(4.0)	2.0(6.7)	0.5(1.3)	2.6(12.0)	1.1(2.7)	0.0(0.0)
Bispyribac-Na	20.0	1.6(4.0)	0.0(0.0)	1.6(4.0)	1.8(5.3)	0.0(0.0)	2.6(12.0)	0.5(1.3)	0.0(0.0)
Pretilachlor	750	3.0(20.0)	2.4(10.7)	1.1(2.7)	2.6(12.0)	2.8(16.0)	3.2(24.0)	2.2(8.0)	0.0(0.0)
Pretilachlor *fb* 1 HW (at 45 DAT)	750	2.2(8.0)	0.0(0.0)	0.5(1.3)	1.6(4.0)	1.6(4.0)	2.7(14.7)	0.5(1.3)	0.0(0.0)
Penoxsulam *fb* 1 HW (at 45 DAT)	22.5	2.0(6.7)	0.5(1.3)	1.1(2.7)	1.8(5.3)	1.1(2.7)	2.7(13.3)	1.1(2.7)	0.0(0.0)
Pretilachlor + without water stagnation in field upto one week	750	3.1(21.3)	2.6(12.0)	2.0(6.7)	2.7(13.3)	3.0(18.7)	3.3(26.7)	2.3(9.3)	0.0(0.0)
Pretilachlor + without water stagnation in field upto one week *fb* bispyribac-Na	750 *fb* 20.0	0.5(1.3)	0.0(0.0)	0.5(1.3)	0.0(0.0)	0.0(0.0)	1.8(5.3)	0.0(0.0)	0.0(0.0)
One mechanical weeding using conoweeder *fb* 1 HW at 45 DAT	15 *fb* 45 DAT	3.2(22.7)	2.7(14.7)	2.9(17.3)	2.7(14.7)	3.1(21.3)	3.5(33.3)	2.3(9.3)	2.0(6.7)
Hand weeding (HW) twice at 20 and 40 DAT	20 and 40 DAT	1.1(2.7)	0.5(1.3)	1.8(5.3)	1.1(2.7)	1.6(4.0)	2.0(6.7)	0.5(1.3)	1.8(5.3)
Untreated (weedy check)	-	3.7(41.3)	3.2(22.7)	3.3(25.3)	3.4(29.3)	3.9(46.7)	3.9(48.0)	2.7(13.3)	3.4(29.3)
LSD (P=0.05)	-	0.68	0.68	0.89	0.54	0.7	0.28	1.04	0.24

Table 2. Effect of different weed control treatments on weed biomass at 60 DAT

Treatment	Dose (g / ha)	Weed biomass (g / m^2)							
		Grasses				Broad-leaved weeds			Sedges
		E. colona	*E. crusgalli*	*L. chinensis*	*I. rugosum*	*C. axillaris*	*A. baccifera*	*A. sessilis*	*C. difformis*
Penoxsulam	20.0	2.6(12.8)*	1.6(4.2)	2.8(15.8)	3.1(20.1)	1.2(2.5)	0.8(1.2)	1.2(2.2)	0.0(0.0)
Penoxsulam	22.5	2.2(8.3)	0.9(1.5)	2.5(11.4)	2.8(16.3)	1.0(1.9)	0.7(1.1)	1.0(1.9)	0.0(0.0)
Penoxsulam	25.0	1.6(4.2)	0.0(0.0)	1.8(4.8)	2.6(12.6)	0.3(0.4)	0.6(0.8)	0.6(0.9)	0.0(0.0)
Bispyribac-Na	20.0	1.2(2.3)	0.0(0.0)	1.3(3.1)	2.1(7.8)	0.0(0.0)	0.3(0.4)	0.2(0.3)	0.0(0.0)
Pretilachlor	750	2.8(15.8)	1.8(5.2)	1.4(4.6)	3.1(21.1)	2.0(6.1)	1.0(1.7)	1.7(4.6)	0.0(0.0)
Pretilachlor *fb* 1 HW (at 45 DAT)	750	1.5(3.7)	0.0(0.0)	0.6(1.7)	2.2(8.1)	0.8(1.3)	0.4(0.5)	0.3(0.4)	0.0(0.0)
Penoxsulam *fb* 1 HW (at 45 DAT)	22.5	1.6(3.9)	0.3(0.5)	1.1(2.9)	2.4(11.0)	0.5(0.7)	0.4(0.6)	0.5(0.8)	0.0(0.0)
Pretilachlor + without water stagnation in field upto one week	750	2.9(16.6)	1.8(5.3)	2.4(10.9)	3.1(22.2)	1.9(6.0)	1.0(1.6)	1.6(4.1)	0.0(0.0)
Pretilachlor + without water stagnation in field upto one week *fb* bispyribac-Na	750 *fb* 20.0	0.4(0.8)	0.0(0.0)	0.5(1.2)	0.0(0.0)	0.0(0.0)	0.1(0.2)	0.0(0.0)	0.0(0.0)
One mechanical weeding using conoweeder *fb* 1 HW at 45 DAT	15 *fb* 45 DAT	2.9(18.0)	2.0(6.4)	3.0(19.9)	3.3(26.3)	2.0(6.7)	1.0(1.8)	1.6(4.2)	1.7(4.9)
Hand weeding (HW) twice at 20 and 40 DAT	20 and 40 DAT	0.7(1.3)	0.2(0.3)	1.6(4.0)	1.2(3.5)	0.6(0.8)	0.2(0.3)	0.2(0.3)	1.3(2.8)
Untreated (weedy check)	-	3.6(36.8)	2.3(9.1)	3.5(30.6)	3.9(46.8)	2.7(13.4)	1.3(2.8)	1.8(5.2)	3.1(21.4)
LSD (P=0.05)	-	0.52	0.35	0.97	0.61	0.36	0.08	0.51	0.23

*Original values are given in parentheses

Table 3. Cost of cultivation, gross return, net return and B:C ratio of transplanted rice

Treatment	Dose (g/ha)	Cost of cultivation (x10^3 `/ha)	Gross returns (x10^3 `/ha)	Net returns (x10^3 `/ha)	B: C ratio
Penoxsulam	20.0	29.53	61.20	31.67	1.09
Penoxsulam	22.5	29.78	64.45	34.67	1.16
Penoxsulam	25.0	30.00	65.75	35.75	1.19
Bispyribac-Na	20.0	29.30	70.31	41.01	1.39
Pretilachlor	750	28.48	60.54	32.06	1.12
Pretilachlor *fb* 1 HW (at 45 DAT)	750	30.72	67.37	36.65	1.19
Penoxsulam*fb* 1 HW (at 45 DAT)	22.5	32.03	67.05	35.02	1.09
Pretilachlor + without water stagnation in field upto one week	750	28.48	57.94	29.46	1.03
Pretilachlor + without water stagnation in field upto one week *fb*bispyribac-Na	750 *fb* 20.0	30.25	71.61	41.36	1.36
One mechanical weeding using conoweeder *fb* 1 HW at 45 DAT	15 *fb* 45 DAT	30.98	55.99	25.01	0.80
Hand weeding (HW) twice at 20 and 40 DAT	20 and 40 DAT	34.28	70.31	36.03	1.05
Untreated (weedy check)	-	27.53	28.64	1.11	0.04

B:C- Benefit cost ratio

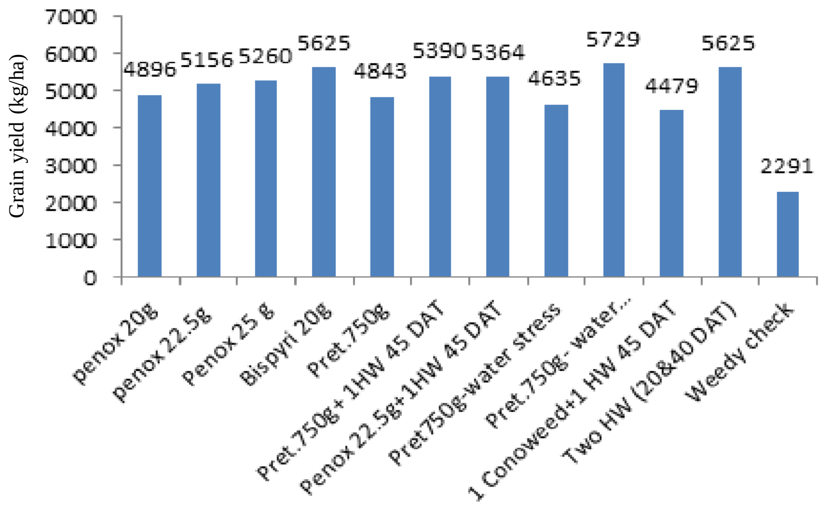

Fig . 1. Effect of different weed control treatments on grain yield

All the weed control treatments registered significantly higher rice grain yield over the weedy check (Fig. 1). Pre-emergence application of pretilachlor750 g/ha without water stagnation in field upto one week along with post-emergence application of bispyribac-Na 20 g/ha recorded the highest grain yield (5.73 t/ha) however it was at par with post-emergence application of bispyribac-Na 20 g/ha alone and hand weeding twice at 20 and 40 DAT. Unweeded control recorded the lowest rice grain yield (2.29 t/ha) with a yield loss of 150% in comparison to the most promising treatment. The possible reason for better performance of pre-emergence application of pretilachlor 750 g/ha without water stagnation in field up to one week *fb* post-emergence application of bispyribac-Na 20 g/ha in terms of grain yield could be attributed to better weed suppression.

The total production cost varied due to differences in cost of weed control treatments. Twice hand weeding (20 and 40 DAT) incurred maximum cost of production among all the treatments (Table 3). Among other treatments, maximum gross return and net profit was recorded with pre-emergence application of pretilachlor 750 g/ha without water stagnation in field up to one week *fb* post-emergence application of bispyribac-Na 20 g/ha followed by post-emergence application of bispyribac -Na 20 g/ha alone while minimum was recorded in one mechanical weeding using cono weeder (15 DAT) *fb* one hand weeding at 45 DAT, as it recorded less rice grain and straw yield. The benefit cost ratio was found to be highest with post-emergence application of bispyribac-Na 20 g/ha alone which was comparable to pre-emergence application of pretilachlor 750 g/ha without water stagnation in field upto one week *fb* post-emergence application of bispyribac-Na 20 g/ha.

It may be concluded that pre-emergence application of pretilachlor 750 g/ha without water stagnation in field upto one week *fb* post-emergence application of bispyribac-Na 20 g/ha is the most effective treatment for managing broad spectrum weed species complex and attain higher rice grain yield and economic returns.

SUMMARY

The present study was conducted to quantify the effect of different weed control treatments alone or in combination with each other on weed growth and grain yield of transplanted rice during *Kharif* season of 2012 at G.B. Pant university of Agriculture and technology, Pantnagar, Uttarakhand. Different weed species responded variably to tested weed control treatments. The dominant weeds in experimental plots were *Echinochloa colona, E. crusgalli, Leptochloa chinensis, Ischeamum rugosum* among grasses and *Ammania baccifera, Alternanthra sessilis* and *Ceasulia axillaris* among broad-leaf weeds and *Cyperus difformis* was the only sedge. Pre-emergence application of pretilachlor 750 g/ha without water stagnation in the field up to one week *fb* post-emergence application of bispyribac-Na 20 g/ha was found superior to rest of the treatments.

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Short communication

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Bioefficacy of some herbicides and their mixtures against complex weed flora in wheat

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Wheat (*Triticum aestivum* L. emend, Fiori and Paol) is widely grown winter cereal and is the back-bone of food security in India. During last four decades, wheat production and productivity have increased almost six times and it alone contributed about one-third of the total food grain production of India. It is grown in about 29.25 million ha area in the country with the production of 93.90 million Mt in India. In Madhya Pradesh, it is grown in 4.89 million ha area with the production of 10.58 million (Agril. Stastistics 2013). Though the production and productivity of wheat have increased in the country during the last five years, but productivity levels are still low in Madhya Pradesh as compared to wheat growing states. There are many factors which affect the yield of the wheat but weed infestation is one of the most serious causes of low yields of irrigated wheat. The reduction in yields is mainly due to severe competition between weeds and crop plants for moisture, nutrient, light and space. The studies of Brar and Walia (2008) revealed that sever competition of grassy weeds like *Phalaris minor* caused 30-80% reduction in grain yield of wheat. Therefore, bioefficacy of some herbicdes was tested to control the weeds of wheat to overcome the yield loss due to wheat..

To study the effect of post-emergence herbicides for controlling weeds in wheat, a field experiment was carried out at Directorate of Weed Science Research, Jabalpur, M.P., India. The experimental field was vertisol (medium to deep depth and black in colour) clayey in texture. It was medium in organic carbon (0.61%), available nitrogen (178 kg N/ha) and phosphorus (40 kg P_2O_5/ha) but high in available potassium (344 kg K_2O/ha). The soil was nearly natural in reaction (7.2 pH) and concentration of soluble salts (0.32/dsm) was below to the harmful limit. The wheat variety '*GW-273*' was sown on November, 23,2012, using a seed rate of 100 kg/ha under furrow irrigated raised-bed system (FIRBS) by keeping two rows/ bed on the top of beds. The crop was raised with all recommended package of practices except the herbicidal treatments. Fourteen treatments consisted with eleven herbicidal treatments, post-emergence application of clodinafop-p-propargyl 60 g/ha (T_1), clodinafop-p-propargyl + 2,4-D (60+500) g/ha (T_2), pinoxaden 60 g/ha (T_3), sulfosulfuron 25 g/ha (T_4), metsulfuron-methyl + carfentrazone 25 g/ha (T_5), metsulfuron-methyl + 0.2% non ionic surfactant 4 g/ha (T_6), carfentrazone + sulfosulfuron 45 g/ha (T_7), sulfosulfuron + metsulfuron-methyl 40 g/ha (T_8), mesosulfuron-methyl + iodosulfuron-methyl sodium 12 g/ha (T_9), penoxsulam + cyhalofop 105 g/ha (T_{10}), penoxsulam + cyhalofop 150 g/ha (T_{11}) and carfentrazone 25 g/ha (T_{12}) along with two hand weedings (T_{13}) and weedy check (T_{14}), were tested in randomized block design with three replications.

Sowing of the experiment was done on November 23, 2012 in 5.0 x 4.5 m plots with seed rate 100 kg/ha by drilling in rows 22.5 cm apart. A uniform dose of 120 kg N, 60 kg P_2O_5, and 40 kg K_2O/ha was given through urea, single super phosphate and muriate of potash, respectively, in all plots. The herbicides were sprayed as post-emergence at 30 days after sowing (DAS) using a spray volume of 500 L/ha with a knapsack sprayer fitted with flat fan nozzle. The data on weed count and weed biomass was recorded at 60 DAS with the quadrate of 0.25/m^2 at two places under each plot. Data on weed population were subjected to square root transformation.

The dominant weed species identified in the experiment of wheat field were *Avena ludoviciana, Phalaris minor, Cichorium intybus, Medicago denticulata, Euphorbia geniculata.* The relative density of monocot and dicot weeds in unweeded plot at 30 days after sowing (DAS) was 86.82 and 13.18 per cent, respectively, indicating the predominance of monocot weeds (Table. 1) in wheat. Among the monocots, *Phalaris minor* (66.38%) was the most dominant weed followed by *Avena ludoviciana*(20.44%),

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while *Cichorium intybus* (11.76%), *Euphorbia geniculata* (0.74%), *Medicago denticulate* (0.32%), *Vicia sativa* (0.20%) and *Physalis minima* (0.13%), *Chenopodium album* (0.03%) were important among the dicot weeds. The density or biomass of predominant weeds was maximum under weedy check plots, where weeds were allowed to grow with wheat crop. But density of weeds and weed biomass reduced identically in pots receiving herbicidal and mechanical weed control.

The post-emergence application of clodinafop-p-propargyl 60 g/ha curbed the density and biomass of *A. ludoviciana.* and *P. minor* at 30 days after application. On the contrary, the efficacy of clodinafop-p-propargyl 60 g/ha, sulfosulfuron 25 g/ha, pinoxaden 60 g/ha, penoxsulam + cyhalofop 105 g/ha, penoxsulam + cyhalofop 150 g/ha and carfentrazone 25 g/ha was poor against *Cichorium intybus, Medicago denticulata* and *E. geniculata*. However, the post-emergence application of sulfosulfuron + metsulfuron-methyl 40 g/ha and clodinafop-p-propargyl +2,4-D (60+500) g/ha curtailed the density and dry weight of both the broad-leaved weeds satisfactory being the higher under ready mix combination of mesosulfuron-methyl + iodosulfuron-methyl sodium 12 g/ha. The hand weeding treatments performed better than all the herbicidal treatments in reducing the density, biomass of weeds and recorded maximum weed control efficiency (71.34%).

Table 1. Effect of weed control treatments on density (no./m²) of different weed

Treatment	Dose g/ha	*Avena ludoviciana*		*Phalaris minor*		*Cichorium intybus*		*Medicago denticulata*		*Euphorbia geniculata*	
		60 DAS	At harvest	60 DAS	At · harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
T_1 - Clodinafop	60	1.25 (1.67)	4.47 (23.0)	0.99 (0.67)	1.70 (3.00)	9.93 (105)	2.05 (4.67)	0.88 (0.33)	1.09 (1.00)	1.50 (3.00)	1.09 (1.00)
T_2 – Clodinafop + 2,4-D	60+5 00	2.63 (6.67)	4.23 (17.7)	0.99 (0.67)	0.70 (0.00)	2.64 (6.67)	2.54 (6.00)	0.70 (0.00)	0.70 (0.00)	1.38 (2.33)	0.99 (0.67)
T_3 - Pinoxaden	60	0.70 (0.00)	4.00 (16.7)	1.25 (1.67)	0.70 (0.00)	5.97 (38.3)	2.38 (5.33)	1.79 (3.67)	2.17 (5.00)	2.07 (5.67)	1.94 (3.33)
T_4 - Sulfosulfuron	25	13.68 (187)	3.8 (14.3)	0.70 (0.00)	1.18 (1.33)	7.79 (67.3)	2.66 (6.67)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	0.88 (0.33)
T_5 – Metsulfuron-methyl 0 + carfentrazone	25	3.70 (19.0)	5.83 (28.0)	18.10 (336)	1.25 (1.67)	3.89 (35.0)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	0.88 (0.33)	1.05 (0.67)
T_6- Metsulfuron-methyl + 0.2% NIS	4	5.10 (25.7)	4.20 (17.7)	15.32 (322)	1.79 (3.67)	0.70 (0.00)	0.70 (0.00)	1.09 (1.00)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)
T_7 – Carfentrazone + sulfosulfuron	45	4.57 (36.3)	4.90 (23.7)	8.96 (92.3)	1.29 (1.33)	0.88 (0.33)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	1.68 (2.33)
T_8 - Sulfosulfuron + metsulfuron-methyl	32	6.84 (51.3)	3.18 (10.0)	3.58 (17.3)	1.32 (2.00)	3.25 (13.7)	2.54 (6.00)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)
T_9 – metsulfuron-methyl + iodosulfuron-methyl sodium	16	1.93 (3.33)	2.57 (8.0)	0.70 (0.00)	1.93 (4.00)	4.05 (18.0)	2.18 (4.33)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	1.38 (1.67)
T_{10} - Penoxsulam + cyhalofop	105	2.45 (11.7)	4.33 (18.3)	7.05 (69.)	1.09 (1.00)	7.30 (54.0)	2.26 (4.67)	0.70 (0.00)	1.18 (1.33)	0.88 (0.33)	1.09 (1.00)
T_{11} - Penoxsulam + cyhalofop	150	1.29 (1.33)	3.39 (15.3)	2.12 (5.00)	0.70 (0.00)	9.40 (89.7)	2.45 (5.67)	1.79 (3.67)	1.09 (1.00)	0.70 (0.00)	0.99 (0.67)
T_{12} - Carfentrazone	20	3.82 (16.3)	3.28 (15.0)	10.35 (362)	1.09 (1.00)	3.05 (12.3)	1.93 (4.00)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	1.29 (1.33)
T_{13} - Hand weeding (2HW)	30, 60 DAS	1.83 (3.67)	3.59 (12.7)	2.82 (16.3)	0.70 (0.00)	3.84 (16.3)	1.32 (2.00)	0.70 (0.00)	0.88 (0.33)	1.09 (1.00)	0.70 (0.00)
T_{14} - Weedy check	-	20.42 (724)	4.45 (20.0)	21.73 (477)	1.44 (2.67)	11.64 (137)	2.32 (5.00)	2.70 (8.00)	1.93 (3.33)	2.19 (6.67)	0.99 (0.67)
LSD (P=0.05)		4.18	NS	7.85	NS	4.11	0.99	1.02	0.74	NS	NS

Figures in parentheses are original values and were transformed to $(\sqrt{x+0.5})$ before statistical analyses, DAS – Days after sowing

Table 2. Effect of weed control treatments on weed dry matter, weed control efficiency at 60 DAS, yield attributes and yield of wheat

Treatment	Biomass of weeds (g/m^2)		WCE 60 DAS (%)	Effective tillers/m^2	Effective spike/m	1000 grain weight (g)	Grain yield (t/ha)
	GW	BLW					
T_1	0.0	48.5	67.8	179.0	44.7	44.5	2.41
T_2	12.2	42.3	63.7	197.5	45.3	44.8	2.73
T_3	0.0	56.8	62.3	103.5	42.0	41.0	1.55
T_4	44.4	14.5	60.8	112.2	42.8	41.3	1.61
T_5	108.3	0.0	28.0	121.2	43.6	42.6	1.60
T_6	105.2	0.0	30.0	108.2	41.6	42.0	1.13
T_7	92.4	0.0	38.5	141.0	42.2	42.1	1.71
T_8	22.4	16.8	73.9	200.5	46.0	45.0	3.42
T_9	0.3	33.5	77.5	203.5	46.9	45.3	3.61
T_{10}	34.5	16.6	66.1	124.5	42.1	41.4	1.63
T_{11}	33.3	35.8	54.1	121.8	42.4	42.1	1.80
T_{12}	64.2	2.1	55.9	133.2	41.2	43.5	2.10
T_{13}	10.5	1.2	92.2	210.3	48.0	46.1	3.81
T_{14}	110.4	40.0	0.0	103.5	38.2	40.0	0.73
LSD (P=0.05)	49.33	20.96	-	15.1	NS	NS	1.47

Figures in parentheses are original values and were transformed to ($\sqrt{x+0.5}$) before statistical analyses, GW – Grassy weed, BLW – Broad leaf weed

The value of growth parameters *viz.* plant height, number of tillers/m^2, leaf area index and crop biomass were minimum under weedy check plots, which improved in plots receiving post-emergence application of clodinafop-p-propargyl 60 g/ha, sulfosulfuron 25 g/ha, penoxsulam + cyhalofop 105 g/ha penoxsulam + cyhalofop 150 g/ha and carfentrazone 25 g/ha. However, these parameters were further improved with the application of sulfosulfuron + metsulfuron-methyl 40 g/ha and clodinafop-p-propargyl + 2,4-D (60+500 g/ha).These parameters attained the superior values under ready mix combination of mesosulfuron-methyl + iodosulfuron-methyl sodium 12 g/ha. The hand weeding treatments performed better than all the herbicidal treatments as it had the maximum values of all the growth parameters.

The yield attributing traits, *viz.* effective tillers/ m^2, ear head length, grains per ear head and test weight including grain and straw yields, harvest index were affected significantly due to weed control treatments. These attributes attained the poorest values under weedy check plots and were improved due to application of metsulfuron-methyl + iodosulfuron-methyl sodium 12 g/ha and sulfosulfuron + metsulfuron-methyl 40 g/ha being the higher under combined application of clodinafop-p-propargyl + 2,4-D (60+500) g/ha. However, hand weeding in wheat excelled to all the herbicidal treatments as it registered the maximum values of above parameters.

The plant growth yield parameter and yield of wheat grain improved, remarkably, under the post-emergence application of mesosulfuron-methyl + iodosulfuron-methyl sodium 12 g/ha (ready mix) followed by sulfosulfuron + metsulfuron-methyl 40 g/ha and clodinafop + 2,4-D (60+500) g/ha. Use of pinoxaden 60 g/ha or clodinafop 60 g/ha brought about reduction in infestation of grassy weeds. Use of ready mix combination of mesosulfuron-methyl + iodosulfuron-methyl sodium 12 g/ha, sulfosulfuron + metsulfuron-methyl (Total) 40 g/ha and clodinafop + 2,4-D (60+500) g/ha appear to be more profitable and efficient over other treatments.

SUMMARY

The bio-efficacy of clodinafop-p-propargyl 60 g/ ha was better against *Avena ludoviciana* Dur. and *Pharalis minor* Retz. to that of sulfosulfuron 25 g/ha, penoxsulam + cyhalofop 105 g/ha, penoxsulam + cyhalofop 150 g/ha and carfentrazone 25 g/ha but it was poor against broad leaved weeds. However, the mesosulfuron-methyl + iodosulfuron-methyl sodium 12

g/ha, sulfosulfuron + metsulfuron-methyl 40 g/ha and combined application of clodinafop-p-propargyl + 2,4-D (60+500) g/ha gave effective control of grassy and broad leaved weeds. Use of pinoxaden 60 g/ha or clodinafop 60 g/ha a brought about a reduction in infestation of grassy weeds. Presently, some new herbicide ready mix combination of mesosulfuron-methyl + iodosulfuron-methyl sodium 12 g/ha, sulfosulfuron + metsulfuron-methyl 40 g/ha and tank mixture herbicides clodinafop + 2,4-D (60+500) g/ha appeared to be more profitable and efficient over other treatments.

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Short communication

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Tillage and weed management for improving productivity and nutrient uptake of soybean

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Soybean [*Glycine max* (L.) Merr.] has emerged as a potential crop and brought about perceptible change in the economy of the farmers in central India. Weeds are a major constraint and their control is essential for successful crop production. Mostly the farmers use pre-emergence herbicides for weed control in soybean but their efficacy is reduced by various climatic and edaphic factors. Hand-weeding is a traditional and effective method of weed control, but untimely continuous rains and unavailability of labour at peak time are main limitations of manual weeding. The only alternative that needs to be explored is the use of post-emergence herbicides. Such herbicides are promising for control of monocotyledonous or dicotyledonous weeds. Further, herbicide mixtures may broaden the window of weed management by broad-spectrum weed control (Bineet *et al.* 2001). An experiment was conducted to study the performance of soybean grown after wheat under varying tillage and weed control practices.

The experiment was conducted during *Kharif* season 2008 at the research farm of Indian Agricultural Research Institute, New Delhi on sandy loam soil, slightly alkaline (pH 7.6), low in organic C (0.38%), and available N (145 kg/ha), medium in available P (9.01 kg/ha) and high in available K (259.4 kg/ha). The treatments included four tillage and crop establishment practices, *viz.* conventional tillage flat-bed, conventional tillage raised-bed, zero tillage flat-bed and zero tillage raised-bed, and six weed management options, *viz.* control, weed free, pendimethalin 0.75 kg/ha as pre-emergence (PE), chlorimuron-ethyl 6 g/ha as post-emergence (POE) at 15 days after sowing (DAS), pendimethalin 0.75 kg/ha as PE + 1 hand weeding (HW) at 25 days after sowing, pendimethalin 0.75 kg/ha as PE + chlorimuron-ethyl 6.0 g/ha as POE at 15 DAS. Thus, 24 treatment combinations were laid out in a thrice replicated split-plot design, keeping tillage and crop establishment in main plots and weed management options in sub-plots. The gross plot size was 16.8 m^2 and net plot was 15 m^2. After the harvest of *Rabi* crop wheat in April, land preparation was done as per treatment and sowing was done on 10 July, 2008 using '*DS 9814*' variety with a seed rate of 80 kg/ha, and a basal dose of 20 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha was applied at the time of sowing in the furrows. The sowing was done at a row to row spacing of 35 cm from with the help of zero-till seed drill in flat-bed and 20 cm on the top of bed with the help of bed planter. The crop was harvested on 23 October, 2008.

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Weed growth

Major weed flora were: *Echinochloa colona* (12.7%) among grassy; *Digera arvensis* (10.4%) among broad-leaved; and *Cyperus rotundus* (62.5%) among sedges, beside others. Higher weed count was noticed under ZT due to no soil disturbance and simultaneous germination of weeds along with the crop (Table 1). Although paraquat was sprayed before sowing, which desiccated the foliage of all the previously growing weeds, but some of the over-grown weeds regenerated after two weeks. On other hand, all the weeds growing previously were killed due to tillage operation under CT, and emergence of new weeds was delayed compared with crop seedlings. Lower weed population in the bed-planted crop was due to closer row spacing on the bed. More foliage growth of the bed-planted crop also checked weed population in the furrows. There was significant difference in weed dry weight at 60 DAS due to tillage and crop establishment practices. It was comparatively more under ZT because of no-tilling of the soil compared with 3-4 ploughings given under CT. Although there was greater weed infestation in the furrows initially due to more space and better soil moisture condition, the weeds in furrows also got smothered with advancement of crop growth and development of canopy cover. On the other hand, flat-bed crop was sown at uniform spacing (35 cm) provided adequate and uniform inter-row space for the weeds to grow. Several workers reported decrease in weed infestation in furrow-planted compared with flat-sown crop (Behera *et al.* 2005, Mishra and Singh 2009).

Weed management practices brought about significant effect on weed growth. Presumably, the highest weed count was under unweeded control, which was decreased by more than half due to different treatments at all the stages of growth. Pre-emergence application of pendimethalin provided effective control of all species from early stages. Further, HW and post-emergence application of chlorimuron-ethyl at 15 DAS checked the emergence of the second flush of weeds. Both of these treatments, *i.e.* pendimethalin + HW and pendimethalin + chlorimuron-ethyl were equally effective and resulted in near weed-free conditions throughout. The minor weeds emerging late in season did not cause significant adverse effect on crop growth. Pre-emergence application of pendimethalin, followed by post-emergence chlorimuron ethyl was however slightly inferior to pendimethalin + HW. Application of pendimethalin or chlorimuron-ethyl alone was not much effective to control the weeds at initial stage and/or second flash in soybean, respectively.

Pendimethalin is the most popular herbicide for weed management in most crops including soybean. It is widely recommended for weed control without any adverse effect on crop growth. Therefore, pre-emergence application of pendimethalin provided complete elimination of grassy weeds and most of the broad-leaved species. Second flush of the weeds was checked by HW or application of chlorimuron-ethyl at 15 DAS. Thereafter, there was no weed emergence due to development of adequate canopy cover, which suppressed late emerged weeds. These results indicate that post-emergence application of chlorimuron-ethyl was as good as HW in reducing weed count (Behera *et al.* 2005, Jadhav and Gadade 2012).

Seed and stover yield

Seed yield was significantly influenced by the treatments of tillage and crop establishment but the differences in stover yield were not significant (Table 1). Seed yield was the highest under CT–raised-bed, which was on par with CT-flat and ZT-raised bed. The lowest seed yield was under ZT-flat-bed, which was significantly lower than CT-raised-bed. Weed management treatments brought about large increases in crop productivity, when weeds were controlled effectively by chemical and cultural means. Favourable environment was created within the crop canopy, which led to higher growth and yield attributes, and thereby yield performance. Two weed control practices, *viz.* pendimethalin + HW and pendimethalin + chlorimuron-ethyl resulted in almost similar weed control; thus gave equal seed and stover yield, which was significantly higher than unweeded control. The mean increase in seed yield under these treatments was 39.1%. The loss of seed yield in unweeded control was 38.3%. Mishra and Singh (2009) also found a similar response with the application of 1.0 kg/ha of pendimethalin + hand weeding at 20-30 DAS.

Table 1. Weed growth at 60 days after sowing, and yield of soybean as influenced by tillage and crop establishment, and weed management practices

Treatment	Weed count (no./m^2)	Weed dry weight (g/m^2)	Seed yield (t/ha)	Stover yield (t/ha)
Tillage and crop establishment				
CT – raised-bed	6.13 (39.1)	5.93 (44.5)	2.17	5.36
CT – flat-bed	5.49 (31.9)	5.62 (39.6)	2.31	5.28
ZT – raised-bed	6.11 (38.9)	9.23 (104.0)	1.72	3.96
ZT – flat-bed	5.83 (35.9)	7.41 (69.2)	2.20	4.85
LSD (P=0.05)	0.27	0.37	0.20	NS
Weed management				
Pendimethalin 0.75 kg/ha	6.09 (37.0)	7.30 (58.8)	2.15	4.83
Chlorimuron-ethyl 6 g/ha	6.73 (45.0)	9.69 (97.8)	1.97	4.62
Pendimethalin 0.75 kg/ha + 1 HW	5.03 (25.0)	3.12 (9.5)	2.18	5.01
Pendimethalin 0.75 kg/ha + chlorimuron-ethyl 6 g/ha	6.04 (36.2)	7.35 (61.5)	2.00	4.40
Control	8.02 (64.0)	12.2 (151.9)	1.84	4.51
Weed free	3.44 (11.5)	2.56 (6.6)	2.47	5.56
LSD (P=0.05)	0.27	0.26	0.15	0.65

*Square root transformed values ($\sqrt{x + 0.5}$), original values are in parentheses

Table 2. Effect of tillage and crop establishment, and weed management options on N, P and K uptake (kg/ha) of soybean

Treatment	N		P		K	
	Grain	Stover	Grain	Stover	Grain	Stover
Tillage and crop establishment						
CT – raised-bed	100.1	83.5	12.3	10.2	34.2	95.5
CT – flat-bed	108.1	85.5	13.0	10.5	36.3	96.6
ZT – raised-bed	80.1	80.4	12.5	9.6	34.6	70.8
ZT – flat-bed	103.2	62.1	9.8	7.7	27.2	88.6
LSD (P=0.05)	11.4	NS	1.20	NS	3.78	NS
Weed management						
Pendimethalin 0.75 kg/ha	100.1	77.0	12.5	9.4	34.1	88.1
Chlorimuron-ethyl 6 g/ha	92.5	76.0	11.2	8.7	31.1	84.8
Pendimethalin 0.75 kg/ha + 1HW	101.1	79.7	12.2	9.7	34.1	89.7
Pendimethalin 0.75 kg/ha + chlorimuron-ethyl 6 g/ha	93.3	70.2	11.2	8.3	31.5	78.6
Control	85.8	73.5	10.4	9.2	29.0	83.5
Weed free	115.1	90.7	13.9	11.6	38.8	102.5
LSD (P=0.05)	14.2	NS	1.85	NS	4.46	12.03

Nutrient concentration and uptake

Concentration of N, P and K in seed and stover of soybean was not influenced due to tillage and weed management (data not given). However, the uptake of nutrients was significantly different under tillage and weed management practices (Table 2). The uptake increased due to higher biomass production under different treatments. The nutrient uptake was the highest under CT-raised-bed, while the lowest value was observed under ZT-flat-bed. These results indicate that better crop growth following reduced weed infestation under CT and raised-bed condition provided adequate supply of nutrients to the crop plants, leading to higher nutrient uptake. Weed management practices caused large and significant differences in nutrient uptake. The uptake of N and K was maximum under pendimethalin + HW, which was significantly more than pendimethalin + chlorimuron-ethyl. However, all the five weed control treatments were significantly superior to unweeded control. The decrease in uptake of N, P and K under unweeded control was to extent of 30.2-37.0%. These variations were evident from the fact that the weeds removed large quantity of nutrients under unweeded control, while under other weed management treatments, the nutrients available in soil were effectively utilized by crop plants for growth and development.

SUMMARY

In this study the population and dry matter of weeds was significantly more under under ZT than CT. Seed yield of soybean was the highest under CT–raised-bed, followed by ZT-raised-bed, CT–flat-bed and ZT-flat-bed. Application of pendimethalin + HW and pendimethalin + chlorimuron-ethyl resulted in almost similar weed control efficiency and gave equal seed yield. Uptake of N, P and K by grain was maximum under pendimethalin + HW, which was significantly more than rest of treatments. It was concluded that soybean can be grown under permanent raised-bed with pre- and post-emergence herbicides for realizing higher productivity.

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Short communication

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Weed management in lentil with post-emergence herbicides

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Lentil (*Lens culinaris* Medikus) is an important grain legume crop. In 2012, globally it was grown on 4.24 million hectare area with a total production of 4.55 million tonnes and average productivity of 1070 kg/ha (FAOSTAT 2013). Canada, India, Turkey, Australia, USA, Nepal and China are the important lentil-producing countries. Poor weed management is an important reason for low productivity of lentil. Lentil is a short-statured crop due to which weeds pose a severe competition and reduce crop yields considerably. Various pre-plant incorporation/pre-emergence herbicides such as trifluralin, pendimethalin recommended for controlling weeds in lentil, are effective only for the initial about one month period, whereas lentil is a long duration crop (145 days) and weeds emerging later also compete with crop plants. Information regarding use of post-emergence herbicides in this crop, particularly in India is meager. Therefore, the present study was undertaken.

A field experiment was conducted during *Rabi* (winter) 2009-10 at the research farm of Punjab Agricultural University, Ludhiana (30° 562 N, 75° 522 E, altitude 247 m), India. The soil of the experimental site was loamy sand (80.3% sand, 14.3% silt and 5.4% clay), having pH 8.7, organic carbon 0.29%, available P 11.5 kg/ha and available K 410 kg/ha. A total 30 cm rainfall was received during the crop growing season. Twelve treatments (Table 1) were taken in a randomized block design with three replications. The herbicides were sprayed at different timings, *i.e.* 25 and 35 days after sowing (DAS) using 375 litres of water per hectare with a Knapsack sprayer fitted with a flat fan nozzle. In the case of two hand weedings (HW), weeds were removed manually with weeding tool at 30 and 60 DAS and in weedy plots, weeds were allowed during the whole crop growing season. The crop (variety *LL-699*) was sown on 7 November, 2009 in rows 22.5 cm apart using a seed rate of 35 kg/ha. The crop was harvested on 8 April, 2010.

Dry weight of nodules and plants was determined after drying to constant weight at 65 °C. Chlorophyll content of leaves was estimated by using the method of Witham *et al.* (1971). Data on weed density were recorded 75 and 105 DAS from a randomly selected area of 50×50 cm from each plot. Weed control efficiency (WCE) was calculated as per the standard formula.

The major weed flora at the experimental site included *Oenothera drumundii, Lepidium sativum, Medicago denticulata, Anagallis arvensis, Spergula arvensis, Chenopodium album* and *Rumex dentatus* in decreasing order (Table 1). In general, imazethapyr treatments had lower weed density than those of quizalofop-ethyl. In the present study, there was infestation of broad-leaf weeds only which were not controlled by quizalofop-ethyl as this herbicide is effective mainly for annual and perennial grassy weeds only (Davis 1987). Imazethapyr 90 g/ha at 21 or 28 DAS have been reported to provide effective control of weeds in blackgram (Veeraputhiran *et al.* 2008).

Among the herbicide treatments, all treatments except quizalofop-ethyl 30 g/ha applied at 25 or 35 DAS recorded significantly lower biomass of weeds than the unweeded check at 75 DAS (Table 2). At 105 DAS and at harvest, all herbicide treatments had significantly lower biomass of weeds than the weedy check. However, none of the herbicide treatments was as effective as two hand weeding treatment for reducing the biomass of weeds at any of the three stages of observation. Our finding is in accordance with those of Meena and Jadon (2009).

Imazethapyr, when applied at 25 or 35 DAS, showed phytotoxicity in lentil at all the rates of application. Phytotoxicity increased with an increase in the rate of application and it was higher when the herbicide was applied at 25 DAS. Mishra *et al.* (2005) also reported phytotoxic effects of imazethaypyr in lentil, but with time, plants recovered. The crops are known to recover from phytotoxic effects of herbicides (Rao and Rao 2003). Quizalofop ethyl did not cause any visual phytotoxicity to lentil at any of the tested rate and time of application.

Highest number of nodules was recorded with 2 hand weeding treatment followed by imazethapyr 40 g/ha and quizalofop-ethyl 50 g/ha (Table 3). Nodule biom-

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Table 1. Weed density (no./m²) as affected by different weed control treatments in lentil

Treatment	*Oenothera drumundii*	*Lepidium sativum*	*Spergula arvensis*	*Medicago denticulata*	*Anagallis arvensis*	*Rumex dentatus*	*Chenopodium album*	Total
75 Days after sowing								
Quizalofop-ethyl 30 g 25 DAS	6.2 (38)	3.2 (9)	2.6 (6)	3.5 (12)	2.4 (5)	2.0 (4)	1.0 (0)	8.6 (74)
Quizalofop-ethyl 30 g 35 DAS	7.0 (49)	3.2 (10)	2.9 (8)	4.1 (16)	3.2 (9)	1.0 (0)	2.0 (4)	9.8 (96)
Quizalofop-ethyl 50 g 25 DAS	6.8 (46)	4.2 (17)	1.0 (0)	2.4 (5)	2.4 (5)	1.0 (0)	2.2 (4)	8.8 (77)
Quizalofop-ethyl 50 g 35 DAS	5.5 (30)	3.5 (12)	2.4 (5)	3.2 (9)	2.4 (5)	1.0 (0)	1.4 (1)	7.9 (62)
Imazethapyr 25 g 25 DAS	6.0 (36)	2.9 (8)	1.6 (2)	3.2 (9)	1.0 (0)	1.0 (0)	1.5 (2)	7.6 (57)
Imazethapyr 25 g 35 DAS	4.9 (24)	3.5 (12)	1.4 (1)	3.2 (9)	1.0 (0)	1.0 (0)	1.0 (0)	6.8 (46)
Imazethapyr 40 g 25 DAS	4.2 (17)	1.0 (0)	1.5 (2)	3.2 (10)	1.0 (0)	1.0 (0)	1.4 (1)	5.5 (30)
Imazethapyr 40 g 35 DAS	6.0 (36)	2.4 (5)	2.4 (5)	3.3 (10)	1.0 (0)	1.0 (0)	2.0 (4)	7.7 (60)
Imazethapyr 55 g 25 DAS	2.0 (4)	1.0 (0)	1.0 (0)	2.4 (5)	1.0 (0)	1.0 (0)	1.6 (2)	3.4 (11)
Imazethapyr 55 g 35 DAS	3.5 (12)	3.2 (9)	2.4 (5)	2.9 (8)	2.0 (4)	1.0 (0)	1.6 (2)	6.3 (40)
Unweeded check	8.1 (65)	4.3 (18)	3.2 (9)	3.7 (13)	3.2 (9)	2.6 (6)	2.6 (6)	11.2 (126)
2 Hand weeding (30&60 DAS)	2.0 (4)	1.4 (1)	1.0 (0)	1.4 (1)	1.0 (0)	1.0 (0)	1.0 (0)	2.4 (6)
LSD (P=0.05)	1.1	0.9	0.7	0.8	0.6	0.5	NS	0.9
105 Days after sowing								
Quizalofop-ethyl 30 g 25 DAS	6.9 (48)	4.5 (20)	1.6 (2)	2.9 (8)	2.5 (6)	2.4 (5)	2.4 (5)	9.7 (94)
Quizalofop-ethyl 30 g 35 DAS	7.3 (53)	4.5 (20)	2.6 (6)	4.2 (17)	3.1 (9)	2.4 (5)	2.5 (6)	10.8(116)
Quizalofop-ethyl 50 g 25 DAS	5.9 (35)	5.2(27)	2.2 (4)	3.5 (12)	2.9 (8)	2.2 (4)	2.0 (4)	9.7 (94)
Quizalofop-ethyl 50 g 35 DAS	6.1 (37)	5.0 (25)	2.6 (6)	4.0 (15)	2.4 (5)	1.4 (1)	2.2 (4)	9.6 (93)
Imazethapyr 25 g 25 DAS	5.3 (28)	4.9 (24)	2.4 (5)	3.2 (9)	2.0 (4)	2.4 (5)	1.5 (2)	8.8 (77)
Imazethapyr 25 g 35 DAS	5.3 (28)	3.8(14)	1.5 (2)	3.5 (12)	1.4 (1)	1.5 (2)	2.0 (4)	8.0 (63)
Imazethapyr 40 g 25 DAS	5.1 (25)	2.9 (8)	1.6 (2)	3.7 (13)	2.4 (5)	1.4 (1)	2.2 (4)	7.6 (58)
Imazethapyr 40 g 35 DAS	6.0 (36)	3.8 (14)	1.5 (2)	3.7 (13)	1.4 (1)	2.4 (5)	1.0 (0)	8.4 (71)
Imazethapyr 55 g 25 DAS	4.5 (20)	2.0 (4)	1.4 (1)	3.2 (9)	1.6 (2)	2.2 (4)	2.5 (6)	6.8 (46)
Imazethapyr 55 g 35 DAS	4.5 (20)	2.9 (8)	1.6 (2)	3.5 (12)	2.9 (8)	2.4 (5)	1.5(2)	7.5 (57)
Unweeded check	8.5 (72)	4.7 (22)	1.2 (9)	4.2 (17)	4.2 (17)	2.9 (8)	3.5(12)	12.5(157)
2 Hand weeding (30&60 DAS)	3.3 (10)	1.3 (1)	1.0 (0)	1.4 (1)	1.4 (1)	1.4 (1)	1.0(0)	3.8 (14)
LSD (P=0.05)	0.7	0.8	0.9	0.9	1.1	2.5	1.1	1.1

Original data on density of weeds given in parentheses were subjected to square root transformation $\sqrt{x+0.5}$ before analysis

Table 2. Effect of weed control treatments on biomass of weeds and weed control efficiency (WCE) at different stages in lentil

Treatment	75 DAS		105 DAS		At harvest	
	Biomass of weeds (kg/ha)	WCE (%)	Biomass of weeds (kg/ha)	WCE (%)	Biomass of weeds (kg/ha)	WCE (%)
Quizalofop-ethyl 30 g 25 DAS	533	2.4	1200	24.3	2763	36.4
Quizalofop-ethyl 30 g 35 DAS	466	14.6	1106	30.3	2521	41.9
Quizalofop-ethyl 50 g 25 DAS	400	26.7	1186	25.2	2982	31.3
Quizalofop-ethyl 50 g 35 DAS	373	31.7	1253	21.0	2719	37.4
Imazethapyr 25 g 25 DAS	266	51.3	866	45.4	1447	66.7
Imazethapyr 25 g 35 DAS	240	56.0	733	53.8	1348	68.9
Imazethapyr 40 g 25 DAS	373	31.7	720	54.6	1447	66.7
Imazethapyr 40 g 35 DAS	320	41.4	733	53.8	1451	66.6
Imazethapyr 55 g 25 DAS	200	63.4	906	42.9	1916	55.9
Imazethapyr 55 g 35 DAS	193	64.6	893	43.7	1973	54.6
Unweeded check	546	-	1586	-	4342	-
2 Hand weeding (30 & 60 DAS)	50	90.8	366	76.9	811	81.3
LSD (P=0.05)	96		137		394	

ass in treatments of quizalofop-ethyl 30 g/ha at 35 DAS and imazethapyr 40 g/ha at 35 DAS was significantly higher than unweeded check. Maximum chlorophyll content (1.78 mg/g fresh weight of leaves) was observed in two hand weeding plots, followed by quizalofop-ethyl 30 g/ha at 35 DAS (1.48). The present findings clearly showed that quizalofop-ethyl 30 g/ha and imazethapyr 25 g/ha at both 25 and 35 DAS did not significantly affect nodulation. No adverse effect of imazethapyr on nodulation in lentil was reported by other workers (Tepe

Table 3. Effect of weed control treatments on symbiotic efficacy, growth and yield attributes and yield of lentil

Treatment	Dry weight of nodules/ plant (mg)	Chlorophyll content (mg/g fresh weight of leaves)	Plant height (cm)	Primary branches /plant	Pods/ plant	Seeds /pod	100- seed weight (g)	Grain yield (t/ha)	Harvest index (%)
Quizalofop ethyl 30 g 25 DAS	37.0	1.375	55.2	4.40	79.0	1.58	2.20	1.38	23.7
Quizalofop ethyl 30 g 35 DAS	39.0	1.485	55.5	4.60	85.6	1.63	2.16	1.42	24.1
Quizalofop ethyl 50 g 25 DAS	38.3	1.320	53.6	4.46	83.3	1.51	2.13	1.51	25.8
Quizalofop ethyl 50 g 35 DAS	27.0	0.897	55.4	4.40	83.2	1.50	2.15	1.53	26.0
Imazethapyr 25 g 25 DAS	31.0	1.200	52.3	4.41	88.4	1.73	2.26	1.71	29.0
Imazethapyr 25 g 35 DAS	32.6	1.329	53.8	4.38	86.2	1.80	2.36	1.70	28.3
Imazethapyr 40 g 25 DAS	37.3	1.007	51.4	4.36	91.0	1.76	2.40	1.75	30.1
Imazethapyr 40 g 35 DAS	40.0	1.016	53.4	4.43	89.0	1.70	2.33	1.73	30.1
Imazethapyr 55 g 25 DAS	35.0	0.991	53.0	4.46	86.0	1.65	2.20	1.64	29.8
Imazethapyr 55 g 35 DAS	28.3	0.753	54.4	4.40	84.8	1.70	2.23	1.67	30.0
Unweeded check	30.6	1.329	52.5	4.00	73.1	1.53	2.16	1.16	22.0
2 Hand weeding (30&60 DAS)	53.3	1.784	59.9	4.80	98.8	1.83	2.41	1.78	25.8
LSD (P=0.05)	9.9	0.316	3.8	NS	8.9	NS	NS	0.23	4.3

et al. 2004). Two hand weedings recorded significantly higher plant height than all other treatments (Table 3). Similarly, two hand weeding treatment registered the highest grain yield (1776 kg/ha), which was, however, on par with all imazethapyr treatments. Harvest index, in general, was higher in imazethapyr treatments than in quizalofop ethyl treatments.

Higher grain yield in case of two hand weeding treatment and imazethapyr applied at 25 or 40 g/ha at 25 or 35 DAS was due to higher number of pods/plant which might have been resulted due to better control of weeds as reflected in lower weed density (Table 1) and lower biomass of weeds and higher WCE (Table 2). Pods/plant is known to have significant positive correlation with grain yield in lentil (Singh *et al.* 2009). Harvest index, in general, was higher in imazethapyr treatments than in quizalofop-ethyl treatments.

SUMMARY

A field experiment was conducted at the Punjab Agricultural University, Ludhiana to study the effect of post-emergence herbicides imazethapyr at 25, 40 and 55 g/ha 25 or 35 DAS and quizalofop-ethyl at 30 and 50 g/ha 25 or 35 DAS along with unweeded check and two hand weedings at 30 and 60 DAS on weeds, growth and yield of lentil (*Lens culinaris* Medikus). Imazethapyr caused phytotoxicity to lentil but with time the crop recovered. Imazethapyr at 25 as well as 40 g/ha and quizalofop-ethyl at 30 g/ha, both at 25 and 35 DAS, did not adversely affect nodulation. Imazethapyr at 25 as well as 40 g/ha at either 25 or 35 DAS showed promise in improving the grain yield of lentil.

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Short communication

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Production potential of soybean-wheat cropping system through weed management

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The benefits of tillage are multifaceted as it loosens soil, enhance release of nutrients from soil for plant growth, kill weeds and regulates the circulation of water and air through soil which lead to an enhanced nutrient uptake and better yield of crops. 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). The response of weed flora to different weed control methods also vary depending upon field situation. Tillage affects the weeds by uprooting, dismembering and burying them deep enough to prevent emergence by changing soil environment and so inhibiting weeds germination and establishment, thereby creating favorable soil environment for plant growth (Sawanton *et al*. 2000). Soybean is a miracle crop which is mainly grown for oil and is a good source of protein, used in cattle feeds. Weed infestation in soybean results in a loss of yields to the extent of 30-80 per cent (Yaduraju *et al.* 2002). Hence, an experiment was conducted to identify ideal method of weed management in soybean-wheat cropping system.

Field experiment was conducted at Weed Research Center Farm of M.A.U, Parbhani during *Kharif* and *Rabi* season of 2007, 2008 and 2009. The experiment was laid out in split plot design with three replications. The main plot consisted of tillage treatments including - zero tillage (ZT) - ZT, ZT - conventional tillage (CT), CT - ZT , minimum tillage (MT) - MT and CT - CT and sub-plots included weed control treatments, *viz.* two hand weedings, alachlor 2 kg/ha pre-emergence treatment (PE) in soybean/pendimethalin 1 kg/ha PE in wheat and weedy check in rotation. The gross plot size and net plot size was 10.0 x 2.7 m and 9.0 x 1.8 m, respectively. Soybean crop in *Kharif* was sown during first fortnight of July and wheat crop in *Rabi* was sown during last week of November. Recommended dose of fertilizers and plant protection schedule were followed for respective crops. The data were statistically analyzed using ANOVA and means were separated using LSD test at 5% level of probability.

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Effect on weeds in soybean

Lowest dry weight of grassy weeds was found in CT-CT tillage system during 2008, 2009, which was at par with MT-MT tillage and significantly superior over rest of the treatments in soybean (Table 1). Whereas during 2007 lowest biomass of grassy weeds was found in MT-MT tillage system, which was at par with CT-CT tillage. Lowest biomass of broad-leaved weeds at 60 DAS was recorded in CT-CT tillage system during 2007, 2008 and 2009 (2.89, 2.84 and 15.67 respectively), which was at par with MT-MT tillage (3.57, 3.20, 17.03, respectively).

Significant differences due to weed control treatments were recorded in weed biomass. The lowest biomass of grassy weeds was recorded in 2 hand weedings during 2007, 2008 and 2009 which was at par with alachlor 2.0 kg/ha PE. The lowest biomass of broad leaved weeds was recorded in 2 hand weedings during 2007, 2008 and 2009 (2.22, 3.09, 11.85 respectively), which was at par with alachlor 2.0 kg/ha PE and significantly superior over weedy check.

Effect on grain yield of soybean

Biomass of grassy weeds in MT- MT tillage system was found lowest during 2008 (2.80 g/m^2). During 2009, the lowest biomass of grassy weeds was recorded in CT-CT which was at par with MT-MT tillage system in wheat (Table 1).

The biomass of broad-leaved weed was found lowest in MT- MT tillage system and was at par with CT-CT and ZT-CT system during all the years of experimentation.

The lowest biomass of grassy and broad-leaved weeds was recorded in 2 hand weedings and was at par with alachlor 2.0 kg/ha PE and significantly superior over weedy check during 2007, 2008 and 2009.

During the year 2007, 2008 and 2009, grain yield loss due to unchecked weeds was 41, 36 and 41%, respectively. During 2007 and 2008, highest grain yield of soybean (3.08 and 2.92 t/ha) recorded in CT-CT treatment was at par with ZT-CT and MT-MT tillage system and found significantly superior over rest of the treatments (Table 2). Whereas, during 2009, the

Table 1. Dry weed weight as influenced by different treatments in soybean and wheat at 40 days after sowing

Treatment	Biomass of weeds in soybean (g/m^2)						Biomass of weeds in wheat (g/m^2)					
	Broad-leaved weeds			Grassy weeds			Broad-leaved weeds			Grassy weeds		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
Main plot (Tillage)*												
ZT-ZT	4.99	5.78	23.00	6.56	6.00	23.90	8.67	7.90	27.74	5.54	4.63	28.34
ZT-CT	4.08	4.90	18.72	5.63	4.98	19.40	7.07	5.84	22.20	3.96	4.40	23.12
CT-ZT	4.27	4.55	18.28	5.30	3.10	12.25	7.50	6.80	26.35	5.18	4.98	27.42
MT-MT	3.53	3.20	17.03	5.02	2.89	08.00	5.66	3.88	17.33	3.30	2.80	20.84
CT-CT	2.89	2.84	15.67	5.16	2.69	5.30	6.21	2.94	15.73	3.92	4.50	19.23
LSD (P=0.05)	1.72	0.45	4.68	NS	1.80	5.57	0.85	2.04	2.18	NS	0.80	4.22
Sub-plot (weed control methods)**												
Two hand weedings	2.22	3.09	11.85	1.42	2.10	7.58	5.15	4.00	14.28	3.85	3.66	18.04
Alachlor 2 kg/ha PE in soybean and pendimethalin 1 kg/ha PE in wheat	2.62	3.80	13.11	3.33	2.80	9.55	6.78	4.73	15.75	3.94	3.87	20.45
Weedy check	5.43	5.86	30.66	9.05	6.89	24.19	9.15	7.68	35.58	5.35	5.27	32.88
LSD (P=0.05)	0.67	0.53	3.12	1.18	1.11	2.62	0.65	1.30	1.68	0.95	0.57	3.68

*ZT = Zero tillage; CT = Conventional tillage; MT = Minimum tillage; ** PE = pre emergence treatment

Table 2. Soybean and wheat grain yield as influenced by different treatments

Treatment	Grain yield of soybean (kg/ha)			Grain yield of wheat (kg/ha)		
	2007	2008	2009	2007	2008	2009
Main plot (Tillage)*						
ZT-ZT	1.82	1.63	1.43	2.73	2.51	1.92
ZT-CT	2.09	1.97	1.61	2.99	2.75	2.31
CT-ZT	2.90	2.74	2.11	2.98	2.61	2.08
MT-MT	2.78	2.50	2.27	3.35	3.48	2.74
CT-CT	3.08	2.92	2.53	3.09	3.23	2.83
LSD (P=0.05)	0.41	0.21	0.43	0.30	0.29	0.33
Sub-plot (weed control methods)**						
Two hand weedings	2.88	2.74	2.34	3.32	3.02	3.19
Alachlor 2 kg/ha PE in soybean and pendimethalin 1 kg/ha PE in wheat	2.87	2.57	2.23	3.22	2.97	3.10
Weedy check	1.85	1.75	1.39	2.59	2.77	2.22
LSD (P=0.05)	0.29	0.23	0.14	0.31	0.23	0.39

*ZT = Zero tillage; CT = Conventional tillage; MT = Minimum tillage; ** PE = pre emergence treatment

highest grain yield of soybean (2.53 t/ha) was recorded by CT-CT tillage system which was found at par with MT-MT tillage system and significantly superior over rest of the treatments.

During 2007, 2008 and 2009, highest grain yield values were recorded under two hand weedings treatment which was at par with alachlor 2 kg/ha PE and was significantly superior over weedy check. Effect on weeds in wheat

Effect on grain yield of wheat

During the year 2007 and 2008, the maximum grain yield of wheat (Table 2) was recorded in MT-MT (3.35 and 3.48 t/ha, respectively) followed by CT-CT tillage system. Whereas during 2009, highest grain yield (2.83 t/ha) of wheat was recorded in CT- CT treatment which was at par with MT- MT tillage system (2.74 t/ha).

Two hand weedings treatment resulted in highest grain yield and straw yield, which was found at par with pendimethalin 1 kg/ha PE and significantly superior over weedy check during 2007, 2008 and 2009.

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Weed control in onion with herbicides

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Onion (*Allium cepa* L.) is the most important vegetable spices in the world and top most export commodity among vegetables. The extremely slow growth in the initial stages, non-branching habit, sparse foliage and shallow root system in onion exhibit greater susceptibility to weeds and results into low productivity. Hand weeding is a tedious expensive and time consuming task due to closer spacing. Non-availability of labour during critical period of crop makes hand weeding difficult leading to heavy yield losses. Herbicides when used with one or two hand weeding showed improved efficiency in control of weeds. Therefore, present experiment was conducted to screen different herbicides and to identify their optimum doses alone and in combination for effective control of weeds.

The experiment was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar during *Kharif 20*12. The experiment was laid out in randomized block design consisted of nine weed control treatments, *viz*. weed free, weedy check (control), pendimethalin1.0 kg/ha pre-emergence treatment (PE) *fb* 1 hand weeding (HW) at 45 DAT, oxyfluorfen 0.150 kg/ha (PE) *fb* 1 HW at 45 DAT, as post-emergence (POE) quizalofop-ethyl 0.05 kg/ha at 21 DAT (POE) *fb* 1 HW at 45 DAT, pendimethalin1.0 kg/ha(PE) *fb* oxyfluorfen 0.25 kg/ha at 45 DAT (POE), pendimethalin1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.05 kg/haat 45 DAT (POE), pendimethalin1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 45 DAT and quizalofop-ethyl 0.037 kg/ha+ oxyfluorfen 0.18 kg/ha at 21 DAT (POE) *fb* 1 HW at 45 DAT. The gross and net plot sizes were 3.00 x 4.20 m^2 and 2.40 x 3.80 m^2, respectively. The variety used was '*Baswant-780*'. The soil was low in available nitrogen (181.12 kg/ha), low in available P_2O_5 (18.44 kg/ha) and very high in available K_2O (410.44 kg/ha) and slightly alkaline in reaction (pH 7.8). The seedlings were transplanted at 15 cm x 10 cm spacing on ridges and furrow. The recommended dose of fertilizer *i.e.* 100 kg N/ha, 50 Kg P_20_5/ha and 50 kg K_20/ha was applied. Along with growth and yield parameters, the weed density and biomass were recorded and weed control efficiency and weed index were estimated as measures of weed control efficiency.

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Weed flora

The major weed species observed in the experimental plot were sedges *Cyperus rotundus,* monocot weeds *Cynodon dactylon*, *Echinochloa crusgalli* and broad-leaf weeds, *Parthenium hysterophorus*, *Amaranthus spinosus*, *Convolvulus arvensis*, *Digera arvensis* and *Euphorbia* sp.

Weed density

The weed density/m^2 at all growth stages was significantly lowest in weed free treatment. Among the herbicide treatment it was lower in application of quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 21 DAT (POE) *fb*1 HW at 45 DAT at all days of observations. The results were in conformity with those obtained by Bhutia *et al.* (2005) and Khalid *et al.* (2006).

Weed biomass

In the weed free treatment, there was no weed dry matter due to absence of weeds. The treatment quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 21 DAT (POE) *fb* 1 HW at 45 DAT recorded the lowest weed biomass/ha (22 kg/ha). The weedy check recorded the highest weed biomass (194 kg/ha). This might be due to highest weed intensity and its dominance which utilized the sunlight, nutrients, moisture, CO_2 *etc.* over crop plants and resulted into higher growth and ultimately the higher weed biomass in weedy check. Similar results were reported by Warade *et al.* (2006) and Chopra and Chopra (2007).

Weed control efficiency (WCE)

Among the herbicidal treatments, application of quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 21 DAT (POE) *fb* 1 HW at 45 DAT recorded significantly higher weed control efficiency (88.49%). The weed free treatment was found significantly superior by recording 100% weed control efficiency. The higher WCE in these treatments might be due to the significant reduction in weed biomass because of the effective weed control practices through application of pre-emergence and/or post-emergence herbicides and hand weeding. The results were well collaborating with the findings of Kathiresan *et al.* (2004).

Weed index (WI)

Among the herbicidal treatments, application of quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ ha at 21 DAT (POE) *fb* 1 HW at 45 DAT recorded the lower weed index (4.42%). It was at par with sequential application of herbicides *i.e.* pendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 45 DAT (4.86 %). Weed free treatment recorded the lowest weed index (0%) indicating that there was no reduction in bulb yield in this treatment due to weed infestation. The highest weed index (72.16%) was recorded in weedy check (control) as a result of uncontrolled weed growth which lead to higher competition with the crop. The similar results were obtained by Kathiresan *et al.* (2004).

Bulb yield

The onion bulb yield (24.43 t/ha) was recorded significantly higher in weed free treatment and it was at par with the integrated treatment *i.e.* application of quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ ha at 21 DAT (POE) *fb* 1 HW at 45 DAT (23.80 t/ha) and the treatment *i.e.* application of pendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 45 DAT (23.50 t/ha). This might be due to vigorous growth of the crop due to the availability of sufficient nutrients, moisture, light and space owing to absence of weeds and/or presence of minimum weed densities because of higher weed control efficiency which would compete for the same.This enabled plants to efficiently utilize sun light and water for photosynthesis which led to higher plant height, increased number of leaves and finally the increase in bulb yield. The lowest onion bulb yield (0.70 t/ha) was recorded in weedy check as the presences of more weeds which interfered with growth and development of the crop and compete for the nutrients, moisture, light and space. These results were in close confirmity with those reported by Warade *et al.* (2006) and Patel *et al.* (2012).

Economics of various treatments

The cost of cultivation (` 77,148/ ha) and gross monetary returns (` 2,44,246/ha) were significantly higher in weed free treatment. It was followed by the application of quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 21 DAT (POE) *fb* 1 HW at 45 DAT which recorded cost of cultivation ` 70,178 / ha and gross monetary returns ` 2,38,017/ha. While B: C ratio (3.48) was significantly higher in application ofpendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 45 DAT. It was followed by integrated weed management treatment *i.e.* quizalofop-ethyl 0.037 kg/ha + oxyfluorfen

Table 1. Weed density, weed biomass, weed control efficiency (WCE) and weed index (WI) as influenced by different treatments

Treatment	Dose kg/ha	Time of application	Weed density (no./m^2) 28 DAT	56 DAT	84 DAT	Weed biomass at harvest (kg/ha)	WCE (%)	WI (%)
Pendimethalin as PE *fb* 1 HW	1.0	45 DAT	1.91 (2)	2.5 (4)	1.91 (2)	53.0	73.3	8.09
Oxyfluorfen as PE *fb* 1 HW	0.150	45 DAT	5.16 (22)	2.5 (4)	3.66 (10)	54.0	65.1	13.21
Quizalofop-ethyl as POE *fb* 1 HW	0.05	21 and 45 DAT	7.43 (48)	2.3 (3)	2.95 (6)	67.0	60.6	16.52
Pendimethalin as PE *fb* oxyfluorfen as POE	1.0 0.25	45 DAT	1.91 (2)	3.33 (8)	3.82 (11)	77.0	72.1	10.35
Pendimethalin as PE *fb* quizalofop-ethyl as POE	1.0 & 0.05	45 DAT	1.91 (2)	3.33 (8)	4.37 (15)	81.0	58.4	22.16
Pendimethalin as PE *fb* quizalofop-ethyl as POE + oxyfluorfen as POE	1.0 & 0.037 0.18	45 DAT	1.5 (1)	2.23 (3)	2.23 (3)	46.0	76.1	4.86
Quizalofop-ethyl as POE + oxyfluorfen as POE *fb* 1 HW	0.037& 0.18	21 and 45 DAT	2.23 (3)	0.7 (0)	2.23 (3)	22.0	88.5	4.42
Weed free	-	-	0	0	0	0.0	100	0
Weedy check	-	-	9.33 (78)	10.3 (96)	10.89 (108)	194.0	0	72.16
LSD (P=0.05)			2.13	1.65	2.33	0.97	0.72	5.44

Figures in parentheses indicate actual values, HW = Hand weeding, *fb* = Followed by, DAT = Days after transplanting, PE = Pre-emergence, POE = Post-emergence

Table 2. Herbicide efficiency and economics as influenced by different treatments

Treatment	Dose kg/ha	Time of application	Bulb yield (t/ha)	Cost of cultivation (x10^3 `/ha)	Gross monetary returns (x10^3 `/ha)	Net monetary returns (x10^3 `/ha)	B: C ratio
Pendimethalin as PE *fb* 1 HW	1.0	45 DAT	22.91	69.98	229.08	159.10	3.27
Oxyfluorfen as PE *fb* 1 HW	0.150	45 DAT	21.62	68.73	216.24	147.50	3.15
Quizalofop-ethyl as POE *fb* 1 HW	0.05	21 and 45 DAT	20.78	69.65	207.83	138.17	2.98
Pendimethalin as PE *fb* oxyfluorfen as POE	1.0 0.25	45 DAT	22.34	66.48	223.44	156.95	3.36
Pendimethalin as PE *fb* quizalofop-ethyl as POE	1.0 & 0.05	45 DAT	19.41	66.93	194.12	127.18	2.90
Pendimethalin as PE *fb* quizalofop-ethyl as POE + oxyfluorfen as POE	1.0 & 0.037 0.18	45 DAT	23.50	67.46	235.04	167.58	3.48
Quizalofop-ethyl as POE + oxyfluorfen as POE *fb* 1 HW	0.037 & 0.18	21 and 45 DAT	23.80	70.17	238.02	167.84	3.39
Weed free	-	-	24.43	77.14	244.25	167.10	3.16
Weedy check	-	-	07.1	62.83	70.63	7.79	1.12
LSD at P=0.05	--	--	01.31	-	13.19	13.19	0.18

HW=Hand weeding, *fb* = Followed by, DAT = Days after transplanting, PE = Pre- emergence, POE = Post-emergence

0.18 kg/ha at 21 DAT (POE) *fb* 1 HW at 45 DAT (3.39). The net monetary returns among weed control treatments was recorded maximum (` 1,67,839/ ha) in integrated weed management, *viz*. spraying of quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ ha at 21 DAT *fb* 1 HW at 45 DAT than rest of the weed control treatments (Table 2)

It was concluded that for obtaining higher yields and net monetary returns, onion be planted with the use of quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 21 DAT (POE) *fb*1 HW at 45 DAT for effectively managing weeds in *Kharif* season.

SUMMARY

A field experiment was conducted at PGI farm, M.P.K.V., Rahuri during *Kharif*, 2012. The experiment was laid out in randomized block design with three replications and nine treatments consisted of different weed control treatments, *viz*. weed free, weedy check (control), pendimethalin 1.0 kg/ha (PE) *fb* 1 HW at 45 DAT, oxyfluorfen 0.150 kg/ha (PE) *fb* 1 HW at 45 DAT, quizalofop-ethyl 0.05 kg/ha at 21 DAT (POE) *fb* 1 HW at 45 DAT, pendimethalin 1.0 kg/ha(PE) *fb* oxyfluorfen 0.25 kg/ha at 45 DAT (POE), pendimethalin 1.0 kg/ha(PE) *fb* quizalofop-ethyl 0.05 kg/haat 45 DAT (POE), pendimethalin 1.0 kg/ha(PE) *fb* quizalofop-ethyl 0.037 kg/ha+ oxyfluorfen 0.18 kg/ haat 45 DAT (POE), quizalofop-ethyl 0.037 kg/ha+ oxyfluorfen 0.18 kg/haat 21 DAT (POE) *fb* 1 HW at 45 DAT. The onion, *cv*. '*Baswant-780'*, was transplanted on ridges and furrow. The lowest weed population, weed biomass, weed index and higher weed control efficiency were recorded in weed free check and were at par with application of quizalofop-ethyl 0.037 kg/ha+ oxyfluorfen 0.18 kg/ha at 21 DAT (POE) *fb* 1 HW at 45 DAT which was followed by spraying of pendimethalin1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 45 DAT. Pendimethalin1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 45 DAT proved to be the most remunerative weed control treatment, which recorded the highest benefit: cost ratio (3.48). However, the highest net monetary returns (` 1,67,839/ ha) was recorded quizalofop-ethyl 0.037 kg/ha + oxyfluorfen 0.18 kg/ha at 21 DAT (POE) *fb*1 HW 45 DAT with benefit:cost ratio of 3.39.

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Short communication

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Integrated weed management in sweet corn

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Sweet corn (*Zea mays* L. var. *Saccharata* Sturt), is a variety of maize with a high sugar content. It is also called Indian corn, sugar corn and pole corn. Nature of weed problem in *Rabi* maize is quite different from that of the rainy season maize. In the rainy season, emergence of maize and weed start simultaneously in which first 20-30 days are most critical looking to crop-weed competition while in winter maize, weeds emerge most often after the first irrigation. However, wider row spacing and liberal use of irrigation and fertilizers lead to more growth of weeds (Porwal 2000). Therefore, the study was carried out to find economically effective method of weed control for realizing higher productivity and profitability of sweet corn.

The experiment was carried out at Instructional Farm, Department of Agronomy, JAU, Junagadh during *Rabi* 2010-11. The experiment comprised nine treatments, namely, atrazine 0.5 kg/ha as pre-emergence (PE) + hand weeding (HW) and interculturing (IC) at 30 days after seeding (DAS), pendimethalin 0.9 kg/ha as PE + HW and IC at 30 DAS, oxadiargyl 90 g/ha as PE+ HW and IC at 30 DAS, atrazine PE+ 2,4-D (SS) 0.5 kg/ha at 30 DAS, pendimethalinas PE+ 2,4-D (SS) at 30 DAS, oxadiargyl PE + 2,4-D (SS) at 30 DAS, HW and IC twice, weed free and weedy check. These treatments were replicated three times in RBD. The experimental soil was clayey in texture and low in available N and P, and moderate in available potash. The sweet corn (*Sugar-75*) was sown with seed rate of 15 kg/ha in the rows of 60 cm apart. After uprooting of weeds, the weeds were sun-dried completely till reached to constant weight and finally the weed biomass at harvest was recorded for each treatment and expressed as kg/ha. Weed control efficiency (WCE), weed index (WI) and herbicidal efficiency index (HEI) were also calculated.The crop was harvested in last week of March. Net return and BCR (Benefit cost ratio) were also calculated.

Table 1. Effect of different treatments on cob length and girth, yields, weed indices and economics of sweet corn

Treatment	Cob length (cm)	Cob girth (cm)	Green cob yield (t/ha)	Green fodder yield (t/ha)	WI	WCE	HEI	Cost of cultivation (x10^3` /ha)	Net return (x10^3` /ha)	BCR
Atrazine 0.5 kg/ha as PRE + HW and IC at 30 DAS	20.8	14.9	6.27	34.5	18.2	63.4	16.5	34.52	62.76	2.82
Pendimethalin0.9 kg/ha as PRE + HW and IC at 30 DAS	20.8	13.8	6.29	33.3	18.0	51.1	16.9	35.37	60.87	2.72
Oxadiargyl90 g/ha as PRE + HW and IC at 30 DAS	20.7	13.4	5.86	28.1	23.6	45.9	8.9	35.17	51.54	2.47
Atrazine 0.5 kg/ha as PRE + 2,4-D (SS) 0.5 kg/ha at 30 DAS	20.6	13.9	6.00	30.3	21.8	53.2	11.4	33.67	56.63	2.68
Pendimethalin0.9 kg/ha as PRE + 2,4-D (SS) 0.5 kg/ha at 30 DAS	20.6	13.7	6.00	30.3	22.0	50.3	11.2	34.37	55.80	2.62
Oxadiargyl 90 g/ha as PRE + 2,4-D (SS) 0.5 kg/ha at 30 DAS	20.5	13.6	5.80	27.7	24.4	40.5	7.7	34.17	51.52	2.51
HW and IC at 15 and 30 DAS	22.3	15.7	6.64	35.7	13.4	79.2	-	35.27	66.92	2.90
Weed free	22.9	16.2	7.67	37.6	0.0	100	-	36.47	77.93	3.14
Weedy check	17.4	12.7	5.38	25.5	29.8	0.0	0.0	32.87	46.54	2.42
LSD (P=0.05)	NS	2.1	1.19	5.7	10.7	7.4	11.8	5.70	-	-

Note: WI- Weed Index, WCE- Weed Control Efficiency, HEI- Herbicidal Efficiency Index, BCR- Benefit Cost Ratio.

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Table 2. Effect of different treatments on weed density at 30, 60 DAS, and at harvest and biomass of weeds at harvest

Treatment	Monocot weeds/m²		Dicot weeds/m²		Sedges weeds/m²		Biomass of weed (kg/ha)
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	
Atrazine 0.5 kg/ha as PE + HW and IC at 30 DAS	2.24 (4.53)	1.83 (2.87)	1.74 (2.53)	1.42 (1.53)	2.52 (5.87)	1.83 (2.87)	322.9
Pendimethalin0.9 kg/ha as PE + HW and IC at 30 DAS	2.29 (4.77)	1.89 (3.10)	1.80 (2.77)	1.60 (2.10)	2.62 (6.43)	2.05 (3.77)	431.6
Oxadiargyl90 g/ha as PE + HW and IC at 30 DAS	3.14 (9.54)	2.87 (7.87)	2.74 (7.20)	2.70 (6.87)	3.50 (11.9)	2.87 (7.87)	477.0
Atrazine 0.5 kg/ha as PE + 2,4-D (SS) 0.5 kg/ha at 30 DAS	2.96 (8.46)	2.78 (7.46)	2.64 (6.79)	2.55 (6.46)	3.27 (10.3)	2.96 (8.26)	412.5
Pendimethalin0.9 kg/ha as PE + 2,4-D (SS) 0.5 kg/ha at 30 DAS	3.04 (8.92)	2.81 (7.58)	2.76 (7.25)	2.53 (6.25)	3.26 (10.3)	3.00 (8.52)	437.8
Oxadiargyl 90 g/ha as PE + 2,4-D (SS) 0.5 kg/ha at 30 DAS	3.81 (14.1)	3.64 (12.8)	3.53 (12.1)	3.36 (10.8)	4.05 (16.1)	3.89 (14.8)	525.0
HW and IC at 15 and 30 DAS	2.20 (4.38)	1.58 (2.04)	1.95 (3.38)	1.34 (1.30)	1.96 (3.38)	1.73 (2.58)	183.3
Weed free	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.0
Weedy check	5.52 (30.1)	6.72 (44.8)	5.05 (25.1)	6.25 (38.8)	6.29 (39.1)	6.80 (45.8)	882.6
LSD (P=0.05)	0.71	0.61	0.76	0.66	0.61	0.56	94.5

Note: DAS= Days after sowing, HW and IC at 15 and 30 DAS= To remove weed flushes in early growth stage of crop, PE= Pre-emergence

Yield attributes as well as cob and fodder yield were significantly influenced with application of different weed control practices (Table 1). Results showed that significantly highest cob length (22.95 cm), cob girth (16.25 cm), cob yield (7.67 t/ha) and green fodder yield (37.65 t/ha) were recorded under weed free, which remained statistically equivalent to HW and IC at 15 and 30 DAS, atrazine 0.5 kg/ha as PE + HW and IC at 30 DAS and pendimethalin 0.9 kg/ha as PE + HW and IC at 30 DAS. The improved growth and yield attributes under these treatments might be due to periodical removal of weeds by hand weeding or pre-emergence herbicide supplemented with manual weeding as evidenced by less number of weeds and biomass of weeds (Table 2), which might have maintained high soil fertility status and moisture content by means of less removal of plant nutrients and moisture through weeds. These findings are in close conformity with Deshmukh *et al.* (2009).

All the treatments significantly reduced the weed density (Table 2) compared to weedy check. Next to the weed free, HW and IC at 15 and 30 DAS recorded significantly the lowest weed density and biomass of weeds due to removal weed flushes in early growth stage of crop, which remained statistically at par with atrazine 0.5 kg/ha as PE + HW and IC at 30 DAS and pendimethalin 0.9 kg/ha as PE + HW and IC at 30 DAS. Weed free, HW and IC at 15 and 30 DAS contained minimum weed Index (WI), while maximum weed control efficiency (WCE) and herbicide efficiency index (HEI), closely followed by pendimethalin 1 kg/ha as PE + HW and IC at 40 DAS and atrazine 0.5 kg/ha as PE + HW and IC at 30 DAS. These findings were in close conformity with Verma *et al.* (2009).

This study revealed that maximum net realization of ` 77,926/ha and BCR of 3.14 were realized with treatment weed free, followed by treatments HW and IC at 15 and 30 DAS and atrazine 0.5 kg/ha as PE + 1 HW and IC at 30 DAS, respectively.

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Short communication

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Production potential of fenugreek as influenced by weed management practices

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Fenugreek is one of the most important condiment crops of country in general and Rajasthan in particular. The state contributes the major share of India's production, accounting for almost 80%. The state accounts for 82.35 thousand ha area with production of 87.38 thousand tones and the productivity of 1.06 t/ha (National Horticultural Board 2011-12). It is a winter season crop having multiple uses and its every part is consumed in one or the other form. The crop is used as a spice, as a vegetable for human consumption, as forage for cattle and to some extent for medicinal purposes.Weeds have been identified as a serious drawback in achieving its potential yield. Weeds reduce grain yield of this crop upto an extent of 86% (Tripathi and Singh 2008). Scarcity of labour and their increasing wages compel the farmers to opt the alternative of manual weeding. Therefore, the present investigation was under taken to find out the most effective weed management practice in fenugreek.

A field experiment was conducted during *Rabi*, 2011 at Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan). The soil of the experimental field was clay loam having pH 8.2, organic carbon 0.75% and available N, P and K_2O_5 87.0, 20.10 and 340.0 kg/ha, respectively. The experiment was laid out in a randomized block design with 12 treatment combinations comprising pendimethalin 1.0 kg/ha (pre-emrgence application (PE), pendimethalin 0.75 kg/ha PE, pendimethalin 0.75 kg/ha PE followed by (*fb*) manual weeding (MW) 40 DAS, metribuzin 0.20 kg/ha PE, metribuzin 0.15 kg/ha PE, metribuzin 0.15 kg/ha PE *fb* MW 40 DAS, oxyflourfen 0.15 kg/ha PE, oxyflourfen 0.10 kg/ha PE, oxyflourfen 0.10 kg/ha PE *fb* MW 40 DAS, one hand weeding (HW) 20 days after seeding (DAS), HW 20 and 40 DAS and weedy check. The treatments were replicated four times. Fenugreek variety '*R.Mt.-1*' was sown on 6 November, 2011 in 5.0 x 3.6 m gross plot size at 30 x 10 cm spacing. The crop was fertilized with uniform dose of 40 kg N and 40 kg P_2O_5/ha through urea and DAP, respectively at the time of sowing. All the herbicidal treatments were applied using 750 liters of water/ha with the help of knapsack sprayer fitted with flat fan nozzle. In each plot, monocot and dicot weeds were counted from two randomly selected area of 0.25 m^2 using 0.5 x 0.5 m quadrate and converted into one square meter and subjected to square root transformation. At harvest all the weeds of net plot were harvested and categorized as monocot and dicot weeds and were dried in oven to obtain the biomass. Weed control efficiency was calculated on the basis of weed biomass using the standard formula. Observations on other parameters were taken following standard procedures.

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Weed flora of experimental field comprised of *Chenopodium album, Chenopodium murale, Convolvuls arvensis, Partheniun hysterophorus, Cynodon dactylon* and *Phalaris minor.* Overall the experiment was dominated by dicot weeds.

All the weed management practices significantly reduced density of monocot, dicot and total weeds at 60 DAS compared to weedy check. Similarly, all weed management practices significantly reduced biomass of monocot, dicot and total weed at harvest compared to weedy check (Table 1). The lowest density of monocot (1.87/m^2), dicot (3.5/m^2) and total weed (3.90/m^2) at 60 DAS was recorded in pendimethalin 0.75 kg/ha *fb* manual weeding 40 DAS compared to weedy check wherein density of monocot (3.80/m^2), dicot (8.29/m^2) and total weeds (9.09/m^2) were recorded the highest. However, this treatment was closely and non-significantly followed by two MW at 20 and 40 DAS.

The lowest weed biomass of monocot, dicot and total weeds at harvest (0.16, 037 and 0.53 t/ha, respectively) was also recorded with pendimethalin 0.75 kg/ha *fb* MW at 40 DAS compared to weedy check which

Table 1. Influence of weed management practices on weed density at 60 DAS, weed biomass and WCE at harvest

Treatment	Weed density (m^2)			Weed biomass (t/ha)			Weed control efficiency (%)		
	Monocot	Dicot	Total	Monocot	Dicot	Total	Monocot	Dicot	Total
Pendimethalin 1.0 kg/ha	2.44 (5.5)	4.91(23.7)	5.45(29.2)	0.21	0.45	0.66	47.5	57.6	54.7
Pendimethalin 0.75 kg/ha	2.74 (7.0)	5.27(27.2)	5.89(34.2)	0.23	0.46	0.69	44.1	56.4	52.8
Pendimethalin 0.75 kg/ha *fb* manual weeding 40 DAS	1.87 (3.0)	3.50(11.7)	3.90(14.7)	0.16	0.37	0.53	60.5	65.1	63.7
Metribuzin 0.20 kg/ha	2.73 (7.0)	5.12(25.7)	5.76(32.7)	0.23	0.46	0.69	43.9	56.3	52.7
Metribuzin 0.15 kg/ha	2.91 (8.0)	5.33(28.0)	6.04(36.0)	0.24	0.48	0.71	41.9	55.1	51.1
Metribuzin 0.15 kg/ha *fb* manual weeding 40 DAS	2.00 (3.5)	3.93(15.0)	4.34(18.5)	0.18	0.38	0.56	56.9	63.8	61.7
Oxyflourfen 0.15 kg/ha	2.86 (7.7)	5.50(29.2)	6.11(36.9)	0.24	0.47	0.71	41.2	55.7	51.7
Oxyflourfen 0.10 kg/ha	2.95 (8.2)	5.62(31.5)	6.32(39.5)	0.26	0.48	0.74	37.3	54.3	49.4
Oxyflourfen 0.10 kg/ha *fb* manual weeding at 40 DAS	2.23 (4.5)	4.26(17.7)	4.76(22.2)	0.17	0.40	0.57	57.4	62.1	60.6
HW at 20 DAS	2.64 (6.5)	5.03(25.0)	5.64(31.5)	0.22	0.46	0.69	45.1	56.1	52.9
HW at 20 and 40 DAS	2.05 (3.7)	3.56(12.2)	4.05(15.9)	0.16	0.38	0.54	61.0	64.0	63.0
Weedy check	3.80(14.0)	8.29(68.2)	9.09(82.2)	0.41	1.06	1.47	-	-	-
LSD (P=0.05)	0.64	0.58	0.58	0.05	0.06	0.09	-	-	-

Figures in parentheses are mean of original values; Data subjected to square root transformation

Table 2. Influence of weed management practices on yield, yield attributes, net returns, B:C ratio in fgenugreek

Treatment	Pods/ plant	Seeds/ pod	Test weight (g)	Seed yield (t/ha)	Haulm yield (t/ha)	Harvest index (%)	Net returns ($x10^3$ `/ha)	B:C ratio
Pendimethalin 1.0 kg/ha	34.14	13.24	11.81	1.32	2.14	38.19	29.20	2.37
Pendimethalin 0.75 kg/ha	33.26	12.34	10.93	1.26	2.07	37.78	27.39	2.31
Pendimethalin 0.75 kg/ha *fb* manual weeding 40 DAS	39.24	15.10	13.04	1.64	2.50	39.55	39.58	2.74
Metribuzin 0.20 kg/ha	33.32	12.28	11.23	1.20	2.09	36.66	26.04	2.29
Metribuzin 0.15 kg/ha	32.47	11.57	11.01	1.19	2.01	37.11	25.47	2.27
Metribuzin 0.15 kg/ha *fb* manual weeding 40 DAS	35.33	13.70	12.16	1.42	2.39	37.16	32.65	2.49
Oxyflourfen 0.15 kg/ha	31.46	11.91	10.69	1.16	1.99	37.02	24.13	2.17
Oxyflourfen 0.10 kg/ha	30.63	11.64	10.25	1.13	1.92	37.14	23.04	2.13
Oxyflourfen 0.10 kg/ha *fb* manual weeding at 40 DAS	33.87	13.23	12.35	1.38	2.28	37.72	30.82	2.39
HW at 20 DAS	32.46	11.97	10.76	1.21	1.97	37.96	23.74	2.06
HW at 20 and 40 DAS	37.27	14.19	12.44	1.51	2.42	38.43	32.25	2.27
Weedy check	28.83	10.21	9.29	0.89	1.54	36.56	14.86	1.76
LSD (P=0.05)	3.13	1.42	0.88	0.21	0.29	NS	-	-

was at par with MW carried out at 20 and 40 DAS. The results are analogous to those reported by Sharma (2009). Heavy weed density and biomass of weed under weedy check were reported earlier by Bodake *et al*. (2012). The highest total weed control efficiency (63.7%) was also recorded with application of pendimethalin 0.75 kg/ha integrated with MW at 40 DAS followed by two manual weeding (63.0%), while minimum (49.4%) with oxyfluorfen 0.10 kg/ha PE.

Among weed management practices, application of pendimethalin 0.75 kg/ha *fb* MW carried out at 40 DAS as well as two manual weeding carried out at 20 and 40 DAS being at par significantly increased pods/plant, seeds/pod, 1000-seed weight, seed, haulm and biological yield compared to weedy check (Table 2). The highest yield and yied attributes under these treatments were attributed due to lower crop-weed competition. The maximum seed (1.64 t/ha) and haulm yield (2.50 t/ha) were obtained under application of pendimethalin 0.75 kg/ha *fb* MW carried out at 40 DAS which was at par with manual weeding carried out at 20 and 40 DAS (1.51 t/ha and 2.42 t/ha, respectively).

Harvest index did not significantly influence by any weed management practices. Recorded higher yield and yield attributes under influence of pendimethalin 0.75 kg/ha *fb* MW carried out at 40 DAS and two manual weeding carried out at 20 and 40 DAS corroborates with the findings of Mehta *et al.* (2010) and Choudhary *et al.* (2012). Maximum net return (` 39,582 /ha) and benefit : cost ratio (2.74) were obtained with application of pendimethalin 0.75 kg/ha *fb* MW carried out at 40 DAS which was followed by metribuzin 0.15 kg/ha *fb* manual weeding at 40 DAS.

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Short communication

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Persistence of oxyfluorfen in acid soil and tea leaves

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India is the highest producer of tea in the world. Tea is grown in about 5,78,458 hectares in India. In south India, tea is grown at an altitudes ranging from 500 to 2200 meters above mean sea level in undulating terrains lying between 10 and 16 per cent slopes, even up to 33 per cent gradient (Sharma 1977). Tea is grown in a wide range of soil types that are chiefly acidic in reaction in south India (Barua 1989) and at an altitudes ranging from 500 to 2200 meters above mean sea level in undulating terrains. Weeds pose a serious problem in young tea clearing, pruned fields and vacant patches in mature tea fields. Hence, chemical weed control methods are widely followed by the farmers. Since, tea is grown in sloppy terrains, possibility of the herbicides to runoff and contaminates the water bodies and environment is more. Paraquat, 2,4-D and glyphosate are extensively used herbicides in tea fields and oxyfluorfen, glufosinate ammonium, simazine and diuron are used in a limited scale (Barooah, 2011) in India. Oxyfluorfen is used for broad spectrum pre- and post-emergence control of annual broad-leaved and grassy weeds (Scrano *et al.* 1999) in a variety of crops. Wauchope *et al.* (1992) also reported an average field half life of 35 days for oxyfluorfen.

Oxyfluorfen is classified as a highly toxic and persistent herbicide, which persists in soil and accumulates in terrestrial plants and certain aquatic environments through runoff (USEPA 1992) and parent oxyfluorfen is of toxicological concern for human health risk assessment. Although there are several reports on the efficacy of oxyfluorfen against various weeds, reports on the methods of chemical analysis and environmental fate in tea leaves and its degradation in acid soil is lacking. Therefore, field experiment was undertaken to investigate the behavior of oxyfluorfen in acid soil and the possibility of bioaccumulation in tea leaves and its hazard to environment.

Field experiment pertaining to the persistence of oxyfluorfen in tea and field soil was conducted at the farmer's field near TANTEA Research Farm, Coonoor, Nilgiris, Tamil Nadu. The experimental farm was located in Western Zone of Tamil Nadu at 11°15'00"N latitude and 76°40'00"E longitude with an altitude of 1501 m above mean sea level (MSL). Experiment was laid out in randomized block design and the treatments were replicated thrice. The size of each plot was 5 × 3 m. The spacing between the tea bushes and the rows was 100 cm. The clone variety '*CR 6017*' was used in the field experiment. Oxyfluorfen was applied at four different doses, *i.e.* 200, 250, 300 and 400 g/ha, as a pre-emergence spray in tea plantation field with the help of a knapsack sprayer. Control plot was maintained in triplicate by only spraying water, without herbicide. The treatments were imposed during September after pruning during March.

Soil samples were drawn randomly from 0–15 cm depth using a tube auger from 6–7 spots in each plot. Approximately 500 g of soil was collected from each plot. The soil and tea leaf samples were collected at 0 (2 h), 5, 10, 25, 50, 75 and 100 day time intervals from all the treated and control plots. Soil samples were mixed thoroughly and spread on a glass plate and divided into four parts (quarters). Soil of two opposite quarters was retained, rejecting the remaining two. The process was further repeated to obtain 100 g of representative sample for the final analysis. Newly emerged young tea leaf samples collected (about 200 g) from different treatments were chopped to small pieces, homogenized and a representative sample of 50 g from each treatment was processed for analysis. The soil of the experimental field was sandy clay loam with pH 4.30, EC 0.24 dS/m and 4.10% organic carbon.

A gas chromatography (model GC8610 of Thermo Fischer India Ltd, India) equipped with electron capture detector (GC-ECD) was used for quantitative analysis of oxyfluorfen and its extraction and determination in soil and tea leaves was done as per the protocol described by Janaki *et al.* (2013). Validation of method was also executed in terms of recovery studies before analyzing unknown samples. Oxyfluorfen degradation was described using the first

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order kinetics equation. Under the given conditions of GC-ECD, oxyfluorfen resolved at 4.90 min as a single sharp peak. While the instrument detection limit for oxyfluorfen by GC was 0.01 µg/mL, the method detection limit was found to be 0.01 and 0.05 µg/g of soil and tea leaves respectively. The average recovery of oxyfluorfen across different matrices and levels of oxyfluorfen fortification was acceptable which ranged from 75 - 93 per cent with the RSD values of 1.1 to 3.3.

On day 0, initial deposit of oxyfluorfen was determined 0.078, 0.136, 0.247 and 0.372 mg/kg of soil at 200, 250, 300 and 400 g/ha respectively (Table 1). At all the rates of application, more than 50% oxyfluorfen was dissipated from soil within 10 days. On day 25, while the residue was not detected in the lowest dose applied plot, more than 90% residue was degraded from the 250 g/ha applied plot. This could be the result of high soil binding which is the likely route of its dissipation from soil (Wauchope *et al*. 1992) as influenced by the high organic carbon content. This could also be ascribed to the washing out of residues from soil through runoff from soil (Janaki *et al*. 2012) by the high rainfall (>50 mm) received during that period. At rates of 300 and 400 g/ha, oxyfluorfen dissipated slowly from soil, and the dissipation rate was found to be 87.9 and 87.8% respectively on day 25. More than 95% of the applied oxyfluorfen dissipated from soil at the higher rates of 300 and 400 g/ha application on day 50 and its residue was BDL on 75th and 90th days. The rate of disappearance of oxyfluorfen in soil followed first-order kinetics with the R^2 value ranged of 0.91-0.98. The half life of oxyfluorfen in soil ranged between 5.7 to 6.4 days (Table 1). Such a shorter half life of oxyfluorfen found in the present study might be due to the enhanced photolysis of oxyfluorfen by high temperature and sun shine hours prevailed during the time of herbicide application. The low solubility of oxyfluorfen in water (0.116 mg/L at 20^0C) might have retained it in soil surface and could have augmented the faster photo chemical decomposition from soil as reported for metamifop (Janaki *et al*. 2012).

As there was no growth of new leaves on 0 and 5 day, tea leaf samples were not collected and analyzed for oxyfluorfen residue. On day 10, the oxyfluorfen concentration detected was as 0.045, 0.066, 0.091 and 0.16 mg/kg of leaves at 200, 250, 300 and 400 g/ha respectively (Table 2). This could be ascribed to the increased absorption and translocation of oxyfluorfen from soil in concomitant with the new growth of leaves from the tea plant. On day 25, the oxyfluorfen residue decreased and on day 50, it becomes BDL at lower doses (200 and 250 g/ha) applied plot. Whereas at higher doses (300 and 400 g/ha) applied plot, approximately 70 per cent of the resi-

Table 1. Persistence of oxyfluorfen in tea field soil

Days after herbicide application	Persistence (mg/kg) ± SD[a]			
	200 g/ha	250 g/ha	300 g/ha	400 g/ha
0	0.078 ± 0.004	0.136± 0.005	0.247± 0.015	0.372± 0.007
5	0.049± 0.007	0.062± 0.019	0.108± 0.001	0.184± 0.005
10	0.023± 0.007	0.46± 0.002	0.075± 0.004	0.125± 0.003
25	BDL	0.010± 0.002	0.029± 0.006	0.045± 0.004
50	BDL	BDL	0.011± 0.006	0.019± 0.004
75	BDL	BDL	BDL	0.007± 0.003
90	BDL	BDL	BDL	BDL
Half life	5.66	6.36	5.80	6.35

[a]Average of three replicates, SD = Standard deviation, BDL = Below detection level

Table 2. Persistence of oxyfluorfen in tea leaves

Days after herbicide application	Persistence (mg / kg) ± SD[a]			
	200 g / ha	250 g / ha	300 g / ha	400 g / ha
0	BDL	BDL	BDL	BDL
5	BDL	BDL	BDL	BDL
10	0.045± 0.008 (0)	0.066± 0.002 (0)	0.091± 0.003 (0)	0.166± 0.013(0)
25	0.028± 0.002 (39.1)	0.039± 0.002 (41.6)	0.051± 0.009 (43.8)	0.081± 0.006 (51.4)
50	BDL	BDL	0.019± 0.001 (78.7)	0.027± 0.002(83.8)
75	BDL	BDL	BDL	BDL
Half life	19.55	18.22	19.35	18.00

[a]Average of three replicates, SD = Standard deviation, BDL = Below detection level, figures in parentheses indicate % dissipation

due only dissipated on 50 day. Detectable residues (>0.01 mg/kg) was not found on day 75 of application at any of the dose which is well below the proposed oxyfluorfen tolerance of 0.2, 0.01 and 0.005 mg/kg respectively by India, Japan and European Union for tea (Barooah 2011). The half life of oxyfluorfen in plant was ranged between 18.0 to 19.6 days at the four rates of application (Table 2). Based on the dissipation rate of oxyfluorfen from the tea leaves, the safe waiting period suggested for plucking the tea leaves from the plant after oxyfluorfen spraying is 75 days.

SUMMARY

The present study was undertaken to determine the persistence and residue of oxyfluorfen in tea and sandy clay loam acid soil with a pH of 4.3 and organic carbon content of 4.1%. Results showed that, the application of oxyfluorfen at 200 g /ha persisted in soil up to 10 days while up to 25 days at 400 g/ha and 50 per cent degraded from the soil before 30 days. Within 3 hrs of application, 6.9 to 35.8% of the oxyfluorfen dissipated from the soil. More than 80% of the applied oxyfluorfen degraded from soil before 10 days of its application under 200 g/ha, while it took 25 days at 400 g/ha. Oxyfluorfen residue was not detected in tea leaves upto 50 days. It is concluded that the waiting period of 75 days should be implemented for plucking the tea leaves after the application of oxyfluorfen or else there will be a chances for the herbicide to enter the food chain due to bioma-gnification.

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Short communication

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Enhancing glyphosate translocation by 2,4-D to control purple nutsedge

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Key words: 2,4-D, Herbicide combination, Leaf senescence, Purple nutsedge

Lack of glyphosate translocation to the site of action (growing apex) is the limitation for effective control of purple nutsedge (*Cyperus rotundus* L). Glyphosate is used for weed control in wasteland, zero tillage, directed spray in plantation crops and on quarantine weeds. Senescence of leaf is programmed cell death involving degradation of macromolecules *viz.* proteins, nucleic acids and lipids and during later stage of this process, essential nutrients are remobilizes to the growing apex. Pre-treatment with ethephon (5000 ppm) induced the leaf senescence and reduced callose accumulation in phloem which enhanced 2,4-D and glyphosate translocation and thus their efficacies (Devendra *et al.* 1996). Senescence period of 48 h, induced by glyphosate (1.3 kg/ha) enhanced the efficacy more than 24 or 72 h senescence period (Dhanraj *et al.* 2012). Senescence was found to increase the activity of low affinity (Pht 2,1) phosphate transporter (Daram *et al.* 1999) and high affinity (PhPT1) phosphate transporter (Chapin and Jones 2009). Glyphosate being phosphate having molecule, compete with phosphate with transporter which led to enhanced phloem mobility.

2,4-D, apart from stimulating the enzyme 1-amino-cyclopropane-1-carboxylic acid synthase (ACC-synthase), key enzyme in ethylene production, led to uncontrolled apex groth by increased unwanted DNA, RNA and protein synthesis (Chinalia *et al.* 2007). With this background, attempt was made to assess the pre-treatment of 2,4-D sodium salt for 48 h on glyphosate efficacy in control of perennial *C. rotundus*.

Single *C. rotundus* tuber having same size was planted in a pots of size 30x10x10 cm^3 filled with Kandic Paleustalf–sandy loam soil. Pots were irrigated daily. Twenty-five days after establishment, different treatments, *viz.* 2,4-D sodium salt (2 kg/ha), glyphosate (1.3 kg/ha), 2,4-D sodium salt (1.0 kg/ha) pretreatment 48 h followed by (*fb*) 2,4-D sodium salt (1.0 kg/ha)- (2,4-D *fb* 2,4-D) glyphosate *fb* glyphosate (0.65 *fb* 0.65 kg/ha); 2,4-D *fb* glyphosate in various proportions, *viz.* 1:3, 1:1 and 3:1 were imposed and compared with unsprayed control. There were eight treatments (Table 1) and each treatment had three replications, thus totally 24 plots were used for this study. Pot culture experiment showed that 1:3 proportion of 2,4-D: glyphosate had lowest biomass, hence glyphosate proportions were increased compared to 2,4-D (1:3, 1:4 and 1:5) and treatments were tried under field condition.

Already infested purple nutsedge field was divided into micro plots of size of 2 x 2 m^2 each. Eleven treatments with modified 2,4-D *fb* glyphosate in various proportions *viz.* 1:3, 1:4 and 1:5 were tried. Further, these proportions of 2,4-D and glyphosate used in treatment 6, 7 and 8 were tank mixed and sprayed (Table 2). Each treatment had three replications. Thus, there were 33 plots under micro-plot conditions. Total biomass was recorded 45 days after last spray in both experiments and data was analyzed statistically the Decan's range test was used to assess the significance difference between herbicides and their combination using MSTATC software.

Entry and translocation is the limitation to reduce the dosage of herbicides without affecting their efficacy. In this investigation, attempts were made to reduce the dosage of both herbicide based on their mode of actions. Total biomass of *C. rotundus* data showed that all the herbicide treatments had significantly low biomass compared to unsprayed control both under pot culture and field conditions (Table 1 and Table 2). Under pot culture, lowest biomass was recorded by 1:3 proportion of 2,4-D *fb* glyphosate compared to other treatments it was efficient than 2,4-D alone or 2,4-D *fb* 2,4-D treatments. Rest of the treatments had same effect on reducing the biomass of the weed plant. Though glyphosate (1.3 kg/ha) alone had similar effect of 1:3 proportion of 2,4-D *fb* glyphosate, 2,4-D *fb* glyphosate had relatively more effective in recording lowest biomass and allows reduction in dosage of both herbicides. In 1:3 proportion, 2,4-D concentration was low compared to other proportions. Chinalia *et al.* (2007) suggested that lower the dose of 2,4-D led to

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Table 1. Effect of herbicides and their combinations on total biomass of *Cyperus rotundus* in pot culture

Treatment	kg/ha	Total biomass (g/pot)
Unsprayed control	-	81.0
2,4-D Na salt	2.00	8.1
Glyphosate	1.30	3.4
25% of 2,4-D *fb*75% of glyphosate (1:3)	0.50 *fb* 0.97	2.5
50% of 2,4-D *fb* 50% of glyphosate (1:1)	1.00 *fb* 0.65	5.8
75% of 2,4-D *fb* 25% of glyphosate (3:1)	1.50 *fb* 0.32	7.0
Glyphosate *fb* glyphosate	0.65 *fb* 0.65	5.7
2,4-D *fb* 2,4D	1.0 *fb* 1.0	24.4
LSD (P=0.05)		15.63

fb = Followed by (48 h pre-treatment with 2,4-D or glyphosate)

Table 2. Effect of herbicides and their combinations on total biomass of *Cyperus rotundus* in field (micro-plot of size 2 x 2 m^2)

Treatment	kg/ha	Total biomass (g/m^2)
Unsprayed control	-	655.2
2,4-D Na salt	2.00	324.8
Glyphosate	0.75	391.2
Glyphosate	1.5	148.0
Glyphosate *fb* glyphosate	0.75 *fb* 0.75	281.2
25% of 2,4-D *fb* 75% of glyphosate (1:3)	0.5 *fb* 1.1	118.8
20% of 2,4-D *fb* 80% of glyphosate (1:4)	0.3 *fb* 1.26	300.0
16% of 2,4-D *fb* 84% of glyphosate (1:5)	0.25 *fb* 1.35	348.0
25% of 2,4-D + 75% of glyphosate (1:3)	0.5 + 1.1	375.2
20% of 2,4-D + 80% of glyphosate (1:4)	0.3 + 1.26	440.8
16% of 2,4-D + 84% of glyphosate (1:5)	0.25 + 1.35	506.8
LSD (P=0.05)		283.2

lowering of the reactive oxygen species (ROS) production, which is one of the mode of action of 2,4-D, thus facilitated membrane intactness and more phosphate transporter action thus increased phloem loading and mobility of glyphosate. Thus in pot culture, percent reduction in nut sedge biomass over unsprayed control in 2,4-D *fb* 2,4-D was 70.4% whereas in 2.4-D alone it was 90%. In glyphosate *fb* glyphosate and glyphosate alone, the percent reduction in weed biomass were 93 and 95% respectively. Whereas in 2,4-D *fb* glyphosate the percent reduction was 97% which was highest amongst all treatments.

Under field condition, an attempt was made to increase the glyphosate concentration than 2,4-D in other proportions, *viz*. 1:3, 1:4 or 1:5. 2,4-D *fb* glyphosate, especially at 1:3 proportion, had lowest biomass compared to other proportions or tank mixed application of these two herbicides. 2,4-D *fb* glyphosate (1:3) had 82% reduced biomass over unsprayed control compared to 77 and 57% reduction over control in glyphosate (1.5 kg/ha) and glyphosate *fb* glyphosate (0.75 *fb* 0.75 kg/ha) (Table 2). Tank mixing of varies proportion of 2,4-D and glyphosate did not showed significant reduction in weed biomass compared to 2,4-D *fb* glyphosate application. Thus, dosage of both herbicides can be reduced from recommended dose in 2,4-D *fb* glyphosate treatment to get maximum suppression of the weed. Application of double the dose of these herbicides in 1:3 proportion might lead to 90% purple nutsedge control under filed condition.

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