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Weed management in conservation agriculture in India

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ABSTRACT

Conservation agriculture (CA) involves minimum soil disturbance, permanent soil cover through crop residues or cover crops, and crop rotations for achieving higher productivity. Even though the adoption of CA in India is still in an early stage, it has been successfully used in the irrigated rice-wheat cropping systems of the Indo Gangetic Plains (IGP) and recently been demonstrated in parts of central India. Increased weed problems during the 'transition period' tends to be the most common hurdle in adoption of CA by farmers. Research has shown that cover crops could play an important role in weed management in CA systems; however, their level of adoption at present is fairly low. Changes in patterns of tillage, planting systems, and other management strategies can alter the soil environment and lead to a major change in weed flora. Herbicide use has been an extremely important component of weed management in CA systems but greater effort is needed to integrate non-chemical weed control tactics with herbicides. Farmer-participatory model of research has proved highly effective in developing CA in rice-wheat system in the IGP. Efforts are required to increase the rate of adoption of direct seeded rice and zero-till wheat throughout the IGP. At present, residue retention on farmer fields tends to be low. Greater awareness of the benefits of residue retention for improved soil health is worthy of an extension campaign in particular and in India in general. Research effort needs to be enhanced to develop CA and promote its adoption in non-rice-wheat cropping systems in India.

Key words: Adoption, Challenges, Conservation agriculture, Future, Opportunities, Socio-economic

Indian agriculture has made significant progress in terms of productivity increase in the last five decades. However, many challenges remain including stagnating net sown area, reduction in per capita land availability, climate change effects and deterioration of land quality. Therefore, a paradigm shift in farming practices is needed to ensure future productivity gains while sustaining the natural resources. Conservation agriculture (CA) has emerged as an effective strategy to enhance sustainable agriculture worldwide. CA has the potential to address the problems of natural resource degradation and environmental pollution, while enhancing system productivity. It is a resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with good production practices of plant nutrition and pest management (Abrol and Sangar 2006).

Cropping system, climate and soils in India

More than half of India's total land mass of 328.7 million hectare (mha) is used for agriculture (Table 1). The net cultivated area increased significantly by about 18% from 119 mha in 1950-51 to 140 M ha in 1970-71 but since then it has been fairly stable, whereas the cropping intensity has increased from 111% to 139%. Irrigated agriculture accounts for 35% of the cropped area and rainfed agriculture is practiced on 65% of the cropped area.

Rice-wheat system is extensive in the sub-tropical areas of the Indo-Gangetic plains (IGP) of India while maize-wheat system is prevalent in tropical, sub-tropical and warm temperate areas. There are mainly three cropping seasons in India: summer (June/July to Sept./Oct.), winter (Oct./Nov. to Feb./Mar.), and spring (Mar./Apr. to May/June). Rice is the main crop in summer while a wide range of crops, including 'Boro' rice in eastern India, wheat, maize, winter pulses (chickpea, lentil, field

Table 1. Land use statistics in India

Land use	Area (m ha)	Per cent of total land use
Forest area	70.0	22.9
Non-agricultural uses	26.3	8.6
Permanent pastures	10.3	3.4
Fallow land	25.4	8.3
Net sown Area	140.8	46.0
Others	55.9	17.0
Total geographical area	328.7	-
Area sown more than once	54.4	-

Source: www.agricoop.nic.in

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peas), potatoes, and mustard are grown in the winter season. In the spring season, short-duration crops such as maize, pulses (green gram, cowpea), and rice are grown.

In India, the IGP are spread over Punjab, Haryana, Uttar Pradesh, Bihar, and West Bengal states (Woodhead *et al*. 1994, Ali and Pande 1999). The climate of the IGP is continental monsoon type with hot summer season with daytime temperatures reaching as high as 45°C in June or July, and cool, dry winter. Temperature extremes are recorded in the west but the weather tends to be milder in the east. Most of the rainfall (~85%) is received during the summer (June-September). Rainfall is very low in the western part (Punjab, Haryana and Uttar Pradesh) (400–600 mm) and increases towards the east (Bihar and West Bengal), which receives heavy rain (up to 1800 mm). Soils are mainly alluvial in nature. Rice-wheat is the dominant cropping system of the IGP followed by rice-fallow-fallow and maize-wheat; sugarcane, cotton, and potato are also major commercial crops (Table 2). The food legumes are generally grown on marginal land in rainfed areas (Ali *et al*. 2000).

Table 2. Areas occupied by crops in different seasons in IGP in India

Summer season	Per cent of net sown area	Winter season	Per cent of net sown area
Rice	65.5	Wheat	67.2
Maize	11.7	Mustard	1.3
Cotton	1.9	Pulse	4.1
Pearl millet	4.9	Potato	0.6
Perennials sugarcane	5.9	Potato-wheat	1.8
Other crops	1.7	Other crops	6.1
Fallow	7.4	Fallow	15.4

Source: Panigrahy *et al*. (2010)

History of development and adoption of CA in India

According to current estimates, CA is being practiced in about 154.8 mha across the globe (FAO, 2014); the major CA practicing countries are USA (26.5 mha), Brazil (25.5 mha), Argentina (25.5 mha), Canada (13.5 mha) and Australia (17.0 mha). Worldwide, CA has spread mostly in the rain-fed agriculture, but India witnessed its success in irrigated rice-wheat cropping systems of the IGP. However, CA systems have not been promoted or adopted in other major agro-ecoregions of India such as rainfed semi-arid tropics and the arid regions of the mountain agro-ecosystems (Bhan and Behera 2014). In India, CA systems have been advocated since 1970s but it is only in the last 2 decades that the area under CA has increased rapidly. Rapid adoption of CA in India appears to be related to the local development of efficient farm machinery and availability of effective herbicides. Over the past few years, zero tillage and CA has been adopted on more than 1.5 mha of agricultural land in India (Jat *et al*. 2012, www.fao.org/ag/ca/6c.html). Zero-till (ZT) wheat in the rice-wheat (RW) system of the IGP is the dominant CA based technology adopted so far by the Indian farmers. ZT wheat has been widely adopted in the north western IGP in the RW systems, and recently its adoption has also started to increase in the eastern IGP (Malik *et al*. 2014).

In Punjab and Haryana, dry direct-seeding rice in unpuddled fields (DSR) has been introduced recently, on the basis of the findings of a research project funded by the Australian Centre for International Agricultural Research (ACIAR). In Punjab alone, the area under DSR increased from 4200 ha in 2012 to 22,000 ha in 2013 and further to 115,000 ha in 2014; the area under DSR was <1000 ha in 2010, the first year of its introduction in this state (www.tribuneindia.com). Such rapid adoption of DSR clearly highlights the ready acceptance of CA technologies among the farmers in the region. Other CA practices including furrow irrigated raised-bed planting, laser assisted land levelling, unpuddled mechanical transplanting of rice and residue management practices are also being adopted by the farmers of the north-western region (IARI, 2012). The adoption of CA also offers avenues for much needed diversification of the rice-wheat system through relay cropping of sugarcane, pulses, and vegetables as intercrop with wheat and maize. For example, many farmers are now practicing intercropping in raised-bed systems. In this system, wheat is planted on the raised beds and mint or sugarcane in the furrows. Inter-cropping systems such as maize+ potato/onion/redbeets or sugarcane+ chickpea/Indian-mustard are also becoming popular with farmers in western Uttar Pradesh (Gupta and Seth 2007). In India, CA is a new concept and its roots are only now beginning to find ground.

In recent years, the CA technologies have been successfully demonstrated at farmers' field in district Jablapur in Madhya Pradesh under the aegis of ICAR Directorate of Weed Research; the yield enhancement varied from 1.5 to 2 times than under conventional practices (Smart Indian Agriculture, 2015) . These results indicated that the black cotton soils of central India are among the best suited for CA, and it has been the fastest growing cultivation technology in this region. The adoption of CA has advanced sowing time of rice, maize, wheat, mustard crops by 10-15 days enabling the farmers to take third crop of green gram in the summer season which was not possible with conventional practices. Encouraged by the success of these demonstrations, the state agriculture department has started providing subsidy for purchase of CA machinery. The long-term study on different CA based systems, initiated under AICRP-weed management, has shown promising results in case of maize-sunflower in Tamilnadu, pearl millet-mustard in Gujarat, rice-chickpea-green gram in Karnataka pointing towards the possibilities of extending the benefits of CA to central and south India (DWR 2014, AICRPWM 2015)

Challenges associated with herbicide use in CA in IGP

Scarcity of farm labour and increases in their wages across India is being reflected in a greater adoption of pesticides. At present, the use of pesticides in India is quite low and estimated at 0.6 kg/ha as compared to global average of 3 kg/ha (www.ficci.com). Currently, in India, herbicides account for 16% of the total pesticide market, and rice and wheat crops consume the major share of herbicides (www.ficci.com). The shift from conventional to conservation agriculture can be particularly difficult with respect to weed control, particularly during the 'transition period', and increased use of herbicides may be necessary under such situations. With the adoption of no-till or zero-till, producers lose the benefit of weed control offered by tillage from seed burial as well as the option to incorporate soil applied pre-emergent herbicides. Moreover, soil applied herbicides that do not require incorporation can have reduced persistence and efficacy in the presence of plant residue that may intercept and bind the chemical before it reaches the soil surface (Potter *et al*. 2008). This reduced efficacy of pre-emergent herbicides has forced producers wishing to adopt conservation practices to become primarily dependent upon post-emergent herbicides, which reduces their weed control options. To further complicate the situation, adoption of CA can lead to major changes in weed population dynamics due to altered distribution of weed seed within the soil (Buhler 1997); perennial weed species also thrive in reduced-tillage systems and can be difficult to control with available post-emergent herbicides (Swanton *et al.* 1993). For example, after the adoption of DSR in Punjab, weed flora has shifted from typical aquatic rice weeds to aerobic grasses and perennial sedges, which are difficult to control with herbicides recommended in puddle transplanted rice (Bhullar *et al*, unpublished data).

New herbicides are often used in tank-mixes to achieve effective weed control. According to Singh *et al* (2015a), CA practices such as ZT can be an important component of integrated weed management in DSR, provided herbicide efficacy can be maintained by adjusting the rate and timing of herbicide application. Even though there is some evidence that weed control in CA becomes easier over the long-term due to more uniform germination and greater seed predation, there remain serious challenges to weed control in the short-term after the adoption of CA (Murphy *et al.* 2006, Swanton *et al.* 2008).

In India, herbicide use has increased in both CT and ZT systems because it provides cost-effective weed control and saves labor, which has become more scarce and expensive (Rao *et al*. 2007). Although herbicides play an important role in facilitating the adoption of ZT practices, over reliance on herbicides can rapidly lead to herbicide resistance in weeds (CAST 2012, Heap 2012). Additionally, public concerns about the potential adverse effect of herbicides on neighbouring water resources (Spalding *et al.* 2003, Guzzella *et al.* 2006) and human health (Pingali and Marquez 1996, EPA 2007) have increased.

Herbicide resistance is a major problem in wheat in India and could also become a problem in DSR. In wheat, sole dependence on post-applied herbicides for weed control has resulted in the evolution of multiple herbicide resistance in *Phalaris minor*, the single most important weed of wheat (Malik and Singh 1995, Bhullar and Walia 2004a, Chhokar and Sharma 2008, Bhullar *et al.* 2014). In rice, no cases of herbicide resistance have been confirmed yet in the IGP. Lack of herbicide resistance development in rice could be partly due to the integration of multiple tactics such as puddling, transplanting, and continuous flooding used in puddled transplanted rice. However, the adoption of direct seeding could increase reliance on herbicides to compensate for the loss of weed suppression from tillage, flooding, and transplanting. Many of the commonly used post-emergent herbicides for weed control in DSR in the IGP are either acetolactate synthase or acetyl-CoA carboxylase inhibitors (Kumar and Ladha 2011), which are prone to evolution of resistance (HRAC 2012). To expand the adoption of ZT in RW systems while minimizing the risks associated with herbicide use, it is important to develop alternative non-chemical weed management packages.

Management of emerging weed species in CA

Weed species shifts and losses in crop yield as a result of increased weed density have been cited as major hurdles to the widespread adoption of CA. The shift from conventional puddle transplanted (CT-TPR) to dry direct-seeding (DSR) in rice with reduced or ZT, typically results in changes in tillage, crop establishment method, irrigation practices, and weed management that influence weed diversity and abundance (Kumar *et al.* 2013). Under ZT-DSR, weed flora often shifts towards more difficult to control and competitive grasses and sedges (Kumar and Ladha 2011, Singh *et al.* 2015a). Based on experiences with ZT-DSR in India and other Asian countries, the shift from CT-TPR to ZT-DSR is expected to favour grass weed species including *Dactyloctenum aegyptium*, *Leptochloa chinensis*, *Eragrostis* sp., weedy rice (*Oryza sativa*), along with *Echinochloa crusgalli* and *E. colona*; sedges such as *Fimbristylis miliacea*, *Cyperus rotundus* and *Cyperus iria;* broadleaf weeds such as *Eclipta prostrata* and *Digera arvensis* also increase in DSR systems (Kumar and Ladha 2011, Singh *et al* 2015a, Singh *et al* 2015b). Most of these species are able to germinate over a wide range of temperatures but prefer moist and warm conditions, which makes them well adapted to rice fields. These species are well adapted to establish at or close to the soil surface, where weed seeds in ZT systems typically concentrate (Chauhan and Johnson 2009). The shift from CT to ZT in wheat has resulted in a shift in weed flora. Emergence of *Phalaris minor* is lower under ZT than CT in wheat (Malik *et al.* 2002, Chhokar *et al.* 2007, Franke *et al.* 2007, Gupta and Seth 2007) but higher for some of the broad-leaf weeds, such as *Rumex dentatus* (Chhokar *et al.* 2007).

Weed control in CA is a greater challenge than in conventional agriculture. The behaviour of weeds and their interaction with crops under CA tends to be complex and not fully understood. Weed species in which germination is stimulated by light are likely to be more problematic in CA, where weed seeds are concentrated close to soil surface. Weeds like *Ipomoea* spp. which germinate well in shade, under closed crop canopy, and twin around the crop plants (Bhullar *et al.* 2012) could also be a problem in residue based CA systems. In CA, the presence of residue on the soil surface may influence soil temperature and moisture, which may affect weed seed germination and emergence patterns over the growing season. Soil surface residues can interfere with the effectiveness of herbicides, so there is a greater likelihood of weed escapes if residue is not managed properly or herbicide application timings or rates are not adjusted. In the absence of tillage, perennial weeds may also become a more serious challenge in this system. In the past, attempts to implement CA have often caused a yield penalty because reduced tillage failed to control weed interference or crop establishment in CA systems was sub-optimal.

Opportunities for managing weeds in CA

As the density of some annual and perennial weeds can increase under CA, effective weed control techniques are required to manage weeds successfully (Moyer *et al.* 1994). Various approaches, including use of preventive measures, crop residue as mulches, intercropping, competitive crop cultivars, herbicide tolerant cultivars, and herbicides are needed to manage weeds in a CA system.

Preventive measures: Preventing invasive and alien weeds in fields is usually easier and less costly than controlling them after severe infestation, as it is difficult to control weeds once they are established. Some weed preventive measures include the use of clean crop seeds, the use of clean agricultural implements, and managing weeds on bunds and roads. The aim should be to minimize the area of weed infestation and decrease the dissemination of weed seeds from one area to another or from one crop to another. Hand-roguing weeds before seed-shed could be an important tactic in India, where farm size tends to be small. Such a practice would be obviously impractical on large farms in many western countries.

Laser land levelling: Laser land levelling provides uniform soil moisture in the entire field and allows uniform crop establishment and growth leading to a reduced weed infestation. Reduction in weed population in wheat was recorded under precisely levelled fields in comparison to traditional levelled fields (Jat *et al.* 2009).

Stale seedbed: Most of the weed seeds remain in the top soil layer in CA, a flush of weed seedlings appears within a week after irrigation or shower. These weed seedlings can be killed by the application of non-selective herbicides such as glyphosate, paraquat or glufosinate. Stale seedbed significantly reduced weed pressure in ZT-wheat (Mahajan *et al.* 1999). In an ongoing study on DSR in Punjab, stale seedbed reduced weed density by 39% (Manpreet Singh, unpublished data). The fallow period (45-60 d) between wheat harvest and the sowing of rice provides an excellent opportunity to implement stale seedbed for weed management before planting DSR. When stale seedbed practice is used, the crop emerges under weed-free conditions and it will have a competitive advantage over late-emerging weed seedlings. With the limited options available to manage weedy rice in ZT-DSR, the stale seedbed technique is recommended as part of an IWM strategy in many weedy rice-infested areas (Rao *et al.* 2007).

Sowing time, tillage and residue management: In CA, sowing time can be manipulated to favour the crop. In the north-western IGP, sowing wheat 2 weeks earlier than the conventional system has been shown to give the crop a head start over *P. minor*. (Singh *et al.* 1999). Similarly, earlier seeding of spring crops can improve their ability to compete with weeds. Franke *et al.* (2007) observed that the density of all three flushes of *P. minor* in wheat sown on the same date were lower in ZT compared with CT. Zero tillage when combined with residue retention on the surface and early sowing, results in the suppression of *P. minor* and other weeds of wheat. Improvements in planting technology like the shredder-spreader (‘Turbo Happy seeder’) has made it possible to sow wheat in heavy residue mulch of up to 8 to 10 t/ha without any adverse effects on crop establishment (Sharma *et al.* 2008, Kumar and Ladha 2011). Such heavy mulch has the potential to reduce the establishment of weeds in crops. For example, Singh *et al.* (2013) recorded 48% reduction in weed population in wheat sown with ‘Turbo Happy seeder’ as compared to conventional till sown wheat in Punjab. Improved weed control with application of rice residues as straw mulch, at sowing time, at 6 t/ha in potato (Bhullar *et al.* 2015) and at 9 t/ha in turmeric (Kaur *et al.* 2008) than without mulch have been reported.

Establishment methods: Zero-till rice can be established either by direct seeding (ZT-DSR) or by transplanting (ZT-TPR) rice seedlings manually or mechanically. Kumar *et al.* (2013) reported that in the absence of weed control measures, yield losses due to weeds were 90% under ZT-DSR, compared with 35 to 42% under ZT-TPR. Where DSR is preferred for saving labor and water resources, ZT-DSR can be rotated with ZT transplanted rice every few years to keep weed pressure under check. Under herbicides and integrated weed management (IWM) treatments, ZT-DSR recorded grain yield similar to CT-DSR and CT-PTR at Ludhiana (AICRP-WM 2014): among DSR methods, under IWM treatment, ZT-DSR with residue retention on the surface recorded 19% higher yield than CT-DSR, however, under herbicides only treatment, CT-DSR recorded 8% higher yield than ZT-DSR. The succeeding wheat crop, sown with CT or ZT with and without residues retention on the surface recorded similar grain yield. Planting wheat on raised beds reduced weed density and biomass as compared to the conventional method of flat seedbed (Dhillon *et al.* 2005).

Seed rate: Weed competition in ZT-DSR can also be reduced by optimizing seed rate and the crop geometry (Chauhan 2012). In the IGP, a seed rate of 20 to 25 kg/ha has been recommended for DSR (Kumar and Ladha 2011, Gill *et al.* 2013) under optimum weed control. However, results of Chauhan *et al.* (2011) suggest that a seeding rate of 95 to 125 kg/ha for inbred varieties and 83 to 92 kg/ha for hybrid varieties is needed to achieve maximum yields in competition with weeds. Reductions in row spacing from 45 to 15 cm had no effect on rice yields under wee-free conditions but increased yields where weeds were present (Akobundu and Ahissou 1985; Chauhan and Johnson 2011b). Even though higher seed rates have been shown to improve crop competitive ability with weeds, local farmers are reluctant to use more than 20 kg/ha seed rate for rice due to concerns about increased cost of production. In ZT wheat also, narrow row spacing (15 cm) reduced *P. minor* biomass by 16% compared with normal spacing of 22.5 cm (Mahajan and Brar 2002). Integrated use of narrow row spacing (15 cm), higher seed rate (150 kg/ha) and 25% lower dose of clodinafop reduced *P. minor* density compared with normal spacing (22.5cm), normal seed rate (125 kg/ ha) and field dose of clodinafop (Bhullar and Walia 2004b).

High-residue cover cropping: This practice can significantly improve weed control in CA. Prior to termination, cover crops compete with weeds for resources; cover crops can also release allelochemicals into the soil, which may be detrimental to competing weed species, particularly to small-seeded weeds (Weston 1996, Foley 1999, Price *et al.* 2008). After termination, weed suppression occurs by physical impedance of weed species with cover crop residue as well as continued leaching of allelochemicals into the soil (Weston 1996). Future adoption of these practices will be dependent upon continued research to identify herbicide strategies that can work effectively in high-residue systems. In ZT rice production in IGP, sowing *Sesbania* sp. at 25 kg/ha along with rice has shown promise for suppressing weeds. *Sesbania* sp. is allowed to grow with rice to suppress weeds and is then killed with 2,4-D ester at 25 to 30 days after sowing. Singh *et al.* (2007) reported 76 to 83% lower broad-leaf weed densities and 20 to 33% lower grass weed densities with this practice compared with only a rice crop.

Competitive crop cultivars: Crop cultivars vary in their growth habit, which can substantially affect the crop-weed competitive balance. Cultivars with high early seedling vigor and spreading nature, which cover the ground quickly during the vegetative stage, result in the suppression of weeds. Currently, cultivars that were bred for CT-PTR are being used in ZT-DSR, and very limited efforts have been made to breed more weed competitive rice cultivars suitable for ZT-DSR. However, several existing cultivars exhibiting superior weed competitiveness have been identified (Singh *et al.* 2009). In general, it has been observed that early maturing inbred and hybrids because of their faster early growth and ground cover are more effective in smothering weeds than medium- to long-duration cultivars (Gill *et al.* 2013, Singh *et al.* 2014). A long-duration rice cultivar '*PR 114*' (145 d) having slower initial growth had 26- 31 days longer critical weed free period than for '*PR 115*' (125 d) (Singh *et al.* 2014).

Wheat varieties with faster early growth, earlier canopy formation, spreading habit and greater height are less susceptible to weed competition (Balyan and Malik 1989; Paul and Gill 1979). Under timely planting conditions, wheat varieties '*PBW-343*' and '*WH-542*' were equally competitive (Chahal *et al.* 2003, Kaur *et al.* 2003), but under delayed sowing conditions, '*PBW-343*' was superior to other cultivars against *P. minor* (Kaur *et al.* 2003).

Water and nutrient management: High soil moisture in RW systems favors moisture-loving weeds like *P. minor*, *R. dentatus* and *P. monspeliensis* (Singh *et al.* 1995). Because wheat can germinate under drier conditions than can many weeds (Chhokar *et al.* 1999), sowing under dry conditions can facilitate reduced weed emergence and competition. Water management has been an important component of weed control in conventionally flooded CT-PTR, where flooding is established from the first day of transplanting. The emergence and growth of most of rice weed species is inhibited when fields are submerged shortly after seeding. In ZT-DSR, flooding cannot be applied immediately after sowing because rice seeds cannot germinate and survive under completely submerged conditions. Therefore, many weeds can emerge in DSR before flooding is possible, making weed management difficult (Chauhan 2012). The development of rice cultivars capable of germinating under anaerobic conditions would greatly facilitate weed management via flooding in DSR (Chauhan 2012). This trait would not only help in weed control but also in enhancing the adoption of DSR in both rainfed and irrigated areas because crop establishment will be improved with this trait if untimely rain comes soon after sowing. Similarly, placement of fertilizer in the crop root zone rather than broadcast application can shift weed–crop competition in favor of the crop.

Depleting weed seed banks: Even after practicing weed control, some weeds can escape and produce a large number of persistent seeds, which can reduce yields or increase weed management costs in subsequent seasons. These weeds need to removed/ uprooted before they set seed and this tactic is affordable for most farmers in the IGP. Another approach to depleting weed seed banks involves enhancing weed seed predation and decay. Weed seeds present on the soil surface in CA are most vulnerable to surface-dwelling seed predators and burial makes seeds largely unavailable to them (Hulme 1994). Therefore, seed predation could be important in systems where newly produced weed seeds remain on the soil surface, for example, in no-till systems. Cromar *et al.* (1999) reported post-dispersal predation of *E. crusgalli* reduced seed input from 2000 to 360 seeds/m^2. Therefore, crop management practices such as ZT and residue retention, which are known to enhance the activity of weed seed decay agents, might contribute to reductions in the weed seed bank in the long run.

Crop rotations: Continuous cultivation of a single crop or crops having similar management practices allows certain weed species to become dominant in the system and, over time, these weed species become hard to control. Rotating crops that have dissimilar life cycles or cultivation practices is an effective cultural practice for disrupting life cycles and improving control of problematic weeds such as *P. minor* (Chhokar *et al.* 2008). Malik and Singh (1995) found fewer resistance cases in *P. minor* where growers used sugarcane, sunflower, and vegetables in the rotation rather than a RW cropping system. On heavy soils, infestations of wild oats that dominated in the maize-wheat system were completely eliminated by growing rice instead of maize (Gill and Brar 1975). Diversification and intensification of the RW system by growing a short-duration vegetable crop (pea or potato) followed by late sown wheat can also improve weed control without increasing herbicide use (Chhokar *et al.* 2008). By replacing wheat with alternate crops such as berseem, potato, sunflower, oilseed rape for 2-3 years in RW cropping system, seedbank of *P. minor* was significantly reduced in Punjab (Brar 2002) (Table 3). Diversified crop rotation can be exploited to improve the management of problematic weeds, because the selection pressure is diversified by changing patterns of weed control tactics.

Table 3. Status of *P. minor* seed bank in different crop rotations in Kapurthala and Patiala districts of Punjab

Crop rotation	No. of *P. minor* seeds/kg top soil			
	0-7.5 cm		7.5 - 15.0 cm	
	Kapurthala	Patiala	Kapurthala	Patiala
Rice-wheat	40	30	18	10
Rice-potato-sunflower/wheat	7	0	3	0
Rice-toria (indian rape)-sunflower	0	-	0	-
Rice-berseem (*Egyptian clover*)	0	0	0	0
Rice-gobhi sarson (oilseed rape)	5	-	0	-
Rice-onion-wheat	-	0	-	0

Source: Brar (2002)

Chemical weed control: Herbicides are an integral part of weed management in CA. In CA, the diverse weed flora present in the field before crop sowing must be killed by using non-selective herbicides. Proper selection of herbicide formulations for CA may be necessary to achieve effective weed control because crop residues may intercept 15 to 80% of the applied herbicides (Chauhan *et al.* 2012). For example, pre-emergence herbicides applied as granules may provide better weed control than liquid-formations in no-till systems. The rotation of herbicides with different modes of action may be important in avoiding or delaying the evolution of resistance. Several low-dose, high-potency, selective, post-emergence herbicides and mixtures are presently available in India for effectively managing weeds in major crops such as rice and wheat grown in CA.

Herbicide-tolerant crops provide growers in many countries with a useful tool for managing weeds in CA systems. At present, herbicide tolerant crops are not available to growers in India. There are also some risks associated with the adoption of herbicide tolerant crops. Continuous use of the same herbicide such as glyphosate may result in shifts in weed flora or it may accelerate the development of glyphosate resistance in weeds. Indeed, glyphosate was successfully utilized for over 2 decades before a resistant biotype of rigid ryegrass (*Lolium rigidum*) was identified in Australia in 1996 (Powles *et al.* 1998). However, since the release of herbicide tolerant crops, several resistant weed biotypes have been reported in glyphosate-tolerant systems in as little as 3 years (Green 2007, Duke and Powles 2008). Therefore, herbicide tolerant crop cultivars should not be considered as a stand-alone component of weed management. An integrated weed management strategy should be used to ensure that this important weed management tool remains effective, profitable and environmentally sound over a long period of time.

Integrated weed management: Any single method of weed control used in isolation cannot provide season-long effective weed control because of variations in the growth habit and life cycle of weeds. Therefore, a combination of different weed management strategies needs to be evaluated for widening the weed control spectrum and efficacy for sustainable crop production. Combining good agronomic practices, timeliness of operations, fertilizer and water management, intercropping and retaining crop residues on the soil surface can improve the efficacy of herbicides and crop competitiveness against weeds. The integration of herbicides with intercropping in sugarcane (Bhullar *et al.* 2006) and with nitrogen fertilization in wheat (Bhullar and Walia 2003) improved weed control than sole cropping or herbicides alone. Weeds of secondary importance may emerge as a primary weed problem because of the continuous use of a single herbicide or herbicides with a similar mode of action. This problem can be avoided by adopting an integrated approach that includes herbicide rotation, herbicide combinations and crop rotation to develop sustainable and effective weed management strategies under CA systems.

Socio-economic influences on the adoption of CA

Crop yield: The success of ZT in north-western parts of India has been attributed to the increase in wheat yields following the adoption of ZT in rice–wheat rotations (Gupta and Seth 2007, Bhan and Behera 2014). In a review of ZT in India, Erenstein and Laxmi (2008) found 5-7% increase in wheat yield as compared to the wheat grown in CT. At long-term field sites established in Punjab within the ACIAR project, the average grain yield of ZT-wheat was 5.82 t/ha as compared to 5.42 t/ha for CT-wheat (*i.e.* 7% yield gain) during 2012-13 (Bhullar *et al.* unpublished data). In the eastern IGP, where late planting of wheat is quite common, yield increase due to timely planting in ZT-wheat can be in the range of 400–1000 kg/ha (Gupta and Seth 2007). Research has shown that the zero-till system allows crops to be sown by at least 1 week earlier than CT, thereby reducing yield losses which can range from 1–1.5%/day after the optimum wheat sowing time (Aslam *et al.* 1993, Ortiz Monasterio *et al.* 1994, Mehla *et al.* 2000, Hobbs and

Gupta 2003, 2004). Because of the benefits observed in ZT-wheat, CA technologies have been tried in other cropping systems in India (Jat *et al.* 2011), but there are large knowledge gaps.

The importance of skill development through experiential learning adoption has been confirmed in DSR in a recent farmer survey conducted by the authors in Punjab. DSR was introduced in Punjab and Haryana as an alternative to CT-PTR to reduce the cost of production and water input. The results of the survey clearly indicated presence of some yield penalty in first one to two years of DSR adoption but after that the farmers were able to achieve similar or higher yields under DSR than CT-PTR. Research and farmer experience shows that the productivity of wheat grown after DSR is greater than wheat grown after CT-PTR. In our recent survey in 2012-13, 70% of farmer respondents reported higher grain yield of wheat after DSR (6.0 t/ha) than after CT-PTR (5.54 t/ha) (Bhullar *et al*, unpublished data). According to Boparai *et al.* (1992) and Aggarwal *et al.* (1995), better root development of wheat the main reason for the higher grain yield of wheat following DSR than after CT-PTR.

Economic benefits: Farmer experiences from several locations in the IGP showed that ZT technology in wheat can reduce land preparation costs by about Rs. 2,500 ($41.7)/ha and reduce diesel consumption by 50–60 l/ha (Sharma *et al.* 2005). According to Erenstein and Laxmi (2008), ZT-wheat after rice in India generates substantial benefits at the farm level by enhancing farm income from wheat cultivation (US$97/ha) through the combined effects of yield improvement and cost-saving (Table 4). Similarly Gupta and Seth (2007) reported net benefits of US$ 150/ha with ZT-wheat in India.

According to our own survey of farmers in Punjab, DSR improved net returns in coarse and in scented rice. The net returns from wheat following DSR was higher by Rs 4050/ha than following CT-PTR. The total returns from DSR-wheat system were Rs. 5050- 8100/ha higher than in the PTR-wheat system, indicating that DSR based cropping sequence provides higher economic returns than PTR (Bhullar *et al*, unpublished data).

Impact on the environment: The adoption of CA based technologies have been shown to enhance soil quality (Jat *et al.* 2009, Gathala *et al.* 2011), avoiding crop residue burning reduces loss of nutrients, and environmental pollution, which reduces a serious health hazard (Sidhu *et al.* 2007). With the development of new drills, which are able to cut through crop residue, for ZT crop planting, burning of straw can be avoided, which amounts to as much as 10 t/ha, potentially reducing release of some 13–14 tons of carbon dioxide (Gupta *et al.* 2004). Zero-tillage on an average saves about 60 l of fuel/ha thus reducing emission of CO_2 by 156 kg/ha/year (Gupta *et al.* 2004). The adoption of CA in the long-term should enhance C sequestration and build-up in soil organic matter and should be considered a practical strategy to mitigate Green House Gas emissions (Saharawat *et al.* 2012). For example, continuous submergence of soils in CT-PTR promotes the production of methane by anaerobic decomposition of organic matter. Incorporation of straw increases methane emissions under flooded conditions, but surface management of the straw under aerobic conditions can mitigate these effects. Thus, adoption of aerobic mulch management with reduced tillage is likely to reduce methane emissions from the system.

Table 4. Summary of key impacts of zero tillage in India's Indo-Gangetic Plains

Indicator	Value
Households directly affected (estimate)	620,000
Extent of adoption (zero/reduced tillage, estimate)	1.76 m ha
Production cost saving	US$ 52/ha
Increase in crop yields	5-7% (140-200 kg/ha)
Increase in farm income from wheat production	US$97/ha
Increase in real household incomes	US$180-340/farm
Increase in food production	0.7% (343,000 tons)

Source: Erenstein and Laxmi 2008

Research, development, extension and training needs for weed management in CA

Researchable issues

- Developing package of practices for IWM involving crops, tillage, residues, modified planting methods and herbicides in CA to reduce use of herbicides and to minimize cost of production.
- Understanding weed dynamics, their interference potential and suitable management practices with low-cost herbicides in CA. This will help in making weed control timing decisions and maximizing the effectiveness of both chemical and non-chemical weed control tactics.
- Quantifying the effects of different crop residue mulches on different weeds and how much residue of these crops is required to achieve optimum suppression of different weeds without affecting crop establishment.

- Quantifying short- to long-term effects of inclusion of cover crops in the systems on weed suppression during cover cropping and after its termination in succeeding crops, for possible reductions in herbicide inputs for adequate weed control under CA.
- Developing weed-competitive crop cultivars for CA. In case of rice, cultivars with anaerobic germination and iron efficient traits so that early flooding can be used in ZT-DSR for weed suppression.
- Estimating season-long seed predation potential under conventional and conservation agriculture and mechanisms by which seed predation can be enhanced.
- Developing management strategies for emerging problematic weed species.
- Improved understanding of the interactions between retained crop residues and herbicides, and degradation pathways, adsorption-desorption and transport processes of herbicides under CA. Further research on herbicide mixtures for delaying resistance, reducing the cost of weed management, and improving the weed control spectrum is needed.

Policy issues

- Developing and implementing appropriate legislation on prevention and monitoring of crop residue burning through incentives (e.g. carbon credits) and penalties.
- Support the development of CA machinery and ensure its availability at affordable prices through subsidies and promoting custom hiring systems.
- Support for the adoption of CA technologies in local environments by improving the availability of critical inputs.
- Classifying crop residues as amendments (similar to lime or gypsum) and their use in agriculture should attract a subsidy as is the case for fertilizers or soil amendments.

Capacity building

- Capacity building of under- and post-graduate students and training of farmers. Every agricultural university should have courses in CA both at under- and postgraduate levels. Capacity building of farmers to acquire, test and adopt technologies through participatory approach will enable them to identify suitable CA practices for their farms and thus they can reduce their production cost and combat production constraints.
- Establishing self-help groups and encouraging unemployed youths to take up custom hiring of CA machinery as a profession.
- Including CA in the soil health card for proper monitoring of crop residues retention/burning and its impact on soil health.
- Training personnel at the KVKs and the state agricultural departments for awareness generation and adoption of CA by the local farmers.

Extension activities

- Each university, research institute and NGO committed to sustainable development of agriculture should start working directly with farmers. Their experience should be used for improving the CA technology and overcoming its constraints to make CA a success.
- Organizing farmers' field days, holding of field demonstrations, cross-farm visits of extension experts and effective use of mass media for the transfer of CA technology could play a major role in promoting CA to the farming community.
- Improvement in the coordination among various stakeholders (research, extension service, farmers, service providers, agricultural machinery manufacturers, etc.) for more effective transfer of technologies will play a pivotal role in accelerating the adoption of new interventions.

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Weed persistence, crop resistance and phytotonic effects of herbicides in direct-seeded rice

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ABSTRACT

Results of experiment conducted during *Kharif* season of 2010 and 2011 with ten different herbicides and combinations on yield of direct seeded rice revealed that crop resistance index and agronomic management index were maximum in hand weeding treatment followed by fenoxaprop + (chororimuron + metsulfuron) and cyhalofop butyl +(chlorimuron + metsulfuron). Weed persistence index was also maximum in Hand weeding treatment followed by cyhalofopbutyl and pyrazosulfuron. Hand weeding treatment has maximum phytotonic effect followed by fenoxaprop + (chororimuron + metsulfuron) and cyhalofop butyl + (chlorimuron + metsulfuron). Fenoxaprop + (chororimuron + metsulfuron) and cyhalofop butyl + (chlorimuron + metsulfuron) were best herbicides for direct seeded rice from economics and environmental point of view. Fenoxaprop + (chororimuron + metsulfuron) and cyhalofop butyl + (chlorimuron + metsulfuron) have recorded lower persistence of escaped weeds indicating broad spectrum effect in controlling the weeds

Key words- Agronomic management index, Crop resistance index, Phytotonic effect, Weed persistence index

Herbicides are used to control weeds in crop as pre or post emergence application which reduce the population of weeds significantly resulting in higher yield and profit. Some times, the pesticides apart from harming target species also affect the non target living being like microflora or fauna or biochemical reaction in soil and plant which may some times augment yield (Phytotonic effect) or some times produce detrimental effect (phytotoxic) on plant. Scientists many a times ignore such action of herbicides as it requires several cumbersome studies for the purpose (Mishra, 2014). Now, in the days of Global warming and climate change, it is needful to conserve ecosystem and biodiversity along with sustained production of higher yield. Mishra and Mishra (1997) have tried to quantify weed persistence, crop resistance and phytotonic effect of herbicidal treatments by using mathematical formula basing on growth characters where the effect of herbicide treatment can be easily identified which can give an indication basing on which further studies can be under taken for conformation. Prasanna *et al.* (2004) have identified phytotonic effect of thiamethoxam fungicide as seed treatment in cotton. Ribeiro *et al.* (2014) have identified the phytotonic effect of fungicide Pyraclostrobin+methyl thiophanate as seed treatment in soyabean. Such studies on herbicides are very much lacking. The present investigation was undertaken to identify the phytotonic effect of herbicides on weed and crop growth for sustained production.

MATERIALS AND METHODS

The experiment was conducted during *Kharif* season of 2010 and 2011 at Central Research Station, OUAT under East and South Eastern Coastal Plain Zone of the State in a randomized block design with three replications. The soil of the experimental site was sandy loam with low in available N (168 kg/ha), medium in P (14.5 kg/ha) and K (170 kg/ha). Twelve different treatments consisting of different best herbicides/herbicide mixture for weed control in direct seeded rice (cv. *Lalat*) were evaluated for their performance. The crop was sown in the 2nd fortnight of june with seed rate of 75 kg/ha and was fertilized at N P_2O_5 K_2O 60-30-30 kg /ha. Herbicide treatments were applied as per treatment. All total there were 12 treatments constituting 10 different herbicide applications with their combinations and one weed free with one control. The details of treatments were as follows, pyrazosulfuron 25 g/ha at 5-7 DAS, pretilachlor 750 g/ha at 3-5 DAS, cyhalofop-butyl 90 g/ha at 25 DAS, fenoxaprop 60 g/ha at 30 DAS, cyhalofop-butyl + (chlorimuron + metsulfuron) at 90 + 20 g/ha at 25-30 DAS, fenoxaprop + (chlorimuron + metsulfuron) at 60 + 20 g/ha at 25-30 DAS, azimsulfuron at 35 g/ha at 20 DAS, bispyribac

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sodium at 25 g at 20 DAS, fenoxaprop + ethoxy sulfuron at 60+ 15 at 25-30 DAS, oxyflorofen 300 g/ha followed by 2,4-D 500 g/ha at 30 DAS along with one weed free and control

The observation on weeds at 60 days of sowing and dry weight of crop and grain yield at harvest have been presented in (Table 1). The various indices developed by Mishra and Misra (1997) have been used to identify the weed persistence, crop resistance and phytotonic effect due to herbicidal treatments as mentioned below calculated on the basis of mean data of two years and have been presented in (Table 2) along with economics of cultivation.

Weed persistence index (WPI): (Dry weight of weeds in treated plot/dry weight of weeds in control plot) x (weed count in the control plot / weed count in the treated plot).

Crop resistance index (CRI): (dry matter production by crop in the treatment plot/dry matter production by crop in the control plot) x (dry matter production of weed in control plot/dry matter production of weeds in treatment plot)

Agronomic management index (AMI): (percentage increase in yield over control - percentage reduction of weeds)/Percentage control of the pest (weed/insect).

RESULTS AND DISCUSSION

Major weed flora

The floristic composition of the experimental site was dominated with grasses like *Digitaria ciliaris, Cynodon dactylon, Echinochloa colona* and broad-leaf weeds like *Ageratum conyzoides, Cleome viscosa, Celosia argentia, Ludwigia parviflora, Physalis minima, Chrozoffera rottleri.* The dominant sedges observed were *Cyperus rotundus* and *Cyperus irea*. Other weeds observed in lower density were *Panicum repens, Sporobolus diander, Alternanthera sessilis, Eclipta alba.*

Weed density

Significant difference in weed densities was observed at 60 DAS due to weed control treatments in both the years (Table 1). Significantly lowest weed density of 3.6 and 3.5 g/m^2 were noticed with hand weeding treatment during 2010 and 2011, respectively which were at par with application of fenoxaprop + (chlorimuron + metsulfuron) followed by cyhalofop-butyl + (chlorimuron + metsulfuron) treatment in both the years. Significantly maximum weed density was observed in control plot (104.7 and 105.5 g/m^2) in both the years (2010 and 2011). Mean data of weed density of both the years indicated that the hand weeding was superior to all the herbicidal treatments in controlling weeds to the extent of 96.6% as compared to best herbicidal treatment like fenoxaprop + (chlorimuron + metsulfuron) [88.8%] and cyhalofop-butyl+ (chlorimuron + metsulfuron) [87.2%]. The treatment pretilachlor-S recorded the lowest percentage weed control (69.7%).

Weed biomass

The weed biomass recorded at 60 days of growth of rice are presented in Table 1. Different weed control methods exhibited significant effect on weed biomass. Hand weeding treatment recorded significantly lowest weed biomass (4.5/2.8 g/m^2) followed by fenoxaprop + (chororimuron + metsulfuron), cyhalofop-butyl + (chlorimuron + metsulfuron), bispyribac-sodium and fenoxaprop + ethoxysulfuron 5.7/4.7,7.8/6.8,9.8/9.8 g/m^2 as against control of 33.5/26.5 g/m^2 in both the years (2010/2011), respectively. The average data of both the years revealed that hand weeding recorded the lowest biomass of weeds 3.65 g/m^2 followed by fenoxaprop + (chororimuron + metsulfuron), cyhalofop-butyl + (chlorimuron + metsulfuron) and bispyribac sodium in increasing order.

Crop biomass

The total biomass production of crop (Table 1) indicated that the hand weeding treatment produced maximum biomass (7.75/7.55 t/ha) and also in average of two years (7.65 t/ha) followed by fenoxaprop + (chororimuron + metsulfuron), and fenoxaprop+ethoxy-sulfuron, bispyribac sodium, cyhalofop-butyl + (chlorimuron + metsulfuron) in decreasing order. Significantly lowest dry matter was produced in control (3.30/3.47 t/ha) in both the years (2010/2011) and in average of two years also (3.38 t/ha).

Grain yield

The data on grain yield (Table 1) indicated that hand weeding plots recorded significantly highest yield of 3.43/3.43 t/ha where as weedy treatment significantly the lowest yield (1.49/1.55 t/ha) in both the years (2010/2011). Among different method of chemical control, significantly higher grain yield were obtained (3.23/3.18 t/ha) from application of fenoxaprop + (chororimuron + metsulfuron), which were at par with cyhalofop-butyl + (chlorimuron + metsulfuron) and bispyribac-sodium and fenoxaprop + ethoxy-sulfuron recording grain yield of 3.23/3.18 and 3.07/3.02 t/ha and 3.07/3.02 t/ha in both the years (2010/2011), respectively. The mean

Table 1. Effect of different weed control measures on weed density and weed biomass (60 DAS), total biomass and grain yield in direct-seeded rice (DSR)

Treatment	Weed density (g/m^2)*			Weed biomass (g/m^2)			Total biomass of plants (kg/m^2)			Grain yield (t/ha)		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Pyrazosulfuron	5.2(27.5)	5.3(28.5)	28.0	23.5	22.5	23.0	0.62	0.60	0.61	2.72	2.67	2.70
Pretilachlor –S	5.6(30.8)	5.7(32.8)	31.8	24.7	23.7	24.2	0.56	0.54	0.55	2.46	2.41	2.43
Cyhalofop-butyl	5.2(26.7)	5.4(28.7)	27.7	23.4	22.4	22.9	0.60	0.57	0.58	2.64	2.59	2.61
Fenoxaprop	4.9(23.5)	5.1(25.5)	24.5	18.5	17.5	18.0	0.65	0.63	0.64	2.92	2.87	2.89
Cyhalofop-butyl + (chlorimuron + metsulfuron)	3.5(12.5)	3.8(14.5)	13.5	7.8	6.8	7.3	0.73	0.61	0.67	3.23	3.18	3.20
Fenoxaprop + (chlorimuron + metsulfuron)	3.4(11.8)	3.4(11.8)	11.8	5.7	4.7	5.2	0.72	0.71	0.71	3.27	3.22	3.24
Azimsulfuron	4.7(21.7)	4.9(23.7)	22.7	16.5	15.5	16.0	0.68	0.66	0.67	3.00	2.95	2.97
Bispyribac-sodium	3.9(15.5)	4.2(17.5)	16.5	9.8	9.8	9.8	0.70	0.68	0.68	3.07	3.02	3.05
Fenoxaprop + ethoxysulfuron	4.3(18.3)	4.5(20.3)	19.3	12.7	11.7	12.2	0.70	0.68	0.69	3.07	3.02	3.04
Oxyfluorfen + 2,4-D	5.1(25.8)	5.2(27.8)	26.8	21.3	20.3	20.8	0.65	0.63	0.64	2.87	2.82	2.85
Hand weeding	1.9(3.6)	1.8(3.5)	3.55	4.5	2.8	3.65	0.78	0.76	0.77	3.49	3.43	3.46
Weedy	10.2(104.7)	10.3(105.5)	105.1	33.5	26.5	30.0	0.33	0.35	0.34	1.49	1.55	1.52
LSD (P=0.05)	4.60	4.39		2.73	2.73		0.12	0.09		1.39	1.09	

*Figures of weed densities are $\sqrt{x + 0.5}$ transformed, values and in bracket are the original values

Table 2. Effect of weed control practices on various indices of direct-sown rice and economics of cultivation

Treatment	WCE	WI	WPI	CRI	AMI	Net returns (x10^3 `/ha)	B:C
Pyrazosulfuron	23.3	22.0	2.87	2.35	0.06	11.23	1.95
Pretilachlor –S	24.0	42.4	2.67	2.01	-0.14	9.23	1.79
Cyhalofop-butyl	31.0	32.6	2.89	2.26	-0.02	10.36	1.86
Fenoxaprop	66.7	19.7	2.57	3.13	0.18	13.14	2.13
Cyhalofop-butyl + (chlorimuron + metsulfuron)	75.7	7.5	1.89	8.29	0.27	15.78	2.36
Fenoxaprop+(chlorimuron + metsulfuron)	82.7	6.3	1.54	12.41	0.28	15.82	2.33
Azimsulfuron	46.7	14.2	2.47	3.72	0.22	13.92	2.01
Bispyribac-sodium	67.3	11.8	2.08	6.31	0.19	14.46	2.25
Fenoxaprop + ethoxysulfuron	59.3	12.2	2.21	5.05	0.23	14.52	2.26
Oxyfluorfen + 2,4-D	30.7	17.6	2.72	2.72	0.17	12.36	2.03
Hand weeding	87.8	0.0	3.59	18.83	0.32	13.90	1.89
Weedy	0.0	56.1	1.00	1.00	0.0	2.12	1.18

WPI - Weed persistence index, CRI - Crop resistance index, AMI - Agronomic management index

percentage increase in yield revealed that hand weeding recorded 127.6% increase in yield followed by fenoxaprop + (chororimuron + metsulfuron), cyhalofop-butyl +(chlorimuron + metsulfuron), bispyribac-sodium and fenoxaprop + ethoxysulfuron with respective increase in yield of 113.5,110.9, 100.7, 100.3% over control.

Weed control efficiency

The data (Table 2) indicated that maximum WCE was obtained from hand weeding (87.83) closely followed by fenoxaprop + (chororimuron + metsulfuron) (82.66) and cyhalofop-butyl + (chlorimuron + metsulfuron) (75.66). Amongst herbicide, lowest WCE was by pyrazosulfuron and pretilachlor. The WI was lowest in hand weeding (0.00) closely followed by fenoxaprop + (chororimuron + metsulfuron)-(6.35) and cyhalofop-butyl + (chororimuron + metsulfuron)-(7.51).

Weed persistence index (WPI): Weed persistence index indicating relative dry matter accumulation of weeds per count in comparison to control (Table 2) indicated that the hand weeding treatment resulted in higher persistence index (3.59) closely followed by cyhalofop-butyl (2.89) and pyrazosulfuron (2.87) indicating resistance of escaped weeds to control measures. whereas, fenoxaprop + (chororimuron + metsulfuron) [1.54] and cyhalofop-butyl + (chlorimuron + metsulfuron)[1.89] have recorded lower persistence of escaped weeds indicating broad spectrum effect in controlling the weeds.

Crop resistance index (CRI): The crop resistance index (Table 2) indicating increased vigour of crop plant due to weed control measures indicated that the hand weeding treatment recorded maximum crop resistance (18.83) to grow followed by fenoxaprop + (chororimuron + metsulfuron) [12.41] and cyhalofop-butyl + (chlorimuron + metsulfuron)

[8.29] indicating much less harmful effect of herbicides on crop as compared to other treatments. Unweeded control recorded the lowest value of CRI (1.0) indicating highest harmful effect on crop.

Agronomic management index (AMI): The agronomic management index (Table 2) indicating the effect of herbicides on environmental parameters revealed that hand weeding recorded the maximum AMI may be due to maximum phytotonic effect (0.32) closely followed by herbicidal treatments like fenoxaprop + (chororimuron + metsulfuron) [0.28] and cyhalofop-butyl + (chlorimuron + metsulfuron) [0.27]. Whereas, pretilachlor-S and and cyhalofop-butyl were found to have resulted in negative values of AMI indicating its harmful effect on nontarget factors.

Grain yield

The grain yield data (Table 1) indicated that hand weeding produced significantly maximum grain yield of 3.49/3.43 t/ha due to lowest weed count, weed weight and WI with highest WCE and AMI. Although WPI was highest in this treatment, the maximum CRI of this treatment might have also helped in recording maximum yield. The highest value of AMI of this treatment indicated phytotonic effect of hand weeding on growth and yield. This was in agreement with Mishra and Misra (1997). Among the herbicide treatments, fenoxaprop + (chororimuron + metsulfuron), cyhalofop-butyl + (chlorimuron + metsulfuron) were best treatments in yield due to significantly less weed count, weed weight and WPI with higher weed control efficiency as compared to other herbicide treatments. Similar findings have been reported by Ahmed and Chauhan (2014) further, the CRI and AMI of the said treatments were also higher which were next to hand weeding that have favoured to attend higher yield might be due to some phytotonic effect. The grain yields were lower in pretilachlor-S, cyhalofop-butyl and pyrazosulfuron as it recorded higher weed density, weed biomass, WPI with lower CRI, AMI and, WCE. The lower AMI of the said treatments might be due to herbicidal harmful effect on nontarget factors. Similar studies have been conducted by Ahmed and Chauhan *et al.* (2013) and Mallikarjuna *et al.* (2014) in direct seeded rice.

Although, hand weeding recorded maximum yield, the net return and B:C ratio in herbicidal treatments like fenoxaprop + (chororimuron + metsulfuron), cyhalofop-butyl + (chlorimuron + metsulfuron), fenoxaprop + ethoxysulfuron and bispyribac-sodium were higher than the hand weeding due to high cost of cultivation. Chauhan *et al.* (2013) have reported different herbicides have similar weed control effect and can be rotated in cropping system.

It can be concluded that hand weeding has maximum phytotonic effect than herbicides. Herbicide like fenoxaprop + (chororimuron + metsulfuron) and cyhalofop-butyl + (chlorimuron + metsulfuron) have exhibited phytotonic effects in rice. Herbicides like pretilachlor-S and cyhalofop-butyl have been found to have harmful effect under the said dose and method of application of herbicide. Hand weeding treatment has maximum tendency of weed persistence index followed by cyhalofop-butyl and pyrazosulfuron whereas fenoxaprop + (chororimuron + metsulfuron) and cyhalofop-butyl + (chlorimuron + metsulfuron) have lowest values. The crop resistance index was maximum in hand weeding treatment followed by fenoxaprop + (chororimuron + metsulfuron and cyhalofop-butyl + (chlorimuron + metsulfuron). fenoxaprop + (chororimuron + metsulfuron) and cyhalofop-butyl + (chlorimuron + metsulfuron) were best herbicides for rice.

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Integrated weed management under modified water regimes in System of Rice Intensification

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ABSTRACT

A field study was conducted at Chiplima and Sambalpur under West Central Table Land Zone of Odisha during the winter (*Rabi*) seasons of 2013 and 2014 to evaluate different integrated weed management practices under modified water regimes in rice grown under System of Rice Intensification. Application of 5 cm depth of irrigation water before the day of weeding operation was effective in increasing yield significantly (4.72 t/ha) over saturation moisture regime (3.48 t/ha) due to low weed density, weed dry weight and highest number of ear bearing tillers per plant (24) and filled grains/panicle (72). Out of four levels of different weed management systems tested, the application of pretilachlor 750 g/ha (pre-emergence) *fb* chlorimuron-ethyl + metsulfuron-methyl 4 g/ha (post-emergence) recorded minimum weed density and weed dry weight, higher weed control efficiency and significantly higher grain yield of 5.45 t/ha. The same treatment also recorded highest net return (₹ 41, 441/ha) and highest B: C ratio (2.17).

Key words: Irrigation schedule, SRI, Weed control, Water regime

The food security is entirely dependent on total rice production in India (Kabir 2006). The India contributes 20% of the total rice production in the world. There is an increased demand for rice every year and it is estimated that by 2030 the requirement would be 150 million tonnes. To sustain present food sufficiency and to meet future food demand, India has to increase its rice productivity by 3% per annum (Thiyagarajan and Selvaraju 2011). To meet this, the required amount of rice is to be produced without increase in rice area. In order to increase productivity by improving resource use efficiency, System of Rice Intensification (SRI) offers good opportunity to increase production by 50-100% with less use of external input (Stoop *et al.* 2002). The major factors for increased production in SRI are water management, weed management and nutrient management (Uphoff and Randriamiharisoa 2002). Weeds compete with crops for water, light, nutrients and space. Weeds are the important competitors in their early growth stages than later and hence the growth of crops slows down and finally grain yield decreases (Jacob and Syriac 2005). Water resource limitation, shortage of labour during peak period of transplanting and escalating labour wages are making transplanting more expensive which invariably leads to delay in transplanting and results in reduction of yield and profit (Gangwar *et al.* 2008).

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Weeds are at present the major biotic constraints in increasing rice production which can reduce the yield by 50-60%. In SRI method, since the fields are not flooded continuously, weed growth becomes one of the major deterrents to rice yield. Increasing cost of labour and low-efficiency of weeder operation has necessitated working on integrating of chemical weed control and weeder in SRI method for increasing efficiency of weed control and improving yield.

MATERIALS AND METHODS

The study was undertaken during 2013 and 2014 at Regional Research & Technology Transfer Station, Orissa University of Agriculture & Technology, Chiplima, Orissa, India. The soil of experimental field was sandy clay loam, acidic (pH 5.65), low in organic carbon content (0.47%) and available N, P and K content were 242, 9.2 and 155 kg/ha, respectively. The experiment was laid out in split plot design with 3 replications. Main plot treatments consisted of 3 irrigation schedules, *viz.* I_1 – 5 cm standing water on the day before weeding operation, I_2 – 2.5 cm standing water on the day before weeding operation, I_3- Saturation. The sub plots were allotted with four different weed management practices such as W_1-weeding by Mandwa weeder at an interval of 7 days, W_2-application of pre-emergence herbicide + use of Mandwa weeder after 20 DAT at an interval of 7 days, W_3 – weeding by Mandwa weeder at an interval of 7 days up to 20 DAT + application of post-emergence herbicide, W_4- application of one pre- + one post-emergence herbicide. Pretilachlor was used at 750 g/ha as pre-emergence herbicide and chlorimuron-ethyl + metsulfuron-methyl at 4 g/ha was used as post-emergence herbicide. The rice variety '*MTU-1010'* of 125 days duration was grown under SRI and irrigated as per treatment plan. The FYM was applied at 5 t/ha with a fertilizer dose 80-40-40 N-P_2O_5-K_2O kg/ha, respectively. All P was applied as basal and N was applied in 3 splits *i.e.* 50% as basal, 25% 45 DAT and 25% 60 DAT while K was applied in two splits, *i.e.* 50% as basal and 50% at 60 DAT. The plant protection measures were taken as and when required. All other cultural operations were carried out as per recommendation and weed management was followed as per treatment. Rainfall received during the crop growth period was 30 mm (6 rainy days) in 2014 and 62 mm (9 rainy days) in 2015, respectively. The yield parameters were recorded and the economics was calculated at the prevailing price of inputs and produce. The weeds were counted and the weed dry weights were taken at harvest. The weed index (WI) and weed control efficiency (WCE) were calculated from the mean data over two years by using following formulae.

$$\text{Weed Index (WI)} = \frac{a-b}{a} \times 100$$

where 'a' and 'b' are grain yields from the best treatments and treatment for which WI is to be computed.

$$\text{Weed Control Efficiency (WCE)} = \frac{DWC - DWT}{DWC} \times 100$$

where, DWC and DWT are dry weight of weed from unwedded and weeded plots, respectively.

The data were statistically analyzed by Gomez and Gomez (1978).

RESULTS AND DISCUSSION

Weed flora

Major weed flora in experimental field belonged to sedges like *Cyperus rotundus, Cyperus iria* and *Cyperus difformis* followed by grasses like *Digitaria sanguinalis, Echinochloa colona, Echinochloa crusgalli, Cynodon dactylon* and broad-leaved weeds like *Ludwigia parviflora*, *Commelina benghalensis* and *Marsilea quadrifoliata.* The composition of sedge, grass and broad-leaved weeds varied from 65–80, 18–30 and 15-28%, respectively. Emergence of broad-leaf weeds and grasses were earlier than the sedges which were noticed to be predominant after 30 DAT onwards.

Effect on weed flora

Irrigation depth before the day of weeding had significant effect on weed density, weed dry weight and weed control efficiency of grass, sedge and broad-leaf weeds (Table-2). The lowest weed density and highest WCE was achieved with I_1, which was around 50% both for broad-leaves and grasses and 25.66% for sedges. The weed density and dry weight of grasses were unaffected by different weed control treatments. The broad-leaves and sedges were significantly affected and lowest weed density and dry weight was found with W_4 (herbicide mixture of pre- and post-emergence). Weed control efficiency was highest for grasses (81.11%), 69.44% for broad-leaved weeds and 64.83% for sedges. Control of weeds by herbicides during early stage of rice resulted in lower competition for moisture, nutrient and sunlight that influenced the crop to grow better as evidenced in increased yield attributes and yield (Singh *et al.* 2005). The overall weed control efficiency was higher (24.82-26.75%) when irrigation water was provided in comparison to saturation moisture regime, though the variation with respect to depth of water was not significant. Use of chemical herbicide with or without mechanical weeder was found superior to only Mandwa weeder operation. The application of pre- and post-emergence herbicide mixture gave the highest weed control efficiency (77.14%) followed by Mandwa weeder and post-emergence herbicide combination (44.66%)

Effect on crop growth

Filled grains/panicle (72) was significantly higher with I_1 over I_2 (56) and I_3 (58). This might be due to better soil moisture condition which increased effectiveness of herbicides or operation of weeder resulting thereby reduced competition for growth factors. Weed control treatments affected ear bearing tillers/plant, filled grains/panicle significantly and the highest values 30.83, 69.21, respectively were recorded in treatment W_4. This might be due to low crop weed competition and longer weed free period under these treatments which lead to high growth and yield of rice. Fisher *et al.* (1993) found that longer weed free period favoured significantly increase in yield of rice. Kolhe (1999) observed that post-emergence application of fenoxaprop-p-ethyl + ethoxysulfuron was as effective against hand weeding twice. Test weight was not significantly affected by different weed control treatments.

Table 1. Effect of irrigation and methods of weed control on yield and yield attributes in SRI

Treatment	Effective tillers/plant	Filled grains /panicle	Test weight (g)	Grain yield (t/ha)	Yield increase (%)	Net returns ($x10^3$ `)	B:C Ratio
Irrigation							
I_1	24.0	72.0	21.87	4.72	35.7	29.49	1.79
I_2	24.0	56.0	21.95	4.01	16.8	17.80	1.45
I_3	21.0	58.0	21.64	3.48	-	7.50	1.18
LSD (P=0.05	NS	NS	NS	1.77	-	-	-
Weed control							
W_1	16.8	50.1	21.50	2.64	-	10.22	1.24
W_2	20.5	60.2	21.76	3.99	51.4	16.57	1.42
W_3	25.2	68.6	22.20	4.24	60.6	20.58	1.53
W_4	30.8	69.2	21.84	54.52	106.5	41.44	2.17
LSD (P=0.05)	2.74	13.1	NS	10.08			

Table 2. Weed dynamics as influenced by irrigation schedules and weed management practices

Treatment	Grasses			Broad-leaved			Sedges			WI
	No./m^2	Dry weight (g)	WCE (%)	No/m^2	Dry weight (g)	WCE (%)	No./m^2	Dry weight (g)	WCE (%)	
Irrigation										
I_1	8.0	3.0	50.0	5.50	2.31	50.1	180.8	168.0	25.7	13.9
I_2	10.0	5.0	16.7	5.25	2.81	39.3	209.6	204.0	9.73	26.3
I_3	18.0	6.0	-	7.25	4.63	-	258.1	226.0	-	
LSD (P=0.05)	5.04	1.2		2.18	0.72		21.1	12.99		33.2
Weed control										
W_1	16.3	7.2	-	8.33	10.8	-	323.7	320.7	-	26.7
W_2	15.5	4.7	35.6	14.0	9.67	10.5	202.8	224.3	30.1	22.2
W_3	13.8	4.9	32.1	25.0	09.2	14.8	162.5	183.5	42.8	
W_4	5.0	1.3	81.1	6.0	03.3	69.4	108.8	112.8	64.8	
LSD (P=0.05)	NS	NS		4.04	2.82		46.55	52.89		

I_1 – 5 cm standing water on the day before weeding operation, I_2 – 2.5 cm standing water on the day before weeding operation, I_3- At saturation. W_1-weeding by Mandwa weeder at an interval 7 days, W_2- application of pre-emergence herbicide + use of Mandwa weeder after 20 DAT at an interval 7 days, W_3 – weeding by Mandwa weeder at an interval of 7 days upto 20 DAT + application of post-emergence herbicide, W_4- application of one pre- + one post-emergence herbicide.

Effect on yield and economics

Crop yield was observed to be highest (4.72 t/ha) in I_1 (Table 1). Significantly higher grain yield was also found at decreasing depth of impounded water on the day before weeding. The response to soil moisture regime was well marked with an increase of 35.68% at I_1 and 16.77% in I_2 over saturation moisture regime.

Weed control by application of both pre- and post-emergence herbicide (W_4) resulted in highest yield (5.45 t/ha) followed by W_3. The increase in yield by 106.51%, 60.61% and 51.44% in W_4, W_3 and W_2, respectively over W_1 was noticed. This was in conformity with the findings of Babar and Velayutham (2012). This might be due to lesser efficiency of the Mandwa weeder alone to control the weeds. Total chemical control with mixture of pre- and post-emergence herbicide proved that chemical control of weeds is most effective than the mechanical and or mechanical and chemical integration. This might be due to provision of total weed free period due to application of both pre- and post-emergence herbicides which reduced partitioning of available resources like moisture and nutrient.

Weed index showed yield reduction to the tune of 23.3 and 26.3% in I_2 and I_3 than I_1 due to increased weed growth under deficit moisture regime. Among the weed control treatments, yield reduction due to weeds was 22, 26 and 33% in W_3, W_2 and W_1, respectively over W_4.

Highest net returns (` 41, 441/ha) and benefit cost ratio (2.17) was found in W_4 due to highest yield and cultivation cost owing to use of chemicals. One time use of herbicide either as pre or post emergence reduced the net return to 55-60% as in case of W_2 and W_3 and the lowest net return was at par with W_1 due to ineffective weed control and higher labour cost for weeding. This is in conformity with the finding of Walia *et al*. (2012), who reported that sole application of pre- or post-emergence herbicide did not provide effective control of weeds as compared to combination of pre- and post-emergence herbicide. The moisture regime of I_1 with chemical weed control with pre- and post-emergence herbicide mixture gave the highest yield due to cumulative effect of increased level of yield attributes, less weed competition, optimum moisture, reduced depletion of nutrients by weeds and increased uptake by crop.

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Sowing time and weed management to enhance productivity of direct-seeded aromatic rice

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ABSTRACT

Field experiments were conducted during *Kharif* 2012 and 2013 sandy clay loam soil to study the effect of times of planting and weed management in direct-seeded aromatic rice in foot hills J&K Himalayas. Results revealed that direct-seeded basmati rice sown on 15th June and 10th July recorded non-significant results with respect to grain and straw yield. Among herbicidal weed management, post-emergence application of bispyribac at 30 g/ha recorded significantly higher grain and straw yield which was at par with post-emergence application of cyhalofop-butyl + 2, 4-D 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron at 375 g/ha + 15 g/ha with B:C ratio of 2.98 and 3.95 during *Kharif* 2012 and 2013, respectivly. It was owing to higher number of panicles/m^2, grains/panicle and 1000-grain weight along with lowest weed density, weed dry matter, higher weed control efficiency and lowest weed index.

Key words: Aromatic rice, Direct-seeded, Sowing time, Weed control, Yield

Basmati rice has occupied a prime position in national and international markets because of their excellent quality characters. Traditionally, basmati rice is grown by hand transplanting of 25-30 day old seedlings after puddling. Basmati rice being a relatively long duration crop needs early establishment to avoid lodging and lower seed setting. Growing rice under direct-dry-seeded can be an option for reducing water losses to a great extent (Rao *et al.* 2007). Hence, direct-seeding instead of conventional transplanting is gaining impetus in India. The low productivity of basmati rice can be attributed to several limiting factors and all but one important factor amongst those has been the poor weed management which becomes more relevant under direct-seeding rice where weeds achieve an advantageous position owing to upland conditions (Shan *et al.* 2012). Aerobic soil condition and dry tillage practices besides alternate wetting and drying conditions are conductive for germination and growth of highly competitive weeds. According to Mamun *et al.* (1993), weed growth reduced the grain yield by 68-100% for direct-seeded rice, 22-36% for modern 'boro' rice and 16-48% for transplanted 'aman' rice. Therefore, keeping weeds below threshold level, herbicides provide the cheapest and most effective tool through which excessive weed population can be controlled before crop-weed competition. The time of sowing being a non–monetary input have noticeable impact on weed intensity and on yield also. Delay in sowing results in slow growth of crop and increased infestation of competing weeds. Therefore, the present investigation was undertaken to assess the times of sowing and weed control measures for improving the productivity in direct-seeded aromatic rice in foot hills of J&K Himalayas.

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MATERIALS AND METHODS

A field experiment was conducted at the research farm of Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during *Kharif* 2012 and 2013. The experimental soil was sandy clay loam in texture medium in organic carbon, available phosphorus and potassium, low in available nitrogen. The experiment was conducted in spilt plot design with three replications. The main plot treatments consisted of two times of sowing, (i) 15th June (ii) 10th July while the sub-plot treatments were comprised of seven methods of weed control practices (i) azimsulfuron 35 g/ha post-emergence (20 DAS) (ii) cyhalofop-butyl + 2,4-D 90 g/ha + 500 g/ha post-emergence (30 DAS) (iii) bispyribac at 30 g/ha post-emergence (30 DAS) (iv) anilophos + ethoxysulfuron 375 g/ha + 15 g/ha post-emergence (15 DAS) (v) oxadiargyl 100 g/ha pre-emergence (vi) weedy check and (vii) weed free. Rice cultivar '*Basmati-370*' was sown at row to row spacing of 20 cm using 40 kg seed/ha. The crop was fertilized with NPK at 30, 20 and 10 kg/ha. Full dose of phosphorus and potassium along with one third of nitrogen were applied as basal dose at the time of sowing and remaining one third of nitrogen was applied in two equal spilts, one third at tillering stage and the one third was applied at panicle initation stage. Pre-emergence and post-emergence herbicides were sprayed by knapsack sprayer fitted with flat fan nozzle using a spray volume of 500 l/ha. Weedy check plots remained infested with native population of weeds till harvest. Data on weed population and dry matter, crop growth and yield were recorded. The data on weeds were subjected to square root transformation $(\sqrt{x+1})$ to normalize their distribution.Weed indices like weed control efficiency was calculated as suggested by Mishra and Mishra (1997) and weed index was calculated as suggested by Raju (1998).

RESULTS AND DISCUSSION

Weed population, weed dry matter, weed control efficiency and weed index

The major weeds in the experimental field were *Cynodon dactylon* (18.72%), *Echinochloa crusgalli* (17.38%), *Commelina benghalensis* (12.50%), *Cyperus rotundus* (16.46%), *Cyperus difformis* (15.94%) and *Ammania baccifera* (13.03%) and other minor species were *Eclipta alba* and *Solanum nigrum*. The grassy weeds dominated the weed flora throughout the crop growth seasons during both the years.

Among times of sowing, crop sown on 15th June had significantly lowest density of weeds at 60 DAS and at harvest as compared to 10th July sown crop (Table 1). Consequently, weed dry matter at 60 DAS and at harvest in 10th July sown crop was significantly higher than 15th June sown crop. This might have happened due to the fact that relatively conducive environment for ensuring better germination and initial plant stand with development of greater amount of foliage providing better smothering capacity to crop plants leading to enhanced weed suppression which provided an opportunity to crop plants to better utilize the natural resources in the vicinity with lower light transmission ratio at the ground level which inhibited the germination of weed seeds and growth of weed. This confirms the findings of Jadhav (2013) and Chalka and Singh (2013).

Among weed management practices, significantly lowest total weed density at 60 DAS and at harvest were recorded with application of bispyribac 30 g/ha as post-emergence followed by post-emergence cyhalofop-butyl + 2,4-D 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron as post-emergence at 375 g/ha + 15 g/ha. Further application of bispyribac as post-emergence at 30 g/ha also recorded significantly lowest weed dry matter followed by cyhalofop-butyl + 2,4-D post-emergence at 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron post-emergence at 375 g/ha + 15 g/ha. Better efficacy and prolonged effectiveness of applied herbicides which did not allow the weeds to germinate and even resulted in rapid depletion of carbohydrate reserves of weeds already germinated through rapid respiration, senescence of leaves, reduction in leaf area and diminution of photosynthesis process (Singh *et al*. 2013).

Table 1. Effect of times of sowing and weed management practices on total weed count, total weed dry weight, weed control efficiency and weed index of direct seeded aromatic rice

Treatment	Total weed count at 60 DAS (no./m^2)		Total weed dry weight at 60 DAS (g/m^2)		Weed control efficiency at harvest (%)		Weed index at harvest (%)	
	2012	2013	2012	2013	2012	2013	2012	2013
Time of sowing								
15th June	10.6 (113)	10.5 (110)	11.4 (129)	11.4 (128)	59.2	60.5	-	-
10th July	12.6 (157)	12.5 (155)	12.4 (154)	12.4 (154)	51.3	52.4	-	-
LSD (P=0.05)	1.93	1.79	1.58	1.67	-	-	-	-
Weed management								
Azimsulfuron 60 g/ha	12.4 (153)	12.4 (152)	12.9 (166)	12.9 (165)	57.3	58.3	35.9	35.6
Cyhalofop-butyl + 2,4-D 90 g/ha + 500 g/ha	10.7 (113)	10.4 (108)	11.5 (131)	11.4 (129)	70.1	71.3	21.9	23.0
Bispyribac 30 g/ha	10.5 (110)	10.3 (106)	11.4 (129)	11.3 (128)	71.8	72.8	15.8	19.6
Anilophos + ethoxysulfuron 375 g/ha + 15 g/ha	10.7 (113)	10.5 (109)	11.5 (131)	11.5 (131)	68.5	70.1	25.2	26.1
Oxadiargyl 100 g/ha	12.5 (156)	12.5 (155)	13.0 (169)	12.9 (165)	56.5	58.1	39.7	41.1
Weedy check	17.3 (298)	20.9 (299)	16.4 (268)	16.4 (269)	0.0	0.0	52.7	56.4
Weed free	1(0.0)	1(0.0)	1(0.0)	1 (0.0)	100	100	0.0	0.0
LSD (P=0.05)	0.78	0.96	0.65	0.98	-	-	-	-

Figures in parentheses are original values

Table 2. Effect of times of sowing and weed management practices on crop and yield attributes of direct seeded aromatic rice

Treatment	Plant height at harvest (cm)		No of panicles/m^2		No. of grains/panicle		1000-grain weight (g)	
	2012	2013	2012	2013	2012	2013	2012	2013
Time of sowing								
15th June	117.8	118.6	144.3	145.1	75.1	76.3	20.8	21.5
10th July	115.6	116.5	142.2	143.9	73.6	75.5	20.0	20.6
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Weed management								
Azimsulfuron 60 g/ha	112.2	114.2	142.2	143.1	71.7	73.8	20.0	21.1
Cyhalofop-butyl + 2, 4-D 90 g/ha + 500 g/ha	119.4	120.2	146.3	147.8	76.1	77.8	21.8	22.9
Bispyribac 30 g/ha	121.0	121.6	147.8	148.6	76.6	78.7	22.0	22.9
Anilophos + ethoxysulfuron 375 g/ha + 15 g/ha	118.7	119.6	146.1	147.2	75.1	77.1	21.1	22.4
Oxadiargyl 100 g/ha	110.3	112.1	141.5	143.0	70.2	73.2	20.0	21.0
Weedy check	104.9	103.5	137.3	136.8	66.8	65.9	18.2	18.0
Weed free	130.4	132.3	151.1	153.8	85.9	88.7	23.0	24.1
LSD (P=0.05)	2.48	2.32	3.29	3.34	2.82	3.01	1.05	1.19

Basmati rice direct-seeded on 15th June recorded highest weed control efficiency (59.23%) at harvest as compared to 10th July sowing. Among weed control methods, post-emergence application of bispyribac at 30 g/ha (71.76%) was superior followed by post-emergence application of cyhalofop-butyl + 2,4-D at 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron at 375 g/ha + 15 g/ha. Lowest weed index was recorded with the post-emergence application of bisypyribac 30 g/ha followed by post-emergence application of cyhalofop-butyl + 2,4-D 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron 375 g/ha + 15 g/ha in the increasing order. Kumar *et al*. (2013) reported similar findings.

Crop growth, yield attributes and yield

Times of planting on 15th June and 10th July failed to show any significant impact on plant height at harvest and yield attributes during both the years registered (Table 2). However, 15th June sowing recorded numerically higher plant height at harvest and yield attributes as compared to 10th July planting. All the weed control treatments recorded significantly more number of panicles/m^2 as compared to weedy check. Application of bispyribac as post-emergence at 30 g/ha recorded significantly highest number of panicles/m^2 which was statistically at par with application of cyhalofop-butyl + 2,4-D as post-emergence at 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron as post-emergence at 375 g/ha + 15g/ ha. Number of grains/panicle and 1000-grain weight was significantly highest with the application of bispyribac post-emergence at 30 g/ha and was statistically at par with application of cyhalofop-butyl + 2, 4-D post-emergence at 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron post-emergence at 375 g/ ha + 15g/ha. The enhanced yield attributes recorded might be due to lowest density and dry weight of weeds and higher weed control efficiency which resulted in better growth of rice crop.

Economics

Statistically non-significant results were observed with respect to grain and straw yield of rice crop among different times of sowing during both the crop seasons (Table 3). However, 15th June sowing recorded slightly highest grain and straw yields as compared to 10th July sowing.

The increase in yield under various weed-management treatments may be attributed to significant reduction in weed dry matter (Table 3), thereby reduction in crop weed competition which provided congenial environment to the crop for the better expression of vegetative and reproductive potential. The lowest grain yield and straw yield of basmati rice was noticed in weedy check as a consequence of stiff competition imposed by weeds resulting in poor source and sink development with poor yield contributing characters and higher weed index. These results corroborated with the findings of Subhas and Jitendra (2007). Amongst the herbicidal treatments, application of bispyribac as post-emergence at 30 g/ha recorded significantly highest grain and straw yields which was statistically at par with cyhalofop-butyl + 2, 4-D post-emergence at 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron post-emergence at 375 g/ha + 15g/ha due to superiority in yield attributes of crop components as a result of reduced crop-weed competition and increased water and nutrient availability (Kumar *et al* 2013).

Table 3. Effect of time of sowing and weed management practices on yield and B:C ratio of direct-seeded aromatic rice

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		B:C ratio	
	2012	2013	2012	2013	2012	2013
Time of sowing						
15th June	2.07	2.18	3.86	4.05	2.46	3.05
10th July	1.96	2.05	3.76	3.95	2.34	3.02
LSD (P=0.05)	NS	NS	NS	NS	-	-
Weed management						
Azimsulfuron 60 g/ha	1.77	1.91	3.40	3.50	2.41	2.88
Cyhalofop-butyl + 2,4-D 90 g/ha + 500 g/ha	2.16	2.29	4.09	4.29	2.93	3.62
Bispyribac 30 g/ha	2.33	2.39	4.20	4.40	2.98	3.95
Anilophos + ethoxysulfuron 375 g/ha + 15 g/ha	2.07	2.20	3.96	4.17	2.87	3.61
Oxadiargyl 100 g/ha	1.67	1.75	3.27	3.43	2.45	2.72
Weedy check	1.31	1.30	2.95	2.76	1.49	1.92
Weed free	2.77	2.97	4.96	5.42	1.69	2.52
LSD (P=0.05)	0.28	0.28	0.40	0.36	-	-

Among the times of sowing, 15th June sowing recorded highest B: C ratio as compared to 10th July sowing. All the weed control treatments recorded considerably higher benefit: cost ratio over weedy check (Table 3). Higher benefit:cost ratio was obtained with the application of bispyribac as post-emergence at 30 g/ha which was closely followed by cyhalofop-butyl + 2, 4-D at 90g/ha + 500 g/ha and anilophos + ethoxysulfuron as post-emergence at 375 g/ha + 15 g/ha.

It was concluded that application of bispyribac as post-emergence at 30 g/ha, cyhalofop-butyl + 2,4-D as post-emergence at 90 g/ha + 500 g/ha and anilophos + ethoxysulfuron as post-emergence at 375 g/ha + 15 g/ha was found effective in reducing weed population, resulted in higher benefit:cost ratio irrespective of whether rice was sown at 15th June and 10th July under subtropical agro eco-systems of Jammu region.

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Development and testing of self-propelled cono-weeder for mechanized rice cultivation

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ABSTRACT

Manual cono weeding in rice is a tedious job requiring more labour and energy. An effort was made to develop prototype of a self propelled cono-weeder under the AICRP on Weed Management at the College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur with an objective to reduce drudgery involved in manual cono-weeding in rice. Main components of the newly developed self propelled cono-weeder are the main frame, a prime mover, front and rear floats and a rotor. Field experiment was conducted at Pattambi in Palakkad district to study the performance of the prototype in comparison with manual cono weeding and conventional weeding methods in rice. The weed density, weed dry weight and the grain and straw yields of rice at various treatments were observed. It was found that self propelled cono-weeder had a field capacity of 0.1 ha/h at an operating speed of 2.0-3.0 km/h. The weeding efficiency of the unit in rice was at par with that of the manual cono-weeder operated twice at 15 and 30 days after transplanting.

Key words: Cono-weeder, Manual weeding, Mechanical weeding, Rice, Self-propelled weeder

Drum seeders, self-propelled rice transplanters and the system of rice intensification (SRI) technique are being increasingly adopted by the rice farmers of our country. When the adoption of these technologies increased, the area under line sown low land rice crop became popular but it had the problem of heavy weed growth and the related labour cost. Farmers were looking for an efficient and cost-effective machinery for weed control. Years ago, a mechanical hand weeder was developed in Japan to facilitate weeding between rows. It had various names and undergone modifications, but was widely known as rotating hoe or rotary hoe. Mechanical weeding using inter row cultivators or rotory weeders needed about 50 to 60 human hours to weed one hectare of rice field (Parthasarathy and Negi 1977).

Engineers at the International Rice Research Institute (IRRI), Philippines subsequently developed a cono-weeder (conical weeder), which work better in various soils, especially heavy clay soils. An improved and modified IRRI cono-weeder was developed for wet field conditions and it was compared with the conventional weeding practices. The field capacity of the weeder was 0.02 ha/h and a weeding efficiency of 80% during the first weeding. The cost of weeding with this weeder amounted to \$ 10 per hectare, while manual weeding did cost \$ 24 per hectare. Sixty per cent of time was saved in comparison to manual weeding (Parida 2002). This modified IRRI cono-weeder was further modified and used for efficient weeding in rows. The implement reduced drudgery due to less time taken from 50 to 55% and its use resulted in saving cost of operation by 45% compared to hand weeding. The weeding efficiency varied between 75 and 100% in clayey soil. This manual cono-weeder could operate an area of one acre in a day of 8 h (Sarma *et.al.* 2006).

The presently available cono-weeder has two rotating cone shaped drums with width adjustability. It has better soil working efficiency and operational simplicity. One of the major constraints in using these hand operated weeders is the physical effort that is needed to push the weeder in the wet and highly resistant clay soil. It was found that the push type cono-weeders are difficult to use as they have to be moved back and forth and do not work well under conditions of highly dried soil, high inundation of flood water and at the existence of bigger sized weeds (Moody 1991). Reports from China by JiaGuo *et al.* (2004) also indicated the complex and laborious nature of management measures for weeding under SRI. In the operation of cono-weeder soil gets tilled deeply and the weeds are uprooted thoroughly, but the farmers find it very hard to operate as it pains the chest and hands (Kumar *et al.* 2006).

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Operational difficulties with the cono-weeder were identified as constraints in SRI practice and the farmers demanded to develop a cost effective motor operated cono-weeder (Manimekalai *et al.* 2006). Labour intensity involved in SRI as well as non-availability of various models of weeders suited to different agro-situations have been identified as the constraints in SRI by Rao and Goud (2007). For scaling up of SRI technique, they suggested to redesign existing models of weeders to suit to the site specific situations. After studying the constraints faced by the farmers of Palakkad district of Kerala, India in the adoption of SRI, Shanmugasundaram *et al.* (2008) also suggested to redesign the cono-weeder so as to ease the weeding operation. In this context of various positive aspects of cono weeding in SRI, it is essential to make available cono-weeders that make the operation untiring and drudgery free.

In the above context, an attempt was made to modify the existing manually operated cono-weeder to a self propelled version so as to reduce drudgery in its operation for weeding in low land rice.

MATERIALS AND METHODS

The presently available cono-weeder with two rotating cone shaped drums was used as the base material for development of prototype of a self propelled cono-weeder. The work was undertaken at the engineering workshop of the Regional Agricultural Research Station, Pattambi, Palakkad district, Kerala during 2008. To start with the study, the existing cono-weeder was given additional fittings and accessories so as to make it self-propelled. The new machine was field tested and noted the limitations for its smooth running. It was then undergone many modifications/refinements and brought to the prototype of a self propelled cono-weeder as a single row machine for weeding in low land rice.

The prototype was field tested in a mechanically transplanted rice field to study its effectiveness on weed control in comparison with other weed control practices. The field study was conducted at the Regional Agricultural Research Station, Pattambi, Palakkad district, Kerala using four treatments. The treatments were arranged in randomized block design (RBD) with three replications each with a gross plot size of 10 x 2 m. The four treatments were:

1. Manual cono weeding twice at 15 and 30 days after transplanting (DAT)
2. Self propelled cono weeding twice at 15 and 30 DAT
3. Manual cono weeding four times at 10, 20, 30 and 40 DAT
4. Hand weeding twice at 20 and 40 DAT.

Observations on weed density (number/m^2), weed dry weight (grams/m^2), rice grain yield (kg/ha) and straw yield (kg/ha) were recorded at 30 and 60 DAT and analysed statistically (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Major components of the newly developed self propelled cono weeder were the main frame, prime mover, floats and a rotor (Fig. 1).

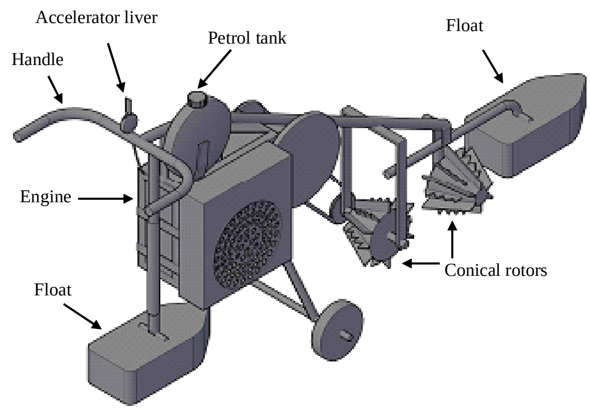

Fig. 1. Components of the self propelled cono-weeder

Main frame: The main frame mounts the engine, control units, float and the rotors. It was fabricated with 25 mm square MS steel pipe. A handle made of mild steel pipe of 25 mm diameter is attached to the frame.

Prime mover: An air cooled 2-stroke petrol engine was used as a prime mover. It had a rated power of 0.9 kW at 5500 RPM with specific fuel consumption of 650 g/kW/h. A cooling fan was provided to cool the engine. Engine power was taken through belt drive to the rotors through a larger pulley and a chain sprocket system. An accelerator was provided in the handle to control the speed of the engine. A clutch engage and disengaged the belt drive which transmits power from engine to the rotor.

Floats: Two floats made of mild steel sheets and shaped into a hollow top covered boat were provided each at the front and rear ends. The front end float was provided with a small swinging action to ensure flexibility. The rear end float with telescopic shaft was provided to prevent the weeder from sinking, especially in deeper clayey soils and to control the depth of operation.

Rotors: The rotors were detachable cone shaped frustums with smooth, serrated metal stripes welded along their periphery. The cono-weeder has two conical rotors mounted in tandem with opposite orientation. As the rotor receives forward motion, the smooth and serrated blades mounted alternately on the rotor uproot and bury the weeds into the soil. It facilitated a satisfactory weeding by the self propelled cono-weeder in a single forward pass without a push pull movement.

Working of the self-propelled cono-weeder

The engine rotates a small pulley of diameter 50 mm which is connected to the crankshaft. This pulley is further connected to a larger pulley of diameter 260 mm by means of a V-belt. This in turn is connected to the rotor (cone frustums) through a chain and sprocket arrangement. A 32-toothed chain with 18 toothed sprocket was used for further speed reduction and to operate the weeder under field condition. This helped to cover an area of 0.1 ha/h with normal working speed of 2.0 - 3.0 km/h. The total weight of the unit is 36 kg. Thus the forward motions of the weeder help in entangling the weeds within the rotors and get uprooted. Further movement enables the weeds to get buried into the soil. As reported by Datta (1981) and Moody (1991), push type cono-weeders were difficult to use as they have to be moved back and forth and do not work well under conditions of highly dry soil, high inundation of flood water, existence of bigger sized weeds etc. The working speed of the unit may be related to its higher self weight of 36 kg and the sticky nature of the rice soil. The heavy weight of the existing power weeder caused it to sink deeper into the wet soil and impeded its forward motion (Singh *et al.* 2006). The orthographic views of the self propelled cono-weeder are shown (Fig. 2).

Density of all types of weeds was the minimum with hand weeding at both the stages of observation. Use of self propelled cono-weeder as well as manual cono-weeder at 15 and 30 DAT responded almost uniformly in reducing the weed density, especially at 30 days after planting (Table 1).

Hand weeding at 20 and 40 DAT recorded the lowest weed dry weight at 30 and 60 DAT and it differed significantly from all the cono-weeder treatments (Table 2). Use of self propelled cono-weeder at 15 and 30 DAT recorded the second lowest weed dry weight at 30 DAT, while at 60 DAT it was by manual cono weeding four times. Grain yield was the maximum in the hand weeded plot, while straw yield was higher with the use of self propelled cono-weeder at 15 and 30 DAT as well as manual cono weeding four times (Table 2). Thus the newly

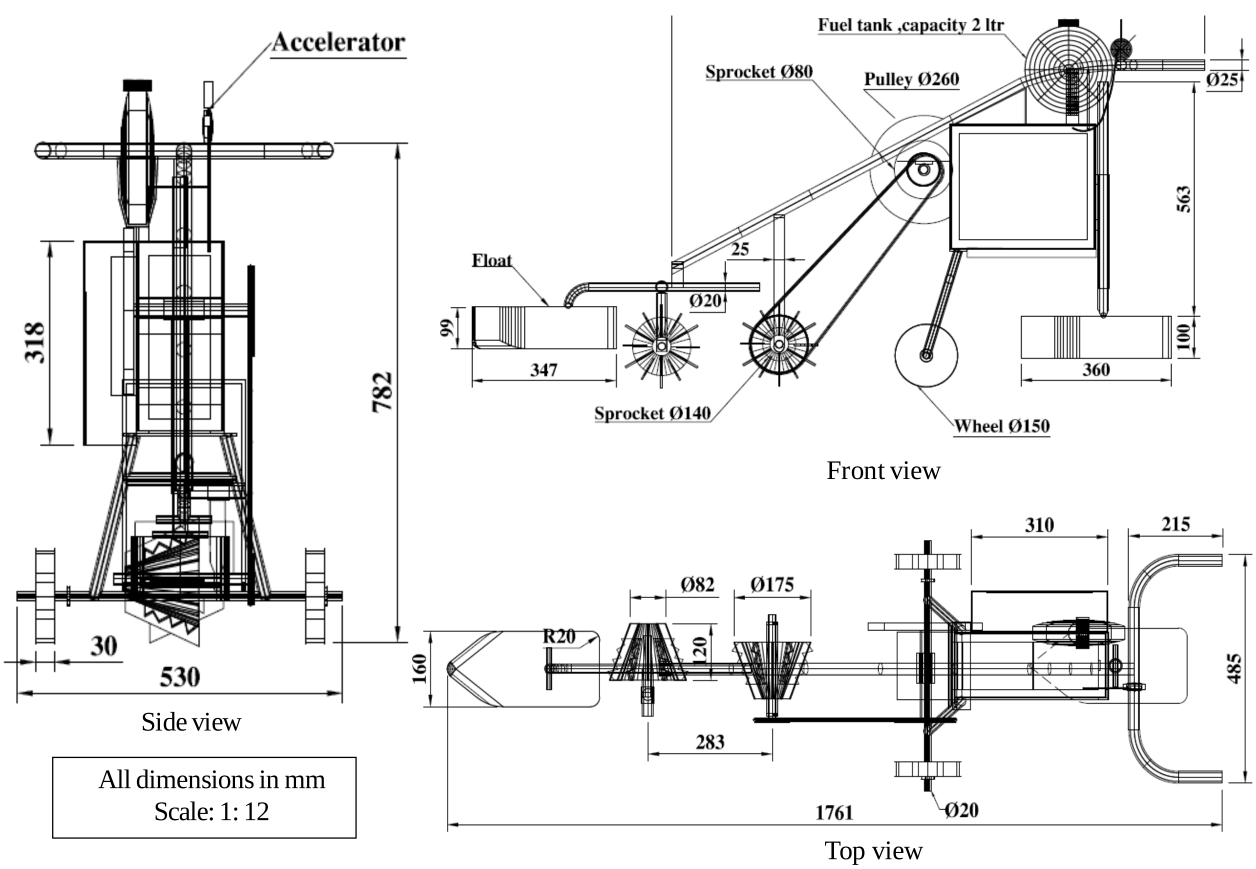

Fig. 2. Orthographic views of the self propelled cono-weeder

Table 1. Weed density (no./m^2) in rice at 30 and 60 DAT as influenced by the different treatments

Treatment	30 DAT				60 DAT			
	Grasses	Sedges	Broad-leaved weeds	Total weeds	Grasses	Sedges	Broad-leaved weeds	Total weeds
Manual cono weding at 15 and 30 DAT	2.72 (7.0)	11.63 (137.2)	7.74 (60.2)	14.2 (204.3)	1.43 (1.8)	8.86 (79.0)	5.51 (30.3)	10.51 (111.2)
Self propelled cono weeding at 15 and 30 DAT	2.32 (5.0)	10.17 (103.7)	9.93 (98.3)	14.39 (207.0)	1.51 (2.2)	10.38 (107.7)	6.55 (42.7)	12.35 (152.5)
Manual cono weeding at 10, 20, 30 and 40 DAT	1.51 (2.0)	6.40 (41.3)	6.82 (46.3)	9.44 (89.7)	1.35 (1.8)	8.89 (79.0)	5.97 (35.7)	10.78 (116.5)
Hand weeding at 20 and 40 DAT	1.08 (0.8)	1.58 (2.8)	2.23 (4.7)	2.87 (8.3)	1.35 (1.8)	2.90 (8.2)	4.11 (16.5)	5.17 (26.5)
LSD (P=0.05)	0.33	0.78	0.54	0.82	NS	0.58	0.49	0.66

(Values are $\sqrt{x+0.5}$ transformed, Original values in parentheses), DAT – days after transplanting

Table 2. Weed dry weight at 30 and 60 DAT, and grain and straw yield in rice as influenced by the different treatments

Treatment	Weed dry weight (g/m^2)		Yield (t/ha)	
	30 DAT	60 DAT	Grain	Straw
Manual cono weding at 15 and 30 DAT	5.59 (30.9)	10.69 (114.9)	2.16	2.19
Self propelled cono weeding at 15 and 30 DAT	4.30 (18.1)	11.7 (136.1)	2.26	2.45
Manual cono weeding at 10, 20, 30 and 40 DAT	4.70 (21.8)	8.69 (75.5)	2.19	2.43
Hand weeding at 20 and 40 DAT	1.05 (0.7)	3.07 (9.1)	2.28	2.10
LSD (P=0.05)	0.270	0.651	0.11	0.13

(Values are $\sqrt{x+0.5}$ transformed, original values in parentheses), DAT – days after transplanting

developed self propelled cono-weeder was successfully operated in the rice field and showed effective weed control. This self-propelled cono-weeder has many desirable qualities of a good weeder as listed out by WASSAN (2006), *viz.* simplicity in design as it was manufactured locally, the rugged and sturdy composite of units suitably attached each other, the easiness in operation and the effectiveness in weed control.

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Response of soil enzymes to elevated CO_2 and temperature in weeds associated with rice-wheat cropping system

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ABSTRACT

Biological properties of the soil have often been proposed as early and sensitive indicators of soil ecological stress or other environmental changes. In the present investigation, the soil samples were collected from weeds associated with rice- wheat cropping system from open- top chambers to assess the effect of elevated CO_2 and temperature on soil enzymes. In *Rabi* season, higher activity of FDA hydrolysis rate was noticed in wild oat with 26.5 (µg fluorescein/g/h) at elevated CO_2 + ambient temperature levels. Dehydrogenase activity was higher at enrichment of CO_2 for *P. minor* with 35.9 (µg TPF/g soil/24 h). Urease significantly was higher in enrichment of CO_2+ elevated temperature with wild oat 34.6 (µg NH_4/g soil/24 h) followed by wheat (31.5µg NH_4/g soil/24 h) with elevated CO_2 + ambient temperature. In *Kharif* season, enrichment of CO_2 concentration in rhizosphere of *Echinochloa crusgalli* recorded with higher FDA hydrolysis rate (19.8 µg fluorescein/g/h), dehydrogenase activity (39.8 µg TPF/g soil/24 h) and urease activity (45.6 µg NH_4/g soil/24 h) respectively. We found the carbon dioxide enrichment significantly increased the soil enzymes like dehydrogenase, fluorescein diacetate (FDA) hydrolysis and urease activity in weeds rhizosphere than the crops.

Key words: Elevated CO_2, Elevated temperature, Open top chambers, Rice, Soil enzymes, Wheat

Indian agriculture has done remarkably well by increasing food production from 50 Mt in 1951 to 252 Mt in 2011-2012 assuring food security to the nation. However, perceived impacts of climate change could adversely affect the food output. Over the last two decades, global warming was easily dismissed as the natural fluctuation in an ever changing global climate. Although there exists natural fluctuations in climate, human induced changes are predominantly during the current global warming trend (Stager 2012). Carbon dioxide is one of the major contributors of greenhouse gases which, being a primary substrate for photosynthesis, may have a significant impact on plant metabolism that directly affect the overall plant growth and soil health. Soil enzyme activities are the indicators of soil microbial functioning, soil physicochemical conditions and nutrient cycling in soils. The use of soil enzymatic activities as possible indicators of changes in below ground processes is induced by CO_2 enrichment. Many factors can influence the activity of soil enzymes. Temperature changes can affect microbial diversity and enzymatic activity directly. A source of microbial substrates for enzymatic decomposition could be rhizodeposition and secretion of soluble root exudates. Microbes could have various positive and negative feedback responses to temperature. Whether, changes in microbial processes lead to a net positive and negative feedback for greenhouse gas emission in unclear. The reason is that microbes live in very diverse communities that that interact with organisms and the environments in complex ways. It is important and there is an urgent need for more empirical knowledge that will fundamentally improve our ability to predict feedbacks of the terrestrial carbon cycle in agricultural ecosystems to anticipated climate change.

Climate change factors such as elevated atmospheric carbon dioxide (CO_2) can exert significant impacts on soil microorganisms and the ecosystem level processes they mediate. Therefore, the present investigation was carried out to study the effects of elevated CO_2 and temperature concentrations on soil enzyme activities in the weeds associated with rice-wheat ecosystem in open- top chambers (OTCs).

MATERIALS AND METHODS

Field experiment was laid out to study the changes of enzyme activity in veritsols under open top chambers (OTCs) to study the effect of elevated CO_2 and temperature on soil enzymes, at crop physiological maturity stage during *Kharif* and *Rabi* season (2013-14). The treatments included i) ambient CO_2 + ambient temperature ii) ambient CO_2 + elevated temperature iii) elevated CO_2 + ambient

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temperature iv) elevated CO_2 + elevated temperature in open top chambers (OTCs) placed in ICAR-Directorate of Weed Research, Jabalpur. The elevated temperature was maintained by putting infrared lamps inside the OTC chambers and was controlled by the automatically calibrated temperature sensors. Air temperature and relative humidity was monitored continuously at every 5 min interval in each OTC chamber by temperature– humidity-calibrated sensors. During sampling, the crops were gently pulled out, and loose soil was shaken off the roots and the soil that adhered strongly to the roots was carefully brushed and sampled as rhizosphere soil. All samples were performed in triplicate, and were used to quantify the soil enzymes.

Dehydrogenase activity was assayed by the method of Casida *et al*. (1964). Moist soil samples (4 g) were placed in 16 x 150 mm^2 test tubes to which was added 1 ml of 3% aqueous solution of 2,3,5-triphenyl tetrazolium chloride, 40 mg $CaCO_3$ and 2.5 ml distilled water. The contents of each tube were then mixed with a glass rod and incubated for 24 h at 37°C. Triphenyl formazan (TPF) was extracted by transferring the soil with the aid of methanol from each tube to a funnel plugged with absorbent cotton and the colour intensity determined in a spectrophotometer at a wave length of 485 nm. The dehydrogenase activity was expressed as µg TPF formed/g soil/24h.

The determination of fluorescein diacetate (FDA) hydrolysis (Schnurer and Rosswall 1982) was carried out in 2 g of field moist soil, where 15 ml of 60 mM potassium phosphate buffer (pH 7.6) was added. 100 µl of substrate solution was added to samples. After 20 min of incubation, the reaction was stopped by adding 15 ml of chloroform: methanol (2: 1). After filtering the solutions (Whatman No. 42), absorbance was measured at 490 nm on a UV Visible Spectrophotometer and calculated from the standard graph of fluorescein. The FDA hydrolysis rate was expressed as µg flurescein/g/h.

Urease activity was assayed by the method of Bremner and Mulvany (1978). Ten gram of dry and sieved soil was taken in a 100 ml volumetric flask. To this 1.5 ml of toluene was added, mixed well and incubated for 15 min. Then 10 ml of 10% urea solution and 20 ml of citrate buffer were added, mixed thoroughly, stoppered and incubated for 3 h at 37^0 C. Then the volume was made up to 100 ml with distilled water, mixed by shaking immediately. The contents were filtered through Whatman No.1 filter paper and 1ml of filtrate was pipetted out into 50 ml volumetric flask. To this 9 ml of distilled water, 4 ml of phenate and 3 ml of NaOCl were added, mixed well and allowed to stand for 20 min. The volume was made up to 50 ml and mixed well. The bluish green colour developed was read at 630 nm. The concentration of urease in the sample was obtained from the standard graph using diammonium sulphate. Urease activity was expressed µg NH_4/g soil/24h.

All the data were subjected to statistical analysis with softwares, SPSS (Kirkpatrick and Feenay 2005) and Microsoft Excel for Windows 2007 add-ins with XLSTAT Version 2010.5.05 (XLSTAT, 2010). Statistically significant differences between the treatments were analyzed using analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) at 5 % significance level.

RESULTS AND DISCUSSION

Alterations in microbial mineralization and nutrient cycling may control the long-term response of ecosystem to elevated CO_2, because microorganisms are regulators of decomposition, and understanding of microbial activity is so crucial. Elevated CO_2 concentration can affect extracellular enzyme activities in several ways.

In *Rabi* 2013, of the three enzymes examined, dehydrogenase, FDA and urease activities were significantly higher in soils under elevated CO_2 than in ambient. In this study, the increased air temperature in vertisols condition coupled with higher amount of C substrates through rhizodeposits geared up the rate of enzyme activity under elevated CO_2 + temperature condition. In the present study, higher activity of FDA hydrolysis rate noticed in wild oat with 26.5 (µg fluorescein/g/h) at elevated CO_2 - ambient temperature levels. Fluorescein diacetate (FDA) hydrolysis rate are the widely accepted as an accurate method for measuring total microbial activity in aerobic soils. Because they mediated simultaneously by protease, esterase and lipase and thereby reflect the activities of these enzymes in soil (Adam and Duncan 2001). Since 90% of energy flow in a system passes through microbial decomposers and heterotrophic microorganisms are predominant in soil, FDA hydrolysis is thought to reflect overall soil microbiological activity (Schnurer and Rosswall 1982). The activity of dehydrogenase is considered as an indicator of the oxidative metabolism in soils and the microbiological activity, because it is extremely intracellular and able to function within the viable cells.

Dehydrogenase activity was higher at enrichment of CO_2 for *P. minor* with 35.9 (µg TPF/g soil/24 h) followed by wild oat (34.8µg TPF/g soil/24 h). Maximum dehydrogenase activities were found at the panicle initiation stage and it declined sharply at maturity (Sarathambal *et al*. 2015). Urease the key enzyme hydrolyses urea to ammonia and CO_2 had significantly higher in enrichment of CO_2-elevated temperature with wild oat 34.6 (µg NH_4/g soil/24 h) followed by wheat (31.5 µg NH_4/g soil/24 h) with elevated CO_2 and ambient temperature. The enzyme activities in soil were strongly influenced by exposure to elevated CO_2 as well as by the interactive effect of the elevated CO_2 and temperature throughout the plant growth stages. Moorhead and Linkins (1997) suggested that elevated CO_2 altered the soil enzyme characteristics in a tussock tundra ecosystem.

The microorganisms in soils play a key role in the responses of ecosystem to global climate changes, as they regulate the dynamics of organic matter deposition and plant nutrient availability. However, the increasing atmospheric CO_2 concentrations will indirectly influence microbial populations in soils, through increased root biomass, total rhizodeposition, chemical composition of plant tissues and root exudates probably change when CO_2 is enriched, because CO_2 concentration in soil is much greater than the atmospheric CO_2 (Yue *et al.* 2007).

Table 1. Soil enzyme activity of wheat and associated weed species under OTCs as influenced by elevated CO_2 and temperature

Level of CO_2/temperature treatment	Crop / weed	Soil enzyme activity		
		Fluorescein diacetate hydrolysis rate (µg fluorescein/g/h)	Dehydrogenase (µg TPF/g soil/24 h)	Urease (µg NH_4/g soil/24 h)
Ambient CO_2 + ambient temperature	Wheat	18.9^{bcd}	25.6^{cd}	25.9^{bcd}
	P. minor	16.5^{de}	24.3^{d}	26.5^{bcd}
	Wild oat	14.6^{ef}	27.8^{cd}	24.6^{cd}
Elevated CO_2 + ambient temperature	Wheat	21.5^{b}	26.9^{cd}	31.5^{ab}
	P. minor	20.6^{bc}	35.9^{a}	20.9^{d}
	Wild oat	26.5^{a}	34.8^{ab}	29.5^{abc}
Ambient CO_2 + elevated temperature	Wheat	15.2^{def}	22.3^{d}	25.2^{cd}
	P. minor	12.3^{f}	23.6^{d}	22.3^{d}
	Wild oat	11.5^{f}	24.5^{dg}	21.5^{d}
Elevated CO_2+ elevated temperature	Wheat	15.6^{def}	26.9^{cd}	30.6^{abc}
	P. minor	16.8^{cde}	28.7^{bcd}	21.8^{d}
	Wild oat	14.6^{ef}	31.5^{abc}	34.6^{a}

Values represent mean of three replications and values followed by the same letter in each column are not significantly different from each other as detected by DMRT (p £ 0.05)

Table 2. Soil enzyme activity of rice and associated weeds under OTCs as influenced by elevated CO_2 and temperature

Levels of CO_2/temperature treatment	Type of cultivar	Soil enzyme activity		
		Fluorescein diacetate hydrolysis rate (µg fluorescein/g/h)	Dehydrogenase (µg TPF/g soil/24 h)	Urease (µg NH_4/g soil/24 h)
Ambient CO_2 + ambient temperature	MRWR27	9.6^{ef}	26.5^{d}	39.1^{ab}
	W1R4	8.9^{efg}	27.6^{bcd}	33.9^{d}
	C9	7.6^{fg}	18.9^{g}	36.5^{c}
	EC	8.7^{efg}	32.4^{b}	36.2^{c}
Elevated CO_2 + ambient temperature	MRWR27	12.3^{d}	28.6^{bc}	39.8^{c}
	W1R4	15.6^{c}	29.8^{bc}	36.9^{c}
	C9	11.2^{de}	19.5^{g}	42.9^{ab}
	EC	18.5^{ab}	39.8^{a}	45.6^{a}
Ambient CO_2 + elevated temperature	MRWR27	6.5^{g}	25.8^{d}	23.6^{f}
	W1R4	9.6^{ef}	20.6^{g}	29.8^{e}
	C9	8.7^{efg}	22.3^{e}	32.8^{d}
	EC	6.9^{g}	18.9^{g}	33.6^{d}
Elevated CO_2 + elevated temperature	MRWR27	12.8^{d}	22.3^{e}	34.6^{d}
	W1R4	18.2^{ab}	18.9^{h}	29.5^{e}
	C9	16.4^{bc}	16.9^{i}	28.9^{e}
	EC	19.7^{a}	34.8^{b}	35.5^{d}

Values represent mean of three replications and values followed by the same letter in each column are not significantly different from each other as detected by DMRT (p £ 0.05); MRWR27-weedy rice; W1R4-wild rice; C9-cultivated rice; EC- *Echinochloa crusgalli*

Repeated soil sampling during *Kharif* 2014, revealed an enhancement of enzyme activities under elevated CO_2 levels (Table 2). Whereas among the rice associated weeds tested, *Echinochloa crusgalli* rhizosphere responds positively to elevated CO_2 and temperature. In the present study, higher FDA hydrolysis rate noticed in *E. crusgalli* with 19.8 and 18.5 (µg fluorescein/g/h) in elevated CO_2 - elevated temperature and in elevated CO_2 - ambient temperature levels respectively. Dehydrogenase activity was higher at enrichment of CO_2 for *E. crusgalli* with 39.8 (µg TPF/g soil/24 h) followed by elevated CO_2-elevated temperature 34.8 (µg TPF/g soil/24 h). Urease the key enzyme hydrolyses urea to ammonia and CO_2 had significantly higher in enrichment of CO_2-ambient temperature with *E. crusgalli* 45.6 (µg NH_4/g soil/24 h) followed by cultivated rice (C9) 42.9 (µg NH_4/g soil/24 h). Earlier studies conducted by Sardans *et al*. (2008) in soil warming experiment also observed higher enzyme activities under soil warming depending upon the seasonal variations. Similar to our findings, activities of the dehydrogenase, FDA hydrolysis, and urease increased under elevated temperature with CO_2 enrichment resulted in higher microbial activities and increased rate of C mineralization (King *et al.* 2004, Naidu and Sarathambal 2012). A further source of microbial substrates for enzymatic decomposition could be rhizodeposition derived from turnover of fine roots, root hairs and secretion of soluble root exudates; and turnover of rhizosphere-associated microbial biomass. Rhizodeposition was roughly doubled in elevated compared with the ambient CO_2 treatment over the last 4 years of the experiment (Pendall *et al*. 2004). Since rhizodeposition and newly formed roots enlarged the pool of easily available substrates mainly in the weed species like *E. crusgalli*, wild oat, *P. minor*, increased enzyme production in this soil than the crops.

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Heavy metal extraction by weeds in wheat and cauliflower irrigated with sewage water

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ABSTRACT

The weed species emerged in wheat and cauliflower were screened for heavy metal accumulation ability under sewage water contaminated sites in Jabalpur and adjoining areas. It was observed that nearly 2-10 times higher accumulation of DTPA extractable heavy metals, *viz*. 0.42-6.30 µg/g cadmium, 2.43-24.1 µg/g lead, 3.06-89.43 µg/g copper, 88.9-226 µg/g manganese and 30-200 µg/g iron were recorded in sewage water soils than the tube well irrigated soils containing 0.69 µg/g Cd, 2.85 µg/g Pb, 62.8 µg/g Mn, 7.36 µg/g Cu, and 37.7 µg/g Fe. Relatively crops accumulated metals to lower extent than the weed species. Among weed species, *Avena ludoviciana* removed higher 69.6-122.3 µg/g manganese and 48.9-104 µg/g copper, *Parthenium hysterophorus extracted* 1065-2507 µg/g iron whereas *Sonchus arvensis* extracted 3.07 µg/g cadmium which were higher than the metal hyperaccumulating *Brassica juncea* (43.5 µg/g Mn, 19.0 µg/g Cu, 1352 µg/g Fe, 1.40 µg/g Cd). Thus, information on the build up of heavy metal concentration in soil and their removal by seasonal weed species grown on sites receiving sewage water indicate risk of metal entry in animal food chain as these weed species except Parthenium are used as a feed for animals. Besides this these weed species can be exploited for phyto-extraction of heavy metals under abiotic stress situation of metalliferrous sites.

Key words: *Avena ludoviciana*, Cadmium, Cauliflower, Copper, Lead, *Parthenium*, Wheat

The sewage water in peri-urban areas provides an irrigation source particularly during dry season, which enables farmers to get an increased crop yields due to content of high nutrient load. (Hunshal *et al*. 1997). Besides being a source of nutrients, these effluents often contain various heavy metals, depending upon the anthropogenic activities from which these are originating. It has been observed to enhance the available metal status of agricultural soils by 2 to 100 times by continuous use of waste water as an irrigation source (Samra 2007). The toxic effect of heavy metals gets amplified along the food chain at each stage of food web. The heavy metals like Cd, Zn, Pb, Cu, Ni, Mn and Fe get entry into the human and animal food chain which have been widely reported.

Therefore, there is a pressing need to deal with excess metals present in soil so as to prevent environmental contamination. There are certain grass species which are capable of accumulating moderate to high levels of heavy metals in the plant shoot. The wild oat (*Avena ludoviciana)* is a grassy weed commonly emerged in wheat. It responds to waste water treatment in terms of increased germination, shoot and root length in lab studies (Khankhane and Varshney 2010). *Parthenium hysterophorus* is serious weed grown in terrestrial environment which were also found to be the potential scavengers of heavy metals from field environment (Fazal and Asghari 2009). Since weedy plants are undesirable plants, potential for heavy metal accumulation have not been studied widely under crops receiving municipal waste water. Moreover, these plants are removed manually are commonly fed to animals in the region. Therefore, the present investigation was carried out to study the build up of heavy metal accumulation in soil and the heavy metal accumulation of weeds emerged in crops irrigated with municipal waste water.

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MATERIALS AND METHODS

Soil samples were collected from heavy metal contaminated sites of Gohalpur, Panagar, Urdhana and Ukhari in Jabalpur city and its adjoining area during the winter season. Five soil samples were collected randomly from each contaminated site. These samples were processed, passed through 2 mm sieve and analyzed for pH, electrical conductivity (1:2.5 soil water suspension), organic carbon (Walkley and Black 1934) and heavy metals (Cd, Cu, Fe, Mn and Pb) in DTPA extract (Lindsay and Norvell

1978) on Atomic Absorption Spectrophotometer. Commonly found different species of weeds was selected at maturity stage depending on their occurrences at contaminated sites. For each species 10 to 15 plants were collected from the wheat and cauliflower irrigated with waste water and tube well water. Along with weeds, the samples of mustard (metal hyper-accumulator) growing as an off plant in wheat, were also collected for comparative study. The weed and crop plant samples were dried at 70 ^{0}C for 48 hours, ground and mixed thoroughly for metal analysis. Plant samples were digested with di-acid mixture (HNO3:HClO4 9:4) and analyzed for the above mentioned heavy metals.

RESULTS AND DISCUSSION

The soil samples at various sites in Jabalpur were slightly alkaline in reaction with pH values ranging between 7.25 to 7.84 (Table 1). The soils under waste water irrigation and tube well water irrigated have similar pH value as contrast to the reports of Singh and Verloo (1996) that the continuous irrigation with waste water decreased the soil pH. The electrical conductivity (EC) values in all the contaminated soils (0.49 to 0.77) were within critical limits as recommended by United States Salinity Staff (1954) but were higher than the tube well irrigated soils (0.33). The mean organic carbon content in waste water irrigated soil (0.81) than the tube well irrigated soil (0, 54%). The DTPA extractable cadmium, lead, copper, iron and manganese in soils receiving waste water irrigation ranged between 1.52-6.30, 2.43-24.1, 3.06-89.4, 46-200 and 88.9-115 mg/kg respectively whereas the corresponding values for tubewell irrigated soils were 0.69, 2,85, 7.36, 37.7 and 62.8, respectively. The results show that waste water resulted accumulation of heavy metals 2-10 times higher than the tube well water irrigation. Similar impact on build up of heavy metals is reported by Som *et al.* (1994) in soils receiving long term waste water irrigation. The higher concentrations of toxic elements were also reported in cereal, oilseed, coarse grain and vegetable crops irrigated with sewage water around cities in Punjab and Andhra Pradesh (Samra and Sharma 2005).

Among major weed flora found in wheat were *Avena ludoviciana, Chenopodium album, Medicago denticulata, Cichorium intybus, Vicia sativa, Parthenium hysterophorus* in wheat. whereas *A. ludoviciana, P. hysterophorus, V. sativa, Melilotus* sp., *Lathyrus aphaca, Anagalis arvensis, Amaranthus viridis, Sonchus arvensis* and *Eclipta alba* were observed in cauliflower. Along with weeds, plants of *Brassica juncea* growing as an off also observed in wheat. The concentration of cadmium, copper, manganese and iron in almost all weed species growing on soils irrigated with waste water were higher than the plants grown on soils irrigated with tube well water. This difference in metal concentration in plants under waste water irrigation are due to increased accumulation of metals by waste water irrigation. These results are in conformity with the results of (Mitra and Gupta 1999) that the heavy metals content in plants irrigated with sewage water were higher than with normal irrigation waters.

The bioaccumulation of cadmium in almost all the weed species was within the critical concentration of cadmium (3 µg/g) as reported by Davis and Beckett (1978). Among the weeds with higher value of cadmium was accumulated by *C. album* (1.53 µg/g), followed by *A. ludoviciana* wheae as *V. sativa* (0.72 µg/g) and *P. hysterophorus* (0.64), absorbed lowest concentration of cadmium (0.64). As far as copper, iron and manganese is concerned these are considered as essential plant nutrient, however, it can also be transformed into toxic elements if its concentration exceeds the required limit. All the weed species exhibited copper concentrations beyond the critical limit (20 µg/g) as suggested by Beckett and Davis (1977) and comparatively higher than *B. juncea* found in the decreasing order of *A. ludoviciana* (48.9 µg/g)

Table 1. Heavy metal accumulation in field soils irrigated with waste water

Property	Sites in Jabalpur					
	Gohalpur	Panagar	Baldeobagh	Uldena	Ukhari	Tubewell
pH	7.84	7.76	7.90	7.68	7.25	7.71
EC (dS/m)	0.66	0.49	0.53	0.63	0.77	0.30
Org. C (%)	0.93	0.76	0.96	0.68	0.87	0.84
Cd (mg/kg)	1.72	1.57	0.42	2.02	6.30	0.69
Pb (mg/kg)	24.1	2.43	4.24	21.2	20.30	2.85
Cu (mg/kg)	53.0	16.50	12.80	3.06	89.43	7.36
Fe (mg/kg)	46.0	200.0	30.00	53.00	83.00	37.70
Mn (mg/kg)	115.0	169.0	175.0	88.90	226.0	62.80

followed by *P. hysterophorus* (44.8 µg/g), *C. album* (39.2 µg/g), *V. sativa (35.4), M. denticulata* (33.8 µg g) and *C. intybus* (28.2 µg/g). Among the weed species, *A. ludoviciana* accumulated higher manganese (122 µg/g) well below the critical limit concentration followed by *V. sativa (*88.0 µg/g), *C. album* (77.4 µg/g) >*P. hysterophorus* (53.2 µg/g) > *M. denticulata* 52 µg/g) > *C. intybus* (46.3 µg/g). As far as iron bioaccumulation is concerned, higher iron concentration were recorded in case of *P. hysterophorus* with a maximum value of 1065 µg/g dry weight, followed by *C. album* (948 µg/g). The lowest iron content was observed in the *M. denticulata* (864 µg/g) and *C. intybus* (646 µg/g). As compared with the *B. juncea*, the copper and manganese concentration in *A.a ludoviciana* found higher than in soil which resulted higher heavy metal ratio between soil and Avena ludoviciana (Table 1).

The overall sequence of the weed species for metal removal in wheat was as follows:

Cadmium: *C. album > M. denticulate> C. intybus*> A. ludoviciana> V. sativa > P. hysterophorus*

Copper: *A. ludoviciana > P. hysterophorus > C. album > V. sativa > M. denticulata > C. intybus*

Manganese: *A. ludoviciana > V. sativa > C. album >P. hysterophorus > C. album > C. intybus > M. denticulata*

Iron: *P. hysterophorus > C. album > M. denticulata > C. intybus >V. sativa.*

In cauliflower, *Sonchus arvensis* (3.07 µg/g) and *Anagalis arvensis/ Amaranthus viridis* accumulated highest cadmium the former was equal to the critical concentration (3.0 µg/g Cd) and the latter were below the critical concentration, however no toxicity was observed in these weeds. In case of copper and manganese, *V. sativa* removed 78.4 and 116 µg/g Cu and Mn, respectively. The lower concentration of cadmium and manganese were observed in cauliflower weeds such as *Melilotus indica* and *Lathyrus sativa*. As far as lower metal removal is concerned, Cunningham (1995) stated that some plants prevent metal from entering their aerial parts or maintain low and constant metal concentration over a broad range of metal concentration in contaminated medium, they mainly restrict metal entry in their roots. This may be due to alteration of its membrane permeability, changing metal binding capacity of cell walls or exude more chelating substances. Ebbs *et al.* (1997) also found such plant species which escape metal entry through an exclusion mechanism. Content of heavy metals such as cadmium and copper in wheat and cauliflower exceeded the prescribed standard limit (EU) for consumption. In view of the bio-magnification of heavy metals in the food chain, the higher toxic metal content such as cadmium and copper in the weeds, which are fed to animals are beyond the consumption levels of animals. Similarly the metal content in cauliflower was exceeding the permissible limit for human consumption. This may create health problems in the long run. The average

Table 2. Heavy metal accumulation by weed species in wheat

Weed species	Heavy metals (µg/g)			
	Cd	Cu	Mn	Fe
Avena ludoviciana	0.96	48.9	122.3	251
Chenopodium album	1.53	39.2	77.4	948
Medicago denticulata	1.10	33.8	52.0	864
Cichorium intybus	1.05	28.2	46.3	646
Vicia sativa	0.72	35.4	88.0	453
Parthenium hysterophorus	0.64	44.8	47.3	1065
Phalaris minor	1.35	ND	ND	ND
Brassica sp.	1.40	19.0	43.5	1352
Wheat	0.97(s)	19.1(s)	40.7 (s)	114.0 (s)

(s) Shoot, ND-Not detected

Table 3. Heavy metal accumulation by weed species in cauliflower

Weed species	Heavy metals (µg/g)			
	Cd	Cu	Mn	Fe
Avena ludoviciana	1.14	104	69.6	2041
Parthenium hysterophorus	1.14	49.4	Nd	2507
Vicia sativa	ND	78.4	116	3485
Chenopodium album	1.11	31.8	66.4	547.5
Melilotus indica	1.30	Nd	19	Nd
Lathyrus sativa	0.77	Nd	132	Nd
Anagallis arvensis	1.55	20.5	30	1060
Alternanthera viridis	1.56	22.6	38	621
Sonchus arvensis	3.07	41.4	35.2	923
Eclipta alba	1.14	48.9	41.4	962
Cauliflower	1.41(s) 1.24(f)	11.7 (s) 13.6 (f)	39.4(s) 25.3(f)	1887(s) 521(f)

s=shoot, f=flower ND: Not detected

Table 4. Heavy metal ratio between soil and weed species in wheat

Weed species	Heavy metals ratio			
	Cd	Cu	Mn	Fe
Avena ludoviciana	1.10	1.00	1.09	1.52
Chenopodium album	0.68	1.05	0.71	4.30
Medicago denticulata	0.54	1.10	0.52	4.48
Chicorium intybus	0.35	0.62	0.42	2.26
Vicia sativa	0.36	0.84	0.71	2.22
Parthenium hysterophorus	0.37	1.01	0.60	6.52
Brassica juncea	1.12	0.51	0.39	7.71
Triticum aestivum	0.36	0.40	0.40	0.66

Table 5. Heavy metal ratio between soil and weed species in cauliflower

Weed species	Heavy metal ratio			
	Cd	Cu	Mn	Fe
Avena ludoviciana	0.537	6.73	0.499	27.23
Parthenium hysterophorus	0.537	3.19	NA	33.44
Vicia sativa	NA	5.07	0.831	46.49
Chenopodium album	0.523	2.05	0.476	7.30
Melilotus indica	0.613	NA	0.136	NA
Lathyrus sativa	0.363	NA	0.946	NA
Anagallis arvensis	0.731	1.32	0.215	14.14
Alternanthera viridis	0.735	1.46	0.272	8.28
Sonchus arvensis	1.448	2.67	0.252	12.31
Eclipta alba	3.16	0.537	0.296	12.83
Cauliflower	0.75	0.665	0.282	25.17

normal concentration of cadmium was 0.05 µg/g (Elinder 1988) and copper was 1.5 µg/g dry weight (PFA 1954). Similar concern of transfer of heavy metals in food chain was reported by Lokeshwari and Chandrappa (2006).

Thus weed species accumulated variable amount of heavy metals which may be a function of their metabolic status. Among the weed species *Avena ludoviciana* removed higher copper and manganese, *Sonchus arvensis* extracted higher cadmium where as *Parthenium hysterophorus* followed by *Chenopodium album* retained higher iron content in their shoot parts. Information on the build up of heavy metal concentration in soil and their accumulation in weedy plants from the sites of deposition in natural field receiving municipal waste water would be helpful for selection of suitable plant species that can be used as accumulator plant to minimize the concentration of these metals in the highly polluted contaminated sites.

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Imidazolinone herbicides for weed control in greengram

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ABSTRACT

A field experiment to study the efficacy of imidazolinone herbicides in greengram was conducted during *Kharif* seasons of 2012 and 2013. Ten weed control treatments *viz.* imazethapyr at 50 and 70 g, premix of imazethapyr + imazamox at 60 and 70 g/ha, both applied as post-emergence at 20 days after sowing; pendimethalin 1000 g and premix of pendimethalin + imazethapyr at 800, 900, 1000 g/ha, both applied as pre-emergence, along with two hand weedings and weedy check were evaluated. Imazethapyr alone and its premixes with pendimethalin and imazamox recorded effective control of mixed weed flora and produced significantly higher greengram seed yield than weedy check. Pendimethalin alone did not control *Commelina benghalensis* and recorded lower seed yield. All the herbicides were safe to crop.

Key words: Greengram, Herbicides, Imazethapyr, Seed yield, Weed control

Greengram (*Vigna radiata* (L.) R. Wilczek) occupies a prominent place among major pulse crops of India and is inseparable ingredients of vegetarian diet, being one of the cheapest sources for protein. Weed infestation is one of the major constraints in greengram grown in *Kharif* (monsoon) season and full season competition with the weeds cause yield reduction to the extent of 25-100% (Punia *et al.* 2004, Malik *et al.* 2005). The crop needs a weed free period of first 30 days, as the crop is short stature and suffers badly if weeds are not controlled at early stages (Mirjha *et al.* 2013). The magnitude of loss as a result of crop-weed competition depends upon type of weed species, associated with crop, their densities and duration of competition with crops.

Weed emergence in greengram begins almost with the crop emergence leading to crop-weed competition from initial stages. *Trianthema portulacastrum* germinates at the same time as greengram crop and completes its life-cycle within 30 days and grassy weeds like*; Dactyloctenium aegyptium* and *Echinochloa colona* germinate with the onset of rains (Punia *et al.* 2013). The conventional methods of weed control (hoeing or hand weeding) are labour intensive and uneconomical and may cause damage to the crop. Chemical weed control is not common as the use of herbicides may be uneconomical due to low yield potential of greengram (Reddy 2004). The available pre- and post-emergence herbicides like pendimethalin, imazethapyr are able to check the emergence and growth of annual weeds (Chhodavadia *et al.* 2013). This study was done to find out the relative efficiency of imidazolinone herbicides when applied alone or as premix in greengram.

MATERIALS AND METHODS

The experiment was conducted at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (Punjab) during *Kharif* 2012 and 2013. The soil of the experimental site was loamy sand with normal soil reaction (pH=7.4) and electrical conductivity (0.15 dS/m). The soil was low in organic carbon (0.30 %) and available nitrogen (261.7 kg/ha) and medium in available phosphorus (12.5 kg/ha) and potassium (169.1 kg/ha). The experiment was laid out in randomised complete block design with ten treatments including pendimethalin 1000 g/ha applied as pre-emergence, premix of imazethapyr + pendimethalin 800, 900 and 1000 g/ha applied as pre-emergence; imazethapyr 50, 70 g/ha applied at 20 days after sowing (DAS), premix of imazethapyr + imazamox 60, 70 g/ha applied at 20 DAS; two hand weedings at 20 and 40 DAS and weedy replicated thrice. The crop was sown with hand drill with seed rate of 20 kg/ha keeping 30 cm row to row spacing using cv. *'SML 668'* during 2012 and cv. '*PAU 911*' during 2013. The pre-emergence herbicides were applied within two days of sowing with knap sack sprayer fitted with flat fan nozzle that delivered 500 liter water/ha whereas post-emergence herbicides were sprayed using 375 l/

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ha of water at 20 DAS when weeds were at 3-4 leaf stage. All other recommended package of practices for crop cultivation was followed. The data of weed count and dry matter was taken at 40 DAS. The data on crop growth, yield attributes and seed yield was recorded at harvest. The data was analysed using 'CPCS1' statistical software. The analysis of individual years was done and comparisons were made at 5 per cent level of significance.

RESULTS AND DISCUSSION

Effect on weeds

The major weeds in the experimental field included *Commelina benghalensis*, *Digitaria sanguinalis*, *Eleucine indica*, *Trianthema portulacastrum*, *Amaranthus viridis* and *Cyperus rotundus* during 2012; only grasses *viz*, *Dactyloctenium aegyptium*, *Commelina benghalensis*, *Digitaria sanguinalis and Acrachne racemose* were recorded during 2013. All the weed control treatments, except pendimethalin 1000 g/ha and imazethapyr 50 g/ha, provided effective control of grasses, broad-leaves (BLW) and sedges and created weed free conditions till first 40 days of sowing during 2012 (Table 1). The pendimethalin was ineffective against sedges and lost its efficacy after 20 days of application against grasses and broad-leaves. Imazethapyr at lower dose provided effective control of broad-leaves however it was poor on grasses and sedges. During 2013, pendimethalin + imazethapyr provided effective control of all the grass weeds and created weed free conditions till first 40 days of sowing. Higher pressure of *Commelina benghalensis* in pendimethalin treated plots increased weed dry matter (Table 2). Imazethapyr at its both levels and premix of imazethapyr + imazamox were relatively poor on *Acrachne* and *Commelina* but controlled *Dactyloctenium aegyptium* and *Digitaria sanguinalis.*

Effect on yield attributes and seed yield

The crop was heavily infested with yellow mosaic virus and hence the yields were very lower and differential effect of weed control treatments on seed yield and yield attributes disappeared during

Table 1. Effect of different weed control treatments on weeds at 40 DAS in greengram during *Kharif* 2012

Treatment	Dose (g/ha)	Weed population/m^2			Weed dry matter g/m^2		
		Grasses	BLW	Sedges	Grasses	BLW	Sedges
Pendimethalin	1000	3.4 (11)	4.3 (18)	5.2 (27)	7.7 (62)	9.7 (101)	6.3 (40)
Imazethapyr	50	2.2 (7)	1.0 (0)	1.8 (3)	2.8 (14)	1.0 (0)	1.2 (1)
Imazethapyr	70	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Imazethapyr + pendimethalin	800	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Imazethapyr + pendimethalin	900	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Imazethapyr + pendimethalin	1000	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Imazethapyr + imazamox	60	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Imazethapyr + imazamox	70	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Hand weeding at 20 and 40 DAS	-	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
Weedy check	-	10.7 (119)	4.9 (23)	2.1 (7)	20.6 (432)	10.8 (118)	5.8 (33)
LSD (P=0.05)		1.8	0.9	1.0	2.7	2.5	0.8

Table 2. Effect of different weed control treatments on weeds at 40 DAS in greengram during *Kharif* 2013

Treatment	Dose (g/ha)	Weed population (no/m^2)				Weed dry matter (g/m^2)
		Commelina benghalensis	*Dactyloctenium aegyptium*	*Digitaria ciliaris*	*Acrachne racemose*	
Pendimethalin	1000	5.7 (32)	1 (0)	1 (0)	1 (0)	24.2 (586)
Imazethapyr	50	2.2 (7)	1 (0)	1 (0)	2.9 (15)	6.6 (105)
Imazethapyr	70	1.5 (2)	1 (0)	1 (0)	2.6 (11)	2.2 (7)
Imazethapyr + pendimethalin	800	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Imazethapyr + pendimethalin	900	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Imazethapyr + pendimethalin	1000	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Imazethapyr + imazamox	60	1.5 (2)	1 (0)	1 (0)	2.4 (9)	2.4 (9)
Imazethapyr + imazamox	70	1.5 (2)	1 (0)	1 (0)	2.1 (5)	2.3 (8)
Hand weeding at 20 and 40 DAS	-	1 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Weedy check	-	4.3 (18)	3.5 (11)	1.8 (3)	8.5 (75)	34.3 (1176)
LSD (P=0.05)	-	1.3	0.9	0.4	2.5	5.4

Figures in parentheses are original values. Data were subjected to square root transformations

Table 3. Effect of different weed control treatments on greengram yield and yield attributes of greengram

Treatment	Dose (g/ha)	Plant height at harvest (cm)		Branches/ plant		Pods/plant		Seed yield (kg/ha)		B:C
		2012	2013	2012	2013	2012	2013	2012	2013	
Pendimethalin	1000	66.4	63.5	5.1	4.8	19	14.3	192	502	0.82
Imazethapyr	50	60.5	74.7	5.2	7.1	20	24.3	177	701	1.02
Imazethapyr	70	61.9	73.8	4.9	7.2	16	24.8	196	715	1.04
Imazethapyr + pendimethalin	800	58.8	74.2	4.8	6.7	14	26.7	179	737	1.07
Imazethapyr + pendimethalin	900	68.3	77.2	6.2	6.7	23	24.3	188	775	1.12
Imazethapyr + pendimethalin	1000	63.0	76.3	6.1	7.3	24	25.9	188	862	1.25
Imazethapyr + imazamox	60	64.7	72.0	5.2	6.7	19	22.7	188	672	0.98
Imazethapyr + imazamox	70	65.7	70.7	5.9	7.1	22	26.3	188	676	0.98
Hand weeding at 20 and 40 DAS	-	73.8	72.7	6.5	7.1	26	27.2	188	843	1.19
Weedy check	-	53.1	64.8	4.4	4.7	11	13.5	210	435	0.77
LSD (P=0.05)	-	NS	5.5	NS	0.7	NS	3.7	NS	220	-

2012. During second year of study, all the post-emergence herbicides treatments recorded significantly higher greengram seed yield and yield attributes such as plant height at harvest, branches/ plant and pods/plant as compared to weedy check and were at par to two hand weedings (Table 3). Greengram yield attributes and seed yield was significantly lower in pendimethalin treated plots as compared to the post emergence herbicides treatments due to more weed dry matter in former. These results are in agreements with Raj *et al.* (2012) that higher seed and haulm yields with higher weed control efficiency were obtained with two hoeing at 20 and 40 DAS and was followed by pendimethalin as pre-emergence 0.75 kg/ha + one hand weeding at 40 DAS. All the herbicides were safe to the crop.

Economics

Pre-emergence application of imazethapyr + pendimethalin 1000 g/ha recorded the highest B:C ratio and it was followed by lower doses of 900, 800 g/ha and two hand weedings at 20 and 40 DAS (Table 3). Lower benefits were obtained when pendimethalin as pre-emergence and imazethapyr + imazamox as post-emergence were applied for weed control.

Hence, post-emergence application of imazethapyr alone or its pre-mix with pendimethalin/ imazamox can be adopted for effective control of weeds in greengram.

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Pre- and post-emergence herbicides for weed control in greengram and their residual effect on succeeding crops

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ABSTRACT

Comparative efficacy of pre- and post-emergence herbicides in greengram and their residual effect on succeeding crops was studied during *Kharif* season of the year 2011-2013. Inter-culturing and hand weeding carried out at 20 and 40 DAS produced the lowest weed dry weight with higher weed control efficiency. Among herbicidal treatments, pre-emergence application of pendimethalin at 500 g/ha or imazethapyr 75 g/ha followed by interculturing and hand weeding at 30 DAS proved to be efficient in reducing weed dry weight with more than 70% of weed control efficiency and recorded higher seed and haulm yield of greengram. Further, it was observed that none of the herbicides applied at tested rates had adverse effect on succeeding wheat, chickpea and mustard crops.

Key words: Greengram, Herbicides, Haulm, Residual effect, Seed, Weed control, Weed dry weight

Greengram (*Vigna radiata* L.) belongs to the family Fabaceae. It is an important conventional pulse crop being cultivated in rainfed area. The lower productivity is mainly due to unawareness and improper use of improved practices by the farming community. The gap between actual and potential production can be minimized with the use of adequate level of inputs in proportionate manner along with other improved cultural practices. Among several factors, proper weed management plays an important role in improving the production. Weeds being the major problem which provide opportunities for harboring insects, pests and diseases and result in yield reduction. They reduce the crop yield and deteriorate the quality of produce and hence, reduce the market value of the turnout. Decrease in mungbean productivity due to weed competition to the extent of 45.6% (Pandey and Mishra 2003).

Therefore, management of weeds in all agro-ecosystems is imperative to sustain our crop productivity and to ensure the food security to the ever increasing population. Herbicides are commonly used for weed control in high-input crop production systems. Due to extensive and injudicious application, most of the unused fractions of herbicides however, may persist within soils (Madhaiyan *et al*. 2006). Hence, information regarding persistence and residual effect of herbicides in soil is essential to use them safely, effectively and for non-hazardous chemical weed control strategy. For that bioassay remains a major tool for qualitative and quantitative determination of herbicides residue in soil. Considering above facts, an attempt has been made to study the comparative efficacy of pre and post emergence herbicide in greengram and their residual effect on succeeding crops.

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MATERIALS AND METHODS

With a view to determine the comparative efficacy of different pre- and post-emergence herbicide in greengram and their residual effect on succeeding crops, the present field experiment was conducted at DWR-Anand Centre, B.A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *Kharif* season of the year 2011 to 2013. The soil of the experimental field was sandy loam in texture having low in available nitrogen and medium in available phosphorus and high in potassium with pH 8.2. The experiment was laid out in randomized complete block design with four replications. Ten treatment comprised, *viz*. pendimethalin 500 g/ha PE, pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS, quizalofop-ethyl 50 g/ha POE *fb* IC at 30 DAS, quizalofop-ethyl 50 g/ha POE *fb* IC+HW at 30 DAS, imazethapyr 75 g/ha *fb* IC at 30 DAS, imazethapyr 75 g/ha *fb* IC+HW at 30 DAS, fenoxaprop-p-ethyl 100 g/ha POE *fb* IC at 30 DAS, fenoxaprop-p-ethyl 100 g/ha POE *fb* IC + HW at 30 DAS, IC + HW at 20 and 40 DAS and weedy check. The herbicides were applied using knapsack sprayer fitted with flat fan nozzle by mixing in 500 litre of water/ha as per treatments. Greengram cv. '*Meha*' was sown manually keeping the distance of 30 cm between two rows in all the three years of experimentation. After harvesting of the greengram, without disturbing the layout, each plot were manually prepared for sowing of succeeding crops crop to know the residual effect of herbicides. Four rows of each succeeding crop, *viz*. chickpea, wheat and mustard were sown in each plot during *Rabi* season at a recommended spacing of respective crop during all the three years of experimentation. The observation of succeeding crops, *viz*. germination (no. of plant/m row length) at 10 DAS while plant height (cm) and dry matter accumulation (g/plant) of chickpea, wheat and mustard crops were recorded at 30 DAS and data were used for analysis.

RESULTS AND DISCUSSION

Effect on weeds

All the weed management practices showed effective control of individual group of monocot and dicot weeds resulting in reduction of weed dry weight as well as increasing weed control efficiency as compared to weedy check (Table 1). Among the herbicidal treatments, significantly the lowest monocot weed count at 25 DAS was observed under imazethapyr 75 g/ha PE *fb* IC at 30 DAS, while significantly lower dicot weed count was noticed under imazethapyr 75 g/ha PE *fb* IC + HW at 30 DAS as compared to rest of the herbicidal treatment except imazethapyr 75 g/ha PE *fb* IC at 30 DAS. At harvest, IC + HW at 20 and 40 DAS recorded significantly lower dry weight of weeds than that of recorded in other treatments except pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS and pendimethalin 500 g/ha PE. Similarly, minimum weed dry weight under manual weeding and with application of pendimethalin was also noticed by Kaur *et al*. (2009) in greengram. Further, it was observed that imazethapyr 75 g/ha PE integrated with either with IC or IC + HW at 30 DAS showed their superiority over quizalofop-ethyl 50 g/ha POE and fenoxaprop-p-ethyl 100 g/ha POE integrated with either with IC or IC + HW at 30 DAS in respect of recording weed dry weight at harvest. Weed control efficiency at harvest was recorded maximum under IC + HW at 20 and 40 DAS followed by pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS and pendimethalin 500 g/ha PE. The higher weed control efficiency under said treatment might be due to effective reduction of dry weed weight at harvest.

Table 1. Number and dry weight of monocot and dicot weeds and weed control efficiency as influenced by different weed management practices in greengram (pooled data)

Treatment	Weed count at 25 DAS (no./m^2)		Dry weed weight at 25 DAS (g/m^2)		Weed dry weight at harvest (g/m^2)	WCE at harvest (%)
	Monocot	Dicot	Monocot	Dicot		
Pendimethalin 500 g/ha PE	11.6^{c} (134.7)	5.7^{ef} (31.7)	9.6^{bc} (91.4)	6.1^{c} (40.8)	8.0^{def} (63.2)	71
Pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS	11.4^{c} (130.2)	6.1^{de} (36.8)	10.3^{b} (108.4)	5.8^{c} (32.7)	7.8^{ef} (59.3)	73
Quizalofop-ethyl 50 g/ha POE*fb* IC at 30 DAS	9.6^{d} (90.9)	9.9^{b} (99.2)	9.5^{bc} (90.3)	7.5^{b} (56.2)	14.0^{bc} (195.1)	11
Quizalofop-ethyl 50 g/ha POE *fb* IC+HW at 30 DAS	9.5^{d} (89.0)	9.3^{c} (85.8)	9.3^{bc} (85.4)	6.0^{c} (35.1)	13.9^{c} (192.5)	12
Imazethapyr 75 g/ha *fb* IC at 30 DAS	8.4^{e} (69.0)	5.2^{fg} (26.1)	7.5^{d} (55.7)	3.2^{e} (9.4)	8.6^{d} (74.5)	66
Imazethapyr 75 g/ha *fb* IC+HW at 30 DAS	9.2^{d} (84.7)	5.0^{g} (24.0)	8.9^{c} (78.1)	3.9^{e} (14.1)	8.5^{de} (71.1)	68
Fenoxaprop-p-ethyl 100 g/ha POE *fb* IC at 30 DAS	12.7^{b} (160.6)	6.1^{de} (36.0)	9.9^{bc} (96.6)	4.8^{d} (24.0)	14.7^{ab} (215.1)	2
Fenoxaprop-p-ethyl 100 g/ha POE *fb* IC+HW at 30 DAS	12.9^{b} (165.4)	6.5^{d} (41.2)	8.8^{c} (77.1)	6.6^{bc} (46.3)	14.3^{abc} (203.5)	7
IC+HW at 20 and 40 DAS	1.0^{f} (0.0)	1.0^{h} (0.0)	1.0^{e} (0.0)	1.0^{f} (0.0)	7.3^{f} (53.1)	76
Weedy check	17.8^{a} (351.4)	11.0^{a} (120.5)	16.4^{a} (269.5)	8.5^{a} (72.1)	14.8^{a} (219.7)	-
SEm±	0.20	0.189	0.37	0.29	0.23	-
LSD (P=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	-
CV (%)	6.94	10.95	10.24	12.06	7.58	-
Y x T SEm±	0.36	0.36	0.46	0.55	0.42	-
LSD (P=0.05)	NS	NS	NS	NS	NS	-

Values followed by the same letter in a column were not significantly different from each other at P=0.05, PE - pre-emergence, POE - post-emergence

Effect on crop

The impact of different weed management practices were clearly reflected their positive impact on yield attributes and yield of green gram (Table 2). Plant stands were unaffected due to different weed management practices. However, periodical plant height measured at 30 DAS and at harvest showed positive effect and maximum plant height was recorded under weedy check treatment at 30 DAS while at harvest it was higher under IC + HW at 20 and 40 DAS. The higher plant height under weedy check treatment at 30 DAS might be due to severe crop weed competition occur during initial stage of the crop, which leads to restrict the development of the plant, hence the height of the plant is increase, while hand weeding treatment provide weed free environment to the crop leads to better growth and development of plant which help in increase the height of the crop. The non-significant variations in dry weight of *Rhizobium* nodules were observed due to different weed management practices.

Further, it was observed that IC + HW carried out at 20 and 40 DAS recorded significantly higher seed and haulm yield of greengram than that of recorded in other treatment except pre-emergence application of pendimethalin 500 g/ha *fb* IC + HW at 30 DAS, pendimethalin 500 g/ha pre-emergence, imazethapyr 75 g/ha post-emergence *fb* IC + HW at 30 DAS and imazethapyr 75 g/ha post-emergence *fb* IC at 30 DAS. Whereas, significantly the lowest seed and haulm yield (584 kg/ha and 932 kg/ha, respectively) was observed in weedy check. Higher seed and haulm yield under IC+HW at 20 and 40 DAS was also recorded by Raj *et al.* (2012) and Kaur *et al.* (2009) in greengram.

Economics

The results of the economics analysis of the weed management practices revealed that maximum net return (₹ 34626/ha) was recorded in IC + HW carried out at 20 and 40 DAS followed by pre emergence application of pendimethalin 500 g/ha, pre emergence application of pendimethalin 500 g/ha *fb* IC + HW at 30 DAS, pre-emergence application of imazethapyr 75 g/ha *fb* IC at 30 DAS and pre emergence application of imazethapyr 75 g/ha *fb* IC + HW at 30 DAS with more than 1.25 BCR. Similarly, Chhodavadia *et al.* (2013) also observed higher BC ratio with IC + HW at 20 and 40 DAS and use of pendimethalin with integration of IC + HW at 30 DAS.

Bioassay study

To know the residual effect of pre and post emergence application of herbicides in greengram, succeeding crops, *viz.* chickpea, wheat and mustard

Table 2. Yield attributes, yield and economics of greengram as influenced by weed management (pooled data)

Treatment	Plant stand (no./m row length)	Plant height at 30 DAS (cm)	Plant height at harvest (cm)	Dry weight of *Rhizobium* nodules (mg/plant) at 35 DAS	Seed yield (kg/ha)	Haulm yield (kg/ha)	Gross realization (x10^3 ` /ha)	BC ratio
Pendimethalin 500 g/ha PE	10.6	50.0^{abc}	73.0^{abc}	60.7	1135^{abc}	1705^{ab}	55.62	1.53
Pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS	10.6	47.9^{bcd}	45.1^{ab}	65.3	1151^{ab}	1762^{a}	56.47	1.38
Quizalofop-ethyl 50 g/ha POE *fb* IC at 30 DAS	10.7	50.6^{ab}	73.1^{abc}	65.9	1028^{def}	1493^{c}	50.27	1.17
Quizalofop-ethyl 50 g/ha POE *fb* IC+HW at 30 DAS	10.7	46.0^{d}	73.3^{abc}	63.3	1062^{cde}	1597^{bc}	52.05	1.13
Imazethapyr 75 g/ha *fb* IC at 30 DAS	10.7	46.0^{d}	70.8^{bcd}	65.6	1097^{abc}	1714^{ab}	53.89	1.33
Imazethapyr 75 g/ha *fb* IC+HW at 30 DAS	10.5	46.4^{cd}	72.3^{abcd}	66.1	1114^{abc}	1698^{ab}	54.75	1.25
Fenoxaprop-p-ethyl 100 g/ha POE *fb* IC at 30 DAS	10.6	47.3^{bcd}	72.3^{abcd}	63.8	987^{f}	1545^{c}	48.49	1.08
Fenoxaprop-p-ethyl 100 g/ha POE *fb* IC + HW at 30 DAS	10.7	47.0^{bcd}	69.9^{cd}	63.8	1003^{ef}	1459^{c}	49.06	1.00
IC+HW at 20 and 40 DAS	10.6	46.8^{cd}	75.5^{a}	68.5	1198^{a}	1809^{a}	58.73	1.45
Weedy check	10.7	52.9^{a}	68.3^{d}	60.5	584^{g}	932^{d}	28.73	0.40
SEm±	0.08	1.15	1.36	2.50	35	45	-	-
LSD (P=0.05)	NS	Sig.	Sig.	NS	Sig.	Sig.		
CV (%)	2.59	4.46	5.90	6.13	7.86	8.48		
Y x T SEm±	0.13	1.0	1.1	4.4	40.71	82.65	-	-
LSD (P=0.05)	NS	NS	NS	NS	NS	NS		

Values followed by the same letter in a column are not significantly different from each other at P=0.05, PE - pre-emergence, POE - post-emergence

Table 3. Residual effect of herbicides applied in greengram on succeeding *Rabi* crops (Pooled data)

Treatment	Germination at 10 DAS (no. of plant/m row length)			Plant height at 30 DAS (cm)			Dry matter at 30 DAS (g/plant)		
	Chickpea	Wheat	Mustard	Chickpea	Wheat	Mustard	Chickpea	Wheat	Mustard
Pendimethalin 500 g/ha PE	10.37	45.12	22.70	13.85	36.82	34.87	1.366	4.542	0.923
Pendimethalin 500 g/ha PE *fb* IC+HW at 30 DAS	10.32	45.62	22.72	14.02	36.97	34.75	1.390	4.634	0.923
Quizalofop-ethyl 50 g/ha POE *fb* IC at 30 DAS	10.62	46.35	22.90	13.97	37.0	34.87	1.395	4.575	0.919
Quizalofop-ethyl 50 g/ha POE *fb* IC+HW at 30 DAS	10.45	45.35	22.35	13.87	37.05	34.87	1.394	4.651	0.912
Imazethapyr 75 g/ha *fb* IC at 30 DAS	10.47	45.30	22.63	13.95	37.12	35.02	1.435	4.686	0.931
Imazethapyr 75 g/ha *fb* IC+HW at 30 DAS	10.45	45.27	22.47	13.75	36.75	34.82	1.433	4.638	0.915
Fenoxaprop-p-ethyl 100 g/ha POE *fb* IC at 30 DAS	10.35	45.22	22.92	13.92	36.92	34.80	1.423	4.636	0.928
Fenoxaprop-p-ethyl 100 g/ha POE *fb* IC+HW at 30 DAS	10.35	45.77	22.97	14.07	36.82	34.82	1.492	4.584	0.931
IC+HW at 20 and 40 DAS	10.42	45.65	22.70	14.0	37.02	34.81	1.409	4.644	0.919
Weedy check	10.37	45.22	22.65	13.97	36.97	34.80	1.415	4.659	0.932
SEm±	0.20	1.76	0.30	0.16	0.24	0.15	0.05	0.06	0.02
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.91	3.19	3.84	3.53	1.97	1.31	4.19	3.74	5.41
Y x T SEm±	0.31	2.53	0.44	0.25	0.36	0.23	0.07	0.09	0.02
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

PE - pre-emergence, POE - post-emergence

were sown and growth parameters, *viz.* germination count (at 10 DAS), plant height as well as dry matter accumulation (at 30 DAS) were recorded. The results in (Table 3) indicated that there was no residual impact of pendimethalin, quizalofop-ethyl, imazethapyr or fenoxaprop-p-ethyl applied as alone or in integration with either IC or IC + HW at 30 DAS on succeeding wheat, chickpea and mustard crops. This indicated that the said herbicides can safely be used in greengram.

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Intercropping and weed management effects on weed dynamics, productivity and economics of pigeonpea

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ABSTRACT

A field experiment was conducted to study the weed dynamics, productivity and economics of pigeonpea [*Cajanus cajan* (L.) Millsp.] under intercropping and weed management practices under rainfed. Among intercropping systems, greengram and blackgram were planted in paired row (2:2) system at 30/90 cm row spacing in main plots and six weed management treatments include pre-emergence herbicides (pendimethalin and oxiflourfen), post-emergence herbicide (imazethapyr) and their combinations in sub plots. Both the intercropping systems (pigeonpea + greengram or pigeonpea + blackgram) recorded higher Crop Equivalent Yield (CEY) (1.23 to 1.36 t/ha), Land Equivalent Ratio (LER) (1.6) and B: C ratio (2.5 - 2.7) than sole pigeonpea. Among herbicide treatments significantly higher weed controlling efficiency was recorded in pendimethalin + imazethapyr and oxyflourfen + imazethapyr (90.6 - 91.5%) as compared to pendimethalin or oxiflourfen or imazethapyr (72.1 - 84.6%).

Key words: Blackgram, Greengram, Intercropping, Pigeonpea, Weed management

The present production of pulses in the country hovers around 13-15 million tonnes from an area of 22-23 million hectares during the last decade (1999-2009). Consequently, per capta availability of pulses in India has declined from 64 g/day (1951/52) to 34 g/day (2010) as against recommendation of 80 g/day. Assuming a moderate requirement of 50 g pulses per capta per day with 10% additional need for seeds and feed wastages *etc*, the projected pulse requirement for the year 2030 is 32 million tonnes, which necessitates annual growth rate of 4.2% in pulse production. To meet the projected requirement the productivity needs to uplift at 1361 kg/ha and about 3.00 million ha has to be bought under pulses besides reducing the post harvest losses (IIPR, Vision 2030).

Pigeonpea because of its slow initial growth rate is very sensitive to weed competition in the first 45 to 60 days after sowing. In many rainfed pigeonpea growing area, optimum land preparation is seldom done and weeds cause severs yield losses ranged from 70 to 90% as reported by Padmaja *et al.* (2013). To achieve the target of additional production of pulses the intercropping is the ultimate solution. It overcomes the drawbacks of mono cropping systems and suppresses weed growth as reported by Kiroriwal and Yadav (2013). Hence keeping all the above aspects in consideration, the present study was undertaken to find out most suitable weed control method and intercropping system for increasing the yield of rainy season pulses per unit area per unit time to achieve the mentioned target.

MATERIALS AND METHODS

Field experiment was conducted at the Research Farm of Mahatma Gandhi Chitrakoot Gramodaya Vishwa Vidhyalaya Chitrakoot, Satna (M.P.) during rainy (*Kharif*) season of 2012-13 and 2013-14. Geographically Chitrakoot is situated between the $25^0 10'$ N latitude and $80^0 52'$ E longitude and about 190-210 meter above mean sea level. The soil of the experimental field was sandy clay loam with pH value 7.44 to 7.46, electrical conductivity 0.32 to 30 dS/m, organic carbon 2.4 to 2.9 g/kg, available N, 193 to 201 kg/ha, available P 16.7 to 20.1 kg/ha and available K 201 to 207 kg/ha. The treatments comprised three intercropping systems sole pigeonpea planted at 60 cm row spacing, pigeonpea + greengram (2:2) planted at 90/30 cm row spacing and pigeonpea + blackgram (2:2) planted at 90/30 cm row spacing in main plots and six weed control treatments weedy check (control), pendimethalin 1.0 kg/ha pre-emergence (PE), oxiflourfen 0.2 kg/ha pre-emergence (PE), imazethapyr 0.1 kg/ha post-emergence (POE), pendimethalin 1.0 kg/ha PE followed by imazethapyr 0.1 kg/ha POE and

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oxiflourfen 0.2 kg/ha PE followed by imazethapyr 0.1 kg/ha POE] as the sub-plot treatments. The experiment was laid out in split plot design with three replications. Pigeonpea variety '*ICPL 88039*', greengram variety '*Samrat*' and blackgram varity '*Azad-1*' were sown at 15, 12 and 15 kg seed per hectare respectively. Pre-emergence herbicides (pendimethalin and oxyflourfen) were applied in the next day after sowing of the crop while post-emergence herbicide (imazethapyr) was applied 25 days after sowing the crop with the help of knapsack sprayer fitted with flat-fan nozzle using 500 liters of water per hectare. Weeds were allowed to grow freely in the control plots throughout the cropping season. Other crop management practices followed as per recommendations for the region.

Weed species associated with the crops in the experimental area were counted periodically and grouped according to the nature of cotyledons and botanical names. The percentage composition of weed flora was estimated from weedy check and relative density of weeds was worked out as per the standard formula at 25 DAS stage. The total weed biomass obtained before harvest was utilized to determine the weed control efficiency of various treatments. Crop equivalent yield was calculated as the pigeonpea equivalent yield by taking into account the seed yield of component crops and their prevailing market rates. Various observations recorded periodically during the course of experiment, analyzed statistically by using analysis of variance technique appropriate to split plot design. The treatment differences were tested for significance by 'F' test and the data in which the treatment effects were found significant the appropriate standard error of mean and the critical different were worked out at 5% level of significance.

RESULTS AND DISCUSSION

Weed dynamics

Pigeonpea sole as well as intercropped faced acute problem of weeds pertaining to both monocot and dicot in nature. *Echinochloa* spp., *Cynodon dactylon, Cyperus rotundus* and *Sorghum helpense* among the monocots, whereas, *Convolvulus arvensis, Commelina benghalensis, Launea splenifolia, Amaranthus virdis* and *Digara arvensis* among the dicots were dominant. Relative weed density of monocot weeds found conspicuously higher as compared to dicot weeds in weedy check (control) plots grown with pigeonpea alone or intercropped with greengram or blackgram. Similar weed flora were also found by Punia *et al.* (2013) in *Kharif* legumes under rainfed conditions.Weed density/m^2 of pigeonpea sole found significantly higher as compared to intercropping systems at every stage of observations. This might be due more plant spaces provided by sole pigeonpea caused more emergence of weeds, while under intercropping systems greengram and blackgram suppressed weed growth. Application of all the herbicidal treatments significantly reduced weed density/m^2 compared with weedy check. The weedy check treatment recorded the maximum weed density at every stage of observations in the studies of Nirala and Dewangan (2012) also.

Weed control efficiency

Weed control efficiency (WCE) of both the intercropping systems (pigeonpea + greengram or pigeonpea + blackgram) was found significantly higher to that of sole pigeonpea at every stage of observations whereas among weed control treatments, it recorded significantly higher (90.58 to 91.51%) under combined influenced of herbicides (pendimethalin PE followed by imazethapyr POE and oxyflourfen PE followed by imazethapyr POE) as compared to the single applied herbicides (pendimethalin or oxiflourfen or imazethpyr alone). Out of single herbicides, pendimethalin proved significantly superior to oxyflourfen and imazethapyr, and oxyflourfen was significantly superior to imazethapyr. The field experiments of Gupta *et al.* (2013) and Padmaja *et al.* (2013) also confirmed that all the weed control treatments recorded significantly higher weed control efficiencies over weedy check.

Yield

Yield attributes of pigeonpea namely: pods/plant, pod length, seeds/pod, seed weight/plant and 1000 seed weight were found significantly higher under sole pigeonpea cropping systems over pigeonpea + greengram and pigeonpea + blackgram. This increase in yield attributes may be due to greater growth parameters and more root nodules formation that might have promoted for greater formation of yield attributes parameters. In case of weed management practices, all the yield attributes were found significantly higher under the use of pendimethalin at 1.0 kg/ha PE followed by imazethapyr at 0.1 kg/ha as compared to other weed control measures. The significantly lowest yield attributes were recorded under weedy check plots.

Seed yield was significantly higher (718 kg/ha) under pigeonpea sole, followed by PP + GG 2:2 and lowest by PP + BG 2:2 intercropping systems. This could be ascribed due to greater value of growth

Table 1. Composition of weed flora in weedy check plots at 25 DAS (pooled for 2 years)

Weed species	Population /m^2	Relative density (%)
Monocot		
Echinochloa spp.	52.6	29.7
Cyperus spp.	27.0	15.1
Cynodon dectylon	9.4	5.4
Sorghum halepense	6.6	3.8
Other monocots	5.1	2.9
Total monocot weeds	95.6	54.4
Dicot		
Digera arvensis	39.3	22.4
Commelina benghalensis	17.4	10.0
Convolvulus arvensis	14.2	8.0
Other dicots	8.8	5.1
Total dicot weeds	74.7	45.6
Total weeds	175.3	100

parameters and yield attributes under sole pigeonpea. Such trend might be due to better spatial arrangement of pigeonpea under sole. Kumawat *et al.* (2013) also observed that pigeonpea sole gave higher grain yield over pigeonpea + blackgram intercropping. In case of weed management practices, the seed yield of pigeonpea was obtained significantly greater (868 kg/ha) under the pendimethalin at 1.0 kg/ha PE followed by imazethapyr at 0.1 kg/ha POE. Such enhancement might be due to least competition between crop plants and weeds which resulted in better interception and utilization of radiant energy leading to higher photosynthesis and finally more formation of yield attributes and ultimately greater seed yield of pigeonpea.

Land equivalent ratio (LER)

Yield advantage in term of LER of pigeonpea + blackgram and pigeonpea + greengram systems recorded higher than sole cropping of pigeonpea. The higher LER under these intercropping systems may be due to better planting geometry and spatial arrangements that might have avoided the coincidence of the peak period of growth of comment crops. This might have helped for efficient use of natural resources by the component crops under intercropping system. Weed control treatments also influenced LER significantly.

Crop equivalent yield (CEY)

Significantly enhanced CEY recorded under intercropping systems (1226 to 1363 kg/ha) than sole pigeonpea (718 kg/ha). This might be due to additional yield advantages from intercrops as compared to the sole crop only. The total increased yield fetched increased market price thereby increased the equivalent yield of main crop. The weed control methods also significantly influenced CEY because of increased total yield due to weed control methods. The result of Sharma *et al.* (2010) and Pandey *et al.* (2013) also indicates that higher LER and CEY was recorded by pigeonpea based intercropping systems over pigeonpea sole.

Economics

The economical parameters like net returns (₹/ha) and return per rupee invested (B: C ratio) significantly influenced due to intercropping systems and weed management treatments. Higher net returns obtained under intercropping systems over sole

Table 2. Weed dynamics as influenced by intercropping and weed management (pooled for 2 years)

Treatment	Weed density/m^2			Dry matter of weeds (g/m^2)			Weed control efficiency (%)		
	25	50	75 DAS	25	50	75 DAS	25	50	75 DAS
Intercropping									
Sole pigeonpea	43.5	46.9	43.4	25.3	30.0	28.9	67.4	69.5	69.7
Pigeonpea + blackgram (2:2)	37.8	41.2	38.4	22.9	26.9	26.0	67.5	69.8	69.6
Pigeonpea + greengram (2:2)	40.1	43.4	40.3	23.9	28.2	26.9	67.5	69.9	69.4
LSD (P=0.05)	0.36	0.36	0.31	0.15	0.20	0.19	0.01	0.02	0.02
Weed control									
Weedy check (control)	162.0	175.3	161.2	74.4	94.2	89.6	0.0	0.0	0.00
Pendimethalin (1 kg/ha)	15.8	19.5	18.8	13.1	13.9	13.5	82.2	85.0	84.6
Oxyfluorfen (0.2 kg/ha)	18.2	26.4	23.5	19.9	20.3	19.7	74.2	78.3	78.5
Imazethapyr (0.1 kg/ha)	24.0	17.6	19.4	23.2	25.3	24.8	68.6	73.0	72.1
Pendimethalin + imazethapyr	10.5	11.9	9.4	7.0	7.9	7.5	90.5	91.6	91.5
Oxyflourfen + imazethapyr	12.2	12.3	12.1	7.9	8.7	8.4	89.3	90.7	90.6
LSD (P=0.05)	3.17	3.43	3.14	1.35	1.75	1.66	1.81	1.85	1.85

Table 3. Yield attributes and yield of pigeonpea as influenced by intercropping and weed management (pooled for 2 years)

Treatment	Pods/ plant	Pod length (cm)	Seeds/ pod	Weed weight/ plant(g)	Test weight (g)	Seed yield kg/ha
Intercropping						
Sole pigeonpea	107.2	5.74	4.66	37.8	94.5	718
Pigeonpea + blackgram (2:2)	100.0	5.52	4.40	35.5	92.7	649
Pigeonpea + greengram (2:2)	99.3	5.48	4.38	35.1	92.3	624
LSD (P=0.05)	3.43	0.13	0.13	1.55	0.41	72
Weed control						
Weedy check (control)	66.6	4.31	4.11	22.6	88.4	369
Pendimethalin (1 kg/ha)	106.3	5.75	4.51	37.8	94.2	704
Oxyfluorfen (0.2 kg/ha)	103.9	5.51	4.37	37.3	93.4	618
Imazethapyr (0.1 kg/ha)	103.3	5.42	4.21	36.1	92.4	637
Pendimethalin + imazethapyr	120.5	6.41	5.04	42.6	96.1	868
Oxyflourfen + imazethapyr	112.3	6.07	4.62	40.5	94.6	785
LSD (P=0.05)	3.13	0.09	0.15	1.46	1.23	11

Table 4. Productivity and economics of pigeonpea as influenced by intercropping and weed management (pooled for 2 years)

Treatment	LER	CEY (kg/ha)	Net income ($x10^3$ `/ha)	B:C ratio
Intercropping				
Sole pigeonpea	1.00	718	12.5	1.54
Pigeonpea + blackgram (2:2)	1.60	1226	35.2	2.45
Pigeonpea + greengram (2:2)	1.62	1363	39.9	2.64
LSD (P = 0.05)	0.12	68	-	0.20
Weed control				
Weedy check (control)	1.20	650	10.3	1.47
Pendimethalin (1 kg/ha)	1.43	1159	32.4	2.40
Oxyfluorfen (0.2 kg/ha)	1.36	1015	25.6	2.09
Imazethapyr (0.1 kg/ha)	1.41	1064	27.5	2.16
Pendimethalin + imazethapyr	1.55	1427	42.7	2.69
Oxyflourfen + imazethapyr	1.50	1300	36.6	2.44
LSD (P=0.05)	0.01	155	-	0.31

cropping owing to more increase in gross return as compared to lesser increase in the cost of cultivation. Benefit: cost ratio was also estimated higher under intercropping system as compared to sole pigeonpea. In case of weed management treatments higher benefit cost ratio was obtained under pendimethalin at 1.0 kg/ha PE followed by imazethapyr at 0.1 kg/ha POE than other treatments.

It was concluded that growth and productivity of pigeonpea proved superior with sole cropping over intercropping systems. In spite of it intercropping of pigeonpea with blackgram or greengram was more remunerative because of better system productivity and more economical returns besides better suppression of weeds.

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Herbicide combinations for control of complex weed flora in garden pea

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ABSTRACT

A field experiment was carried out with twelve weed control treatments during the winter season of 2012-13 and 2013-14 on a silty clay loam soil to evolve an effective herbicide combination to control the complex weed flora in garden pea. *Phalaris minor* (28.8%), *Alopecurus myosuroides* (21.3%), *Avena ludoviciana* (15.8%), *Lolium temulentum* (12.1%) and *Vicia sativa* (16.7%) were found major weeds in experimental area. Pendimethalin 1000 g/ha supplemented with one HW at 45 DAS being statically at par to the application of pendimethalin 1000 g/ha (pre) *fb* imazethapyr + imazamox 60 g/ha (post) significantly reduced the density of major weeds. In general, the efficacy of the formulated mixtures whether as double knock or as a sole application was found better than the sole application of herbicides. Pendimethalin 1000 g/ha *fb* one HW and pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha being statistically alike with weed free resulted in significantly higher number of nodules, green pod yield and straw yield.

Key words: Herbicide combination, Pea, weeds

Garden pea (*Pisum sativum* var. *hortense*) is one of the most important cool season frost hardy crops. In India, it shares 4.6% area with production 2.4% of the total vegetable crops. It is grown in 433.6 thousand ha with production of 3868.6 thousand tonnes and productivity 8.9 t/ha (NHB 2013-14). Pea has great potential for grain as well as vegetable purposes. As vegetable, it is grown in almost all agro-climatic zones of Himachal Pradesh. The green pods from hills are available at a time (April to October), when it cannot be successfully grown in the plains due to high temperature during this period. The fact, the produce is sold at a higher premium bringing lucrative returns to the growers (Sangar 2003). In Himachal Pradesh, it is grown in 23.9 thousand ha with production of 271.1 thousand tonnes and productivity 11.3 t/ha. Himachal Pradesh shares 7.0% of national production of pea.

Weeds are the major threat to the productivity of garden pea. They can be controlled by manual, mechanical and chemical methods. Manual method of weed control is labour intensive, cumbersome and time consuming. The mechanical methods cause injury to roots (Casarini *et al.* 1996). Various pre-plant incorporated and pre-emergence herbicides have been tested and recommended under different agro-climatic conditions of Himachal Pradesh (Singh *et al*. 1996). Post-emergence herbicides are also required when pre-emergence fail to give satisfactory weed control. New post herbicides, *viz.* imazethapyr and imazamox either applied post as alone or in combination of both have been introduced. Therefore, the present investigation was carried out for having an effective management strategy for season long control of weeds in pea under mid hill conditions of Himachal Pradesh.

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MATERIALS AND METHODS

Field investigation was carried out during winter season of 2012-13 and 2013-14 at Palampur (1290.8 m altitude, 32° 06' N latitude and 76° 34' 10'' E longitude). The soil of the experimental site was silty clay loam in texture, acidic in reaction, medium in available N (322.9 kg/ha) and K (276.4 kg/ha) and high in available P (25.8 kg/ha). Garden pea '*Palam Priya*' was treated with bavistin 2.5 g/kg and *Rhizobium* culture 200 g/10 kg seed. The pea seed was sown manually keeping the row to row distance of 45 cm at 60 kg/ha seed rate 17 October 2012 and 25 October 2013. N, P_2O_5 and K_2O (45, 60 and 60 kg/ha, respectively) were applied as basal through urea, SSP, and MOP. The crop was given five irrigations in first year and three irrigations in second year including the pre-sowing irrigation. The experiment was laid out in randomized block design (RBD) with three replications (Table 1). Manually operated knapsack sprayer fitted with a flat fan nozzle (WFN 40) was used for spraying the herbicides. The herbicides were sprayed using a spray volume of 700 litres of water/ha.

Weed count and dry weight were recorded at 60, 90, 120 DAS and at harvest stage. The weed count was recorded species wise using 0.5 × 0.5 m quadrat from four randomly fixed places in each plot and the weeds falling within the frames of the quadrat were counted and the mean values were expressed in number/m^2. The crop was harvested on April 20 and 24 during the first and second year, respectively. Green pod yields were harvested from net plot area of 13.5 m^2 in four pickings.

RESULTS AND DISCUSSION

Effect on weeds

On an average of two years, the major weed flora of the experimental field was composed of *Phalaris minor* (28.8%), *Alopecurus myosuroides* (21.3%), *Avena ludoviciana* (15.8%), *Lolium temulentum* (12.1%) and *Vicia sativa* (16.7%). Other weeds like, *Stellaria media, Poa annua, Anagallis arvensis* and *Coronopus didymus* showed their infestation in very small number during both the year.

All treatments resulted in significantly lower density of weeds over the weedy check at 90 DAS (Table 1). Weed free treatment had lowest weed population during both the years. Among the herbicidal application, pendimethalin 1000 g/ha (pre-) supplemented with one HW at 45 DAS being statically at par- with application of pendimethalin 1000 g/ha as pre *fb* imazethapyr + imazamox at 60 g/ha as post-emergence at 45 DAS resulted in significantly superior control of *P. minor* over rest of the herbicidal treatments. The activity of pendimethalin *fb* HW (Kumar and Singh 1994; Vaishya *et al.* 1996; Prakash *et al.* 2000; Rana 2002) and imazethapyr (Zabara and Yankovskaya 2007) against *P. minor* has been established. Pendimethalin 1000 g/ha applied as pre *fb* one HW at 45 DAS and pendimethalin 1000 as pre-application *fb* imazethapyr + imazamox 60 g/ha applied as post-emergence being statistically similar, were superior to other herbicidal applications in reducing the population of *Alopecurus myosuroides.*

Table 1. Effect of treatments on weed count (no./m^2) at 90 DAS in garden pea

Treatment	*Phalaris minor*		*Alopecurus myosuroides*		*Avena ludoviciana*		*Lolium temulentum*		*Vicia sativa*	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Pendimethalin(1500 g/ha) PE	9.6 (90.7)	9.8 (96.0)	9.0 (80.0)	8.7 (74.7)	8.4 (69.3)	8.6 (73.6)	8.1 (64.0)	7.7 (58.7)	5.7 (32.0)	5.2 (26.7)
Pendimethalin PE *fb* imazethapyr POE (1000 *fb* 100 g/ha)	8.7 (74.7)	8.4 (69.3)	8.1 (64.0)	7.7 (58.7)	8.4 (69.3)	8.4 (69.3)	7.7 (58.7)	7.4 (53.3)	2.0 (5.3)	1.0 (0.0)
Imazethapyr PE *fb* imazethapyr POE (100 *fb* 100 g/ha)	9.8 (96.0)	10.1 (101.3)	8.1 (64.0)	8.4 (69.3)	8.7 (74.7)	8.7 (74.7)	9.0 (80.0)	8.4 (69.3)	6.6 (42.7)	5.1 (26.7)
Imazethapyr + pendimethalin PE (1200 g/ha)	7.7 (58.7)	7.4 (53.3)	7.4 (53.3)	7.0 (48.0)	7.4 (53.3)	7.4 (53.3)	6.2 (37.3)	6.2 (37.3)	4.7 (21.3)	4.7 (21.3)
Imazethapyr + pendimethalin PE (1500 g/ha)	6.6 (42.7)	6.6 (42.7)	7.0 (48.0)	6.6 (42.7)	5.2 (26.7)	4.7 (21.3)	7.0 (48.0)	6.6 (42.7)	5.7 (32.0)	6.2 (37.3)
Imazethapyr + pendimethalin PE *fb* imazethapyr POE 45 DAS(1000 *fb* 100 g/ha)	5.2 (26.7)	5.2 (26.7)	5.7 (32.0)	5.7 (32.0)	6.2 (37.3)	6.2 (37.3)	5.7 (32.0)	5.2 (26.7)	4.7 (21.3)	4.7 (21.3)
Imazethapyr + imazamox POE 45 DAS (60 g/ha)	5.7 (32.0)	5.7 (32.0)	6.2 (37.3)	6.2 (37.3)	6.2 (37.3)	6.2 (37.3)	5.7 (32.0)	5.7 (32.0)	4.7 (21.3)	4.7 (21.3)
Imazethapyr + imazamox POE 45 DAS (90 g/ha)	6.6 (42.7)	6.6 (42.7)	6.6 (42.7)	6.6 (42.7)	6.6 (42.7)	6.6 (42.7)	6.2 (37.3)	6.2 (37.3)	5.2 (26.7)	5.2 (26.7)
Pendimethalin *fb* imazethapyr + imazamox POE 45 DAS (1000 *fb* 60 g/ha)	4.1 (16.0)	4.1 (16.0)	4.7 (21.3)	4.7 (21.3)	5.7 (32.0)	5.7 (32.0)	4.7 (21.3)	4.7 (21.3)	3.1 (10.7)	3.1 (10.7)
Pendimethalin PE *fb* 1 HW 45 DAS (1000 g/ha)	3.1 (10.7)	3.1 (10.7)	4.7 (21.3)	4.7 (21.3)	4.1 (16.0)	4.1 (16.0)	4.1 (16.0)	4.1 (16.0)	2.0 (5.3)	2.0 (5.3)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Weedy check	13.1 (170.7)	12.9 (165.3)	11.6 (133.3)	11.1 (122.7)	10.1 (101.3)	9.6 (90.7)	9.0 (80.0)	8.4 (69.3)	9.6 (90.7)	9.8 (96.0)
LSD (P=0.05)	1.2	1.2	0.9	1.0	1.0	1.0	0.7	1.1	1.7	1.5

*Value in parentheses are the means of original values. Data transformed to square root transformation ($\sqrt{x+1}$); PE = Pre-emergence, POE= Post-emergence

All weed control treatments except imazethapyr 100 g/ha (pre) *fb* imazethapyr 100 g/ha (post 45 DAS) had significantly reduced the population of *A. ludoviciana* over the weedy check (Table 2). In general, efficacy of the formulated mixtures was better than the sole application of herbicide whether as double knock or as a sole treatment. Nelson and Giles (1989) and Haar *et al.* (2010) have reported poor control of *A. ludoviciana* with application of pendimethalin. Population of *L. temulentum* was significantly lower under weed free situation followed by pendimethalin 1000 g/ha *fb* one HW (45 DAS), pendimethalin 1000 g/ha applied as pre *fb* imazethapyr + imazamox 60 g/ha applied as post-emergence (45 DAS) as well as other herbicidal combinations over the weedy check. These results were in accordance with the findings of Lemerle *et al.* (2006) who have reported the lower count of *L. temulentum* in weed free treatment. Pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS), pendimethalin 1000 g/ha *fb* one HW (45 DAS) and pendimethalin 1000 g/ha (pre) *fb* imazethapyr + imazamox 60 g/ha (45 DAS) were as effective as weed free situation in reducing the population of *V. sativa*. Similar findings were also reported by Sandhu *et al.* (1978).

All weed control treatments significantly decreased total weed dry matter accumulation over weedy check (Table 2). Pendimethalin 1000 g/ha *fb* one HW (45 DAS) being at par with application of pendimethalin 1000 g/ha (pre) *fb* combination of imazethapyr + imazamox 60 g/ha applied as post emergence (45 DAS) resulted in significantly lower total dry matter accumulation of weeds over other herbicidal treatments. The superiority of pendimethalin *fb* HW in controlling weeds has been reported by Kumar and Singh (1994). Imazethapyr + imazamox 60 g/ha (45 DAS), imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS), imazethapyr + pendimethalin 1200 g/ha**,** imazethapyr + imazamox 90 g/ha (45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS) behaving statistically alike were the next better treatments.

Effect on crop

Herbicides at the dose tried were selective as is evident from the emergence count which was not significantly affected (Table 2). The plant height increased with sigmoidal pattern with a grand growth stage between 60 and 120 DAS (Fig. 1). Weed control methods significantly affected plant height. Application of pendimethalin 1000 g/ha as pre *fb* one HW (45 DAS), pendimethalin 1000 g/ha (pre) *fb* imazethapyr + imazamox 60 g/ha (45 DAS), imazethapyr + imazamox 90 g/ha (45 DAS),

Table 2. Effect of treatments on total weed dry weight (g/m^2), emergence count, plant height (120 DAS) and count (no./ plant) and weight (mg/plant) of root nodules of pea

Treatment	Total weed dry weight (120 DAS)	Emergence count (no/m^2)	Plant height (cm)	Root nodules: Count		Root nodules: Weight	
				Pre-flowering	Post-flowering	Pre-flowering	Post-flowering
Pendimethalin (1500 g/ha) PE	12.1 (145.6)	17.0	60.73	44.7	27.0	40.4	28.2
Pendimethalin PE *fb* Imazethapyr POE (1000 *fb* 100 g/ha)	10.7 (114.1)	17.0	65.49	45.3	31.3	40.2	27.1
Imazethapyr PE *fb* imazethapyr POE (100 *fb* 100 g/ha)	12.3 (149.3)	18.5	64.67	44.3	28.0	40.0	26.8
Imazethapyr + pendimethalin PE (1200 g/ha)	10.2 (104.0)	18.5	59.00	45.0	28.3	41.3	26.6
Imazethapyr + pendimethalin PE (1500 g/ha)	11.2 (124.8)	17.0	65.87	45.3	29.7	40.0	28.0
Imazethapyr + pendimethalin PE *fb* imazethapyr POE 45 DAS(1000 *fb* 100 g/ha)	10.2 (102.4)	18.5	66.17	46.0	32.3	43.1	29.9
Imazethapyr + imazamox POE 45 DAS (60 g/ha)	9.8 (94.4)	18.5	65.74	45.7	31.7	42.0	28.4
Imazethapyr + imazamox POE 45 DAS (90 g/ha)	10.5 (109.3)	18.5	67.23	45.3	31.3	41.3	28.0
Pendimethalin *fb* imazethapyr + imazamox POE 45 DAS (1000 *fb* 60 g/ha)	8.8 (76.3)	17.0	67.78	46.3	33.3	44.1	32.3
Pendimethalin PE *fb* 1 HW 45 DAS (1000 g/ha)	8.1 (65.1)	18.5	70.39	46.7	34.7	44.7	32.6
Weed free	1.0 (0.0)	18.5	70.93	47.3	35.3	45.4	33.0
Weedy check	17.1 (292.8)	17.0	60.00	33.3	24.3	33.3	19.2
LSD (P=0.05)	0.9	NS	3.98	2.7	1.7	0.9	0.7

Table 3. Effect of treatments on yield attributes and yield of pea

Treatment	Pod/ plant	Pod length (cm)	Seed/ pod	Shelling (%)	Pod yield (t/ha)	
					2012-13	2013-14
Pendimethalin (1500 g/ha) PE	20.7	6.3	5.0	40.3	6.57	6.57
Pendimethalin PE *fb* Imazethapyr POE (1000 *fb* 100 g/ha)	21.0	6.7	5.3	42.0	6.29	6.49
Imazethapyr PE *fb* imazethapyr POE (100 *fb* 100 g/ha)	20.7	6.7	5.3	41.7	6.21	6.37
Imazethapyr + pendimethalin PE (1200 g/ha)	21.7	6.7	5.0	40.0	5.97	6.25
Imazethapyr + pendimethalin PE (1500 g/ha)	21.3	6.3	5.7	42.7	6.13	6.41
Imazethapyr + pendimethalin PE *fb* imazethapyr POE 45 DAS(1000 *fb* 100 g/ha)	21.7	6.7	6.0	43.0	6.09	6.81
Imazethapyr + imazamox POE 45 DAS (60 g/ha)	22.0	7.3	5.7	45.7	6.01	6.69
Imazethapyr + imazamox POE 45 DAS (90 g/ha)	22.3	7.0	6.3	42.0	6.53	6.81
Pendimethalin *fb* imazethapyr + imazamox POE 45 DAS (1000 *fb* 60 g/ha)	21.3	7.0	6.3	45.3	7.01	7.25
Pendimethalin PE *fb* 1 HW 45 DAS (1000 g/ha)	22.3	7.7	6.7	46.7	7.17	7.33
Weed free	22.7	7.7	6.7	47.3	7.21	7.37
Weedy check	20.7	6.0	4.7	39.7	4.34	4.74
LSD (P=0.05)	1.16	0.8	0.9	2.7	0.56	0.90

imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS), pendimethalin 1500 g/ha (pre), imazethapyr + imazamox 60 g/ha (45 DAS), pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ ha (45 DAS) and weed free had an edge over otherherbicidal treatments in influencing plant height of pea at 120 DAS. This may be ascribed to least competition from weeds due to their effective suppression.

Close examinations of the data inferred that pendimethalin 1000 g/ha *fb* one HW (45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) being statistically at par with weed free treatment resulted in significantly higher number of nodules over rest of the treatments at pre-flowering stage. However, application of pendimethalin 1000 g/ha *fb* one HW (45 DAS) being at par with weed free, gave significantly higher number of nodules over rest of the treatments at post-flowering stage. Weed free resulted in highest nodules dry weight both at pre and post-flowering stage. However, it was statistically at par with application of pendimethalin 1000 g/ha *fb* one HW (45 DAS) at pre-flowering stage (Table 2).

All weed control treatments were significantly superior to weedy check in influencing yield attributes and yield of peas (Table 3). Among the treatmens, weed free, pendimethalin 1000 g/ha *fb* one HW (45 DAS), imazethapyr + imazamox 90 g/ha (45 DAS) and imazethapyr + imazamox 60 g/ha (45 DAS) being statistically at par with application of imazethapyr + pendimethalin 1200 g/ha applied as pre-emergence and imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha as post-emergence (45 DAS) resulted in significantly higher pods/plant. Weed free and pendimethalin 1000 g/ha supplemented with one HW (45 DAS) had produced longer pods. However, these were statically similar with application of imazethapyr + imazamox 60 g/ha (45 DAS), imazethapyr + imazamox 90 g/ha (45 DAS) and pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS). Significantly higher seeds/pod were obtained with weed free and application of pendimethalin 1000 g/ha *fb* one HW (45 DAS). Weed free, pendimethalin 1000 g/ha *fb* one HW (45 DAS), pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) and imazethapyr + imazamox 60 g/ha (45 DAS) resulted in significantly higher shelling percentage over weedy check.

Significantly higher green pod yield was obtained in weed free situation followed by application of pendimethalin 1000 g/ha *fb* one HW **(**45 DAS) and sequential application of pendimethalin 1000 g/ha *fb* imazethapyr + imazamox 60 g/ha (45 DAS) treatments. Imazethapyr + imazamox 90 g/ha (45 DAS) and imazethapyr + pendimethalin 1000 g/ha *fb* imazethapyr 100 g/ha (45 DAS) being statically similar with each other, were superior to other herbicidal treatments in influencing green pod yield.

The present investigation conclusively inferred that application of pendimethalin 1000 g/ha (pre) *fb* combination of imazethapyr + imazamox 60 g/ha applied as post-emergence (45 DAS) can be an effective alternative to pendimethalin 1000 g/ha *fb* one HW (45 DAS) as it provided good control of mixed weed flora and increased the pod and straw yield as good as weed free situation.

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Bioprospecting medicinal potential of three widespread weeds from Pakistan

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ABSTRACT

Present study was carried out to explore the antibacterial potential of three weeds *Mazus japonicus, Fumaria indica* and *Vicia sativa* grown widely in Pakistan. Different extracts (aqueous, methanolic and petroleum ether) of the respective weeds were prepared and tested against nine bacterial strains using agar well diffusion assay. Bacterial strains included both gram positive (*Staphylococcus aureus, Bacillus* sp, *Bacillus megaterium, Enterococcus faecium, Enterrococcus faecalis* and *Enteroccocus* sp) and gram negative (*Pseudomonas putida, Escherichia coli* and *Escherichia coli* top10) bacteria. Ten different concentrations of each extracts were used. *Enterococcus faecalis* JH22 and *Bacillus megaterium* MB141 were the most resistant bacteria while *Escherichia coli* top10 was found highly susceptible and inhibited by all three extracts of *M. japonicas* and *F. indica*. *Vicia sativa* was effective only against *Staphylococcus aureus* and *Pseudomonas putida* at limited crude extract concentration while all other strains showed resistance against different extracts of the respective plant. Amongst the plant extracts screened for antibacterial activity, methanolic extracts showed best antibacterial activity whereas aqueous and petroleum ether were found least active. This study significantly supports the usage of these widespread weeds as traditional medicines for various bacterial infections.

Keywords: Assay, Antibacterial, Medicinal use, Weed utilization

There has been a continual battle between the man and microorganisms specially bacteria. These bacterial epidemics have been the major cause of morbidity and mortality of human beings. Since then man is searching for the agents that has the potential to fight against these bacterial infections. Antibiotics were the main agents utilized against pathogenic microorganisms. Different antibiotics have been discovered and invented by human beings for long time. The evidence of tetracycline has been found in human skeletal remains from ancient Sudanese Nubia dating back to 350–550 CE (Nelson *et al.* 2010). Another source of antimicrobials in the preantibiotic era was through the medicinal plants compounds. The best-known example is the discovery of a potent anti-malarial drug, qinghaosu (artemisinin), which was extracted in the 1970s from *Artemisia* plants, used by Chinese herbalists for thousands of years as a remedy for many illnesses (Cui and Su 2009).

Pakistan is one of the countries blessed with extensive floral biodiversity. About 6000 flowering plants have been reported out of which about 400 to 600 are considered to be medicinally important and 1000 species have been recognized to possess phytochemical properties (Shinwari and Gilani 2003, Jabeen *et al.* 2009). Not only the medicinal plants but weeds are also efficiently utilized in developing country like Pakistan as a source of herbal medicines.

Medicinal plants with antibacterial activities have been well recognized and used as traditional medicines since ancient times for the treatment of various diseases. Weeds have also been proved to contain various bioactive constituents that helped in curing various ailments and are thereby used in conventional medications in many parts of the world (Stough *et al.* 2001, Demmaa *et al.* 2007, Immanuel and Elizabeth 2009). Antibacterial, antifungal, Anticancerous, antifeedant, antiviral and antioxidant potential of weeds have been tested by many researchers and found significant results (Adebayo *et al.* 2010, Sanguri *et al.* 2012, Narintorn *et al.* 2014, Huang *et al.* 2014). In our study, three weeds *Mazus japonicus, Fumaria indica and Vicia sativa* grown wildly and commonly in Pakistan were selected and evaluated for antibacterial potential against nine bacterial strains including gram positive and gram negative bacteria.

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The use of plant extracts against these bacterial infections is as old as existence of bacteria. Despite of remarkable development in modern medicine system, potential of plant derived bioactive compounds is considered to be the novel alternative for the physicians against these antibiotic resistant bacteria. Present study, therefore, is aimed to explore the possible antibacterial potential of three wild weeds *Mazus Japonicus* (thunb) kuntze, *Fumaria indica* (Hausskn.) and *Vicia sativa* L. grown widely in Pakistan. Their family, distribution and traditional uses are listed (Table 1).

MATERIALS AND METHODS

Mazus japonicus (2849-JP), *Fumaria indica* (78-NJ) and *Vicia sativa* (6584-RQ) were collected during the month of March and April from different areas of Rawalpindi, Pakistan. The plants were identified by National Herbarium, Department of Plant Sciences, Quaid-e-Azam University, Islamabad, Pakistan. The collected plants were properly washed with tap water and dried under shade for 15-20 days. The dried plant sample was ground into fine powder with electrical grinder and stored in airtight container for further use.

Plant extracts were prepared by maceration technique according to the standard method of Hossain *et al.* 2013 with some modifications. Three different solvents of increasing polarity *i.e.* petroleum ether, methanol and water were used for the preparation of non-polar, semi-polar and polar extracts respectively.

For the preparation of hot aqueous extracts of plants, 50 g of each dried plant powder was dissolved in 800 ml of distilled water and final volume was then made upto 1000 ml. This suspension was soaked overnight. It was then simmered for 2 hours with the help of magnetic stirrer on hot plate at temperature of 45-48°C. The extract was then filtered off through four layered muslin cloth followed by filtration through Whatman filter paper no.1 to remove impurities. Filtrate was then placed on water bath at 50-60 °C until dried mass was obtained.

Fifty gram of each plant powder was soaked in 800 ml of methanol and final volume was then made upto 1000 ml. This suspension was left for 7 to 10 days at 24 °C in growth chamber with successive gentle shaking. The extracts were then filtered off through four layered muslin cloth followed by Whatman filter paper no.1. Then the filtrate was evaporated in water bath at 50ºC until dry mass was obtained. Dry mass was then stored in refrigerator for further use. Ether extract was also prepared following the similar methanolic extraction procedure with the solvent using ether.

Clinically isolated nine bacterial strains were used. Six of them were gram positive *i.e. Staphylococcus aureus (*ATCC6538*), Bacillus* sp. (MB083) (KF055341), *Enterococcus faecalis* (SF17), *Enterococcus faecium (*OG1RF*), Bacillus megaterium* (MB141) *(*KF055342*)*, *Enterococcus faecalis* (JH22) and three of them were gram negative *i.e. Escherichia coli (*Top10*)*, *Escherichia coli* (ATCC 15224), *Pseudomonas putida*. Bacterial strains were provided by Microbiology and Biotechnology Research Lab of Fatima Jinnah Women University Rawalpindi. Bacterial strains were verified and identified by standard gram staining procedure.

To determination turbidity standard was prepared by mixing 0.5 ml of $BaCl_2$ (0.048 M) in 99.5 mL 0.3 6N $H_2SO_4.BaSO_4$. The standard was taken in screw cap test tube to compare the turbidity. The bacterial culture of selected strains were grown overnight, and subsequently mixed with physiological saline. Turbidity was corrected by adding sterile saline until McFarland 0.5 $BaSO_4$ turbidity standard 10^8 Colony Forming Unit (CFU) per ml was achieved. These inocula were used for seeding of the nutrient agar.

Table 1. Summary of weeds, their occurrence and traditional uses

Plant	Family	Local name	Ocurrence in Pakistan	Traditonal use
Mazus japonicas (Thunb.) Kuntze	Scrophulariaceae	-	Found in moist lawns, bottom lands	Used for ornamental purposes in gardens for ground cover, plant is also effective against typhoid fever (Riaz *et al.* 2012).
Fumaria indica (Hausskn.)	Fumariaceae	Shahtara / Papra	Plain and lower hills of Pakistan	Traditionally used for the cure of dermatological diseases, topical ailments, cardiovascular problems, fever and headache (Murad *et al.* 2011).
Vicia sativa L.	Leguminaceae	Rewari / Matri	Rain-fed and irrigated areas	Mostly used as livestock feed and forage and its mixture with other cereals is used for haymaking (Berger *et al.* 2003).

Agar well diffusion method was also employed for the evaluation of antibacterial activity of different plant extracts as employed by Munazir *et al.* (2012). This method depends on the diffusion of extracts from the well through the solidified agar layer in such a way that growth of microorganism is prevented entirely in circular area or zone around the cavity containing the extracts. Ten µl of bacterial suspension were poured with the help of micropipette and spread on the entire plate with the help of glass spreader. The wells of 7 mm in diameter were cut out in the seeded agar layer with the help of the autoclaved cork borer. Thirty µl of extract of each specific concentration was poured into the well with the help of micropipette. Cefotaxime (10 mg/ml) was selected as a positive control and DMSO was used as a negative control. The plates were incubated at 37°C for 24 hours. The antibacterial activity was evaluated by measuring the zone of inhibition around the well. All the reactions were carried out in triplicates and the average results obtained were recorded.

RESULTS AND DISCUSSION

In the present study, *S. aureus* and *E.coli* top 10 showed sensitivity to all the three extracts of *Mazus japonicus.* Maximum inhibitory response was found with ether extract giving inhibition zone of 11.75 mm against *S. aureus* and in case of *E. coli* top 10, aqueous extract revealed distinct zones of 15.5 mm as maximum zone of inhibition (Fig. 1). Moderate antibacterial response was observed by the aqueous and methanolic extracts of *M. japonicus* against *Pseudomonas* and *Bacillus* species,

Table 2. Antibacterial activity of *Mazus japonicus* extracts using agar well diffusion assay

Extracts (mg/ml)	Mean diameter (± SE) of inhibitory zones (mm)								
	S. aureus	*P.putida*	*Bacillus sp.* MB083	*B.megaterium* MB141	*E. coli*	*E. coli* top10	*Enterococcus sp* SF17	*E. faecium* OG1RF	*E.faecalis* JH22
Water									
1	R	R	R	R	R	11.5±0.71	7.75±0.35	R	R
5	R	R	R	R	R	11.5±0.71	7.875±0.35	R	R
10	R	R	R	R	R	11±0.71	8±0.71	R	R
15	R	8.25±0.35	R	R	R	10.75±0.353	9.25±0.35	R	R
20	R	8.5±0.71	R	R	R	12.12±0.53	8.37±0.53	R	R
30	8±0.71	8.5±1.41	R	R	R	13±1.41	8.5±0.35	R	R
40	9±0.35	9.25±1.06	R	R	R	13.75±1.06	8.5±0.35	R	R
60	10±0.1	11±1.41	R	R	R	14±0.71	7.5±0.71	R	R
80	9.75±0.36	11.25±1.06	9.75±1.76	R	R	14±0.70	9.0±0.71	R	R
100	10±0.71	12.25±1.06	10.5±2.12	R	R	**15.5±1.41**	11.25±1.06	R	R
Methanol									
1	R	R	R	R	R	R	R	R	R
5	R	R	R	R	R	8.62±0.88	R	R	R
10	R	R	R	R	R	10.8±.176*	R	R	R
15	7.5±0.1	R	R	R	R	12.25±2.47	R	R	R
20	8±0.1	R	R	R	R	12.5±2.12	R	R	R
30	9.5±0.2	R	8.75±1.06	7.75±0.35	13.1±0.1	11.2±1.41	R	6.87±0.18	R
40	9.5±0.3	R	9.25±1.1	9.0±1.41	14±0.2	12.75±0.35	R	8.3±0.35	R
60	10.1±0.02	R	9.37±0.88	9.75±1.77	14.7±0.35	14.2±0.71	R	8.55±0.71	R
80	10.01±0.2	R	10.5±0.71	11.1±2.83	15.75±0.35	14.25±0.35	R	8.87±0.18	R
100	11.1±0.03	R	11.5±0.35	12±1.41	17.5±0.71	15.25±1.06	R	9.13±0.53	R
Petroleum ether									
1	7.2±0.53	R	R	R	R	10±0.1	R	R	R
5	7± 0.53	R	R	R	R	13.25±0.35	R	R	R
10	8.5±0.2	R	R	R	R	13.6±0.176	R	R	R
15	8.38±0.53	R	R	R	R	10±0.2	R	R	R
20	9.2±0.2	R	R	R	R	10±0.1	R	R	R
30	8.63±1.59	R	R	R	R	13±0.707	R	R	R
40	9±1.41	R	7.5±0.35	R	R	11.75±1.06	R	R	R
60	9.75±1.06	R	7.5±0.35	R	R	13.25±0.35	R	R	R
80	9±1.42	R	9.75±0.35	R	R	12.5±0.707	R	R	R
100	11.75±1.18	R	12.2±0.70	R	R	11.5±0.707	R	R	R
Cefotaxime									
100 µg	37.8±0.176a	33±0.71	24.5±0.71	33±0.71	23.5±0.75	31.5±0.70	36.5±0.2	29±0.70	21.5±1.4

R Resistant/ No inhibition zone Data represents the average of three replicates ± S.D. The bold values represent the optimum zone of inhibition formed by the respective plant extract among the tested bacterial strains

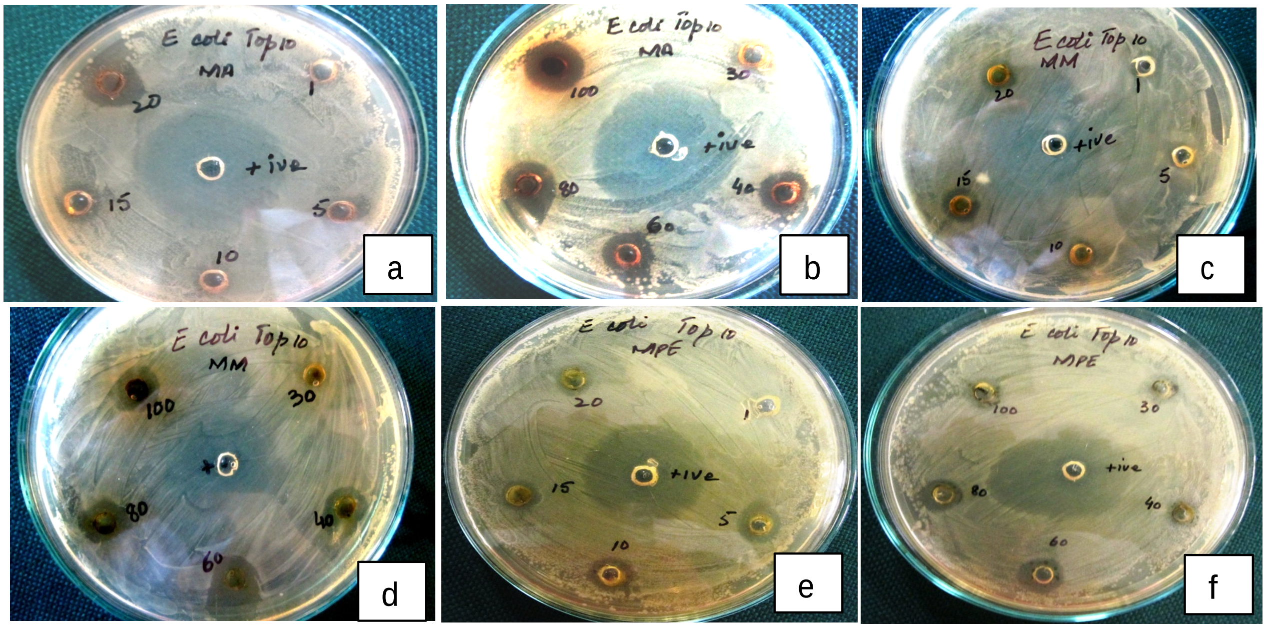

Fig. 1. Antibacterial activity of aqueous (a,b), methanolic (c,d) and petroleum ether (e,f) extracts of *Mazus japonicus* against *E. coli* top10.

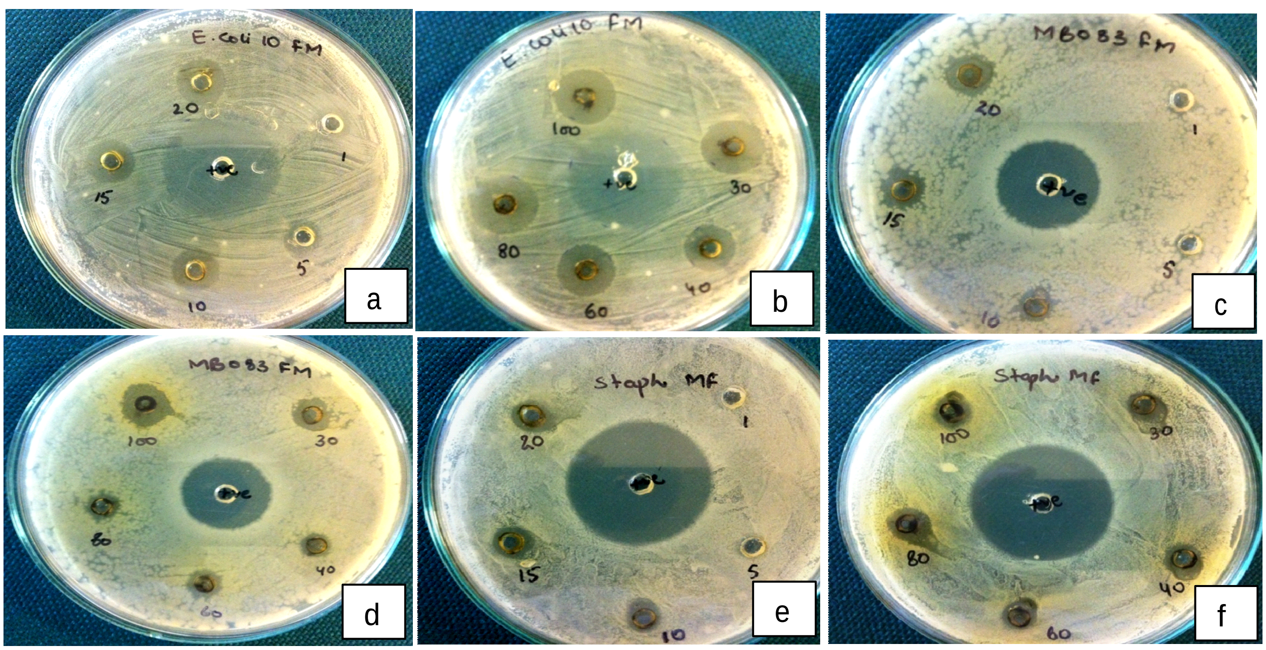

Fig. 2. Antibacterial activity of *Fumaria indica* (methanolic extract) found against *E. coli* top10 (a,b), *Bacillus sp.* MB083 (c,d), *S. aureus* (e,f)

respectively. Among three *Enterococci* species, only *E. faecalis* (JH22) was found resistant to all three extracts of *M. japonicus*. *Enterococcus* sp SF17 and *E. faecium* (OG1RF) showed little sensitivity against aqueous and methanolic extracts, respectively (Table 2).

Tiwari *et al.* (2011), reported that plant extracts from organic solvent found to be more consistent for antimicrobial activity as compared to aqueous extract. Methanol easily penetrates into plant material to extract bioactive substances as compared to aqueous and it is considered more efficient in cell wall and seed degradation. Moreover, alcoholic extracts contain higher amount of polyphenols as antimicrobial components. These compounds make complex or intercalate into cell wall resulting in the inhibition of bacterial growth. Polyphenols are well documented to have bactericide activities against a number of pathogenic bacteria resulting in inhibition of hydrolytic enzymes (proteases and carbohydrolases) or other interactions to inactivate

Table 3. Antibacterial activity of *Fumaria indica* extracts using agar well diffusion assay

Extracts (mg/ml)	Mean diameter (± SE) of inhibitory zones (mm)								
	S. aureus	*P.putida*	*Bacillus* sp. MB083	*B.megaterium* MB141	*E. coli*	*E. coli* top10	*Enterococcus* sp. SF17	*E. faecium* OG1RF	*E.faecalis* JH22
Water									
1	R	R	R	R	R	R	R	R	R
5	R	R	R	R	R	R	R	R	R
10	R	R	R	R	R	R	R	R	R
15	R	R	R	R	R	7.5±0	R	R	R
20	R	R	R	R	R	8.5±0.70	R	R	R
30	R	R	R	R	R	8.5±1.55	R	R	R
40	R	R	R	R	R	11.25±1.06	R	R	R
60	R	R	R	R	R	12.75±2.47	R	R	R
80	R	R	R	R	R	13.16±2.08	R	R	R
100	R	R	R	R	R	14.20±2.43	R	R	R
Methanol									
1	R	R	R	R	R	7.62±0.17	R	R	R
5	R	R	7.25±0.35	R	R	11.12±0.17	R	12*±0.17	R
10	10.08±0.11	R	10.08±0.11	R	R	13.25±0.35	R	10±0.17	R
15	10.37±0.17	R	10.75±0.35	R	R	13.87±0.17	R	8.5±0.35	R
20	10.31±0.26	R	11.25±0.35	R	R	14.37±0.17	R	8.2±1.06	R
30	10.62±0.17	11.3±0.17	9.83±2.58	R	8.5±0.70	18.25±0.35	8.4±0.58	7.1±0.35	R
40	11.12±0.17	11.7±0.06	9.75±1.76	R	9.25±1.06	16.75±2.4	9.125±0.17	9.2±0.17	R
60	10.75±1.06	12.1±0.11	10±0.70	R	10±0.70	17.25±0.35	9.87±0.17	10.1±0.17	R
80	11.62±0.17	12.6±0.17	9.37±0.17	R	10.75±0.35	19.12±0.53	10.12±0.17	11.0±0.17	R
100	11.25±1.76	12.4±0.17	10.75±0.35	R	11.12±0.53	**19.25±1.06**	9.75±1.06	12.0±0.17	R
Petroleum ether									
1	R	R	R	R	R	9.75±1.76	R	R	R
5	R	R	R	R	9.25±0.35	11.75±1.76	R	R	R
10	R	R	R	R	10.75±0.35	12.25±0.35	R	R	R
15	R	R	R	R	11.25±0.35	13±0.70	R	R	R
20	R	R	R	R	12.25±0.35	14.75±0.35	R	R	R
30	R	R	R	R	12.75±0.35	12.5±1.4	R	R	R
40	R	R	R	R	13.75±0.35	14.2±0.2	R	R	R
60	R	R	R	R	14.25±0.35	15.1±0.82	R	R	R
80	R	R	R	R	14.16±1.18	15.92±0.58	R	R	R
100	R	R	R	R	14.62±0.53	16.25±0.35	R	R	R
Cefotaxime									
100µg	37.8±0.176a	33±0.71	24.5±0.71	33±0.71	23.5±0.75	31.5±0.70	36.5±0.2	29±0.70	21.5±1.4

R Resistant/ No inhibition zone Data represents the average of three replicates± S.D., The bold values represent the optimum zone of inhibition formed by the respective plant extract among the tested bacterial strains

microbial adhesins, cell envelope transport proteins, non-specific interactions with carbohydrates (Cowan 1999). There are number of studies which reported methanolic plant extracts as best solvent compared to aqueous and petroleum ether extract for the extraction of antimicrobial substances (El-kamali and El-Karim 2009, Sen and Batra 2012, Ayo *et al.* 2013).

Aqueous extract of whole plant of *Fumaria indica* did not show any promising antibacterial activity against the tested bacterial strains except against *E. coli* top10 (Table 3). Natarajan *et al.* (2005) studied antibacterial activity of *Euphorbia f.* against pathogenic gram positive and gram negative bacteria and its aqueous extract was found active against *E. coli* only. Methanolic plant extract of *Fumaria indica* showed higher antibacterial activity compared to aqueous and petroleum ether plant extracts. Seven out of nine bacterial strains were sensitive towards whole plant methanolic extract of *Fumaria indica*. *E. coli* top10 was highly susceptible and inhibited by all extracts. *Bacillus megaterium* (MB141) and *E. faecalis* (JH22) were most resistant to these extracts. Out of three strains of *E. species,* two strains (SF17 and OG1RF) were sensitive against whole plant methanolic extract of *F. indica* while *E. faecalis* JH22 was resistant. *Bacillus* sp MB083 showed sensitivity to all concentrations (except 1mg/ml) and zone of inhibition was 11.25 mm in size (Fig. 2). Petroleum ether extract of *F. indica* was inactive against all the tested bacterial strains except *E. coli* and *E. coli* top10. Large and clear zones were formed in well diffusion method with maximum inhibition zone of 14.62 mm.

Only methanolic extract of *Vicia sativa* showed zones of inhibition against *Staphylococcus aureus* and *Pseudomonas putida* at selected concentrations. All

Table 4. Antibacterial activity of *Vicia sativa* extracts using agar well diffusion assay

Extracts (mg/ml)	Mean diameter (±SE) of inhibitory zones (mm)								
	S. aureus	*P.putida*	*Bacillus sp.* MB083	*B.megaterium* MB141	*E. coli*	*E. coli* top10	*Enterococcus* sp. SF17	*E. faecium* OG1RF	*E.faecalis* JH22
Water									
1	R	R	R	R	R	R	R	R	R
5	R	R	R	R	R	R	R	R	R
10	R	R	R	R	R	R	R	R	R
15	R	R	R	R	R	R	R	R	R
20	R	R	R	R	R	R	R	R	R
30	R	R	R	R	R	R	R	R	R
40	R	R	R	R	R	R	R	R	R
60	R	R	R	R	R	R	R	R	R
80	R	R	R	R	R	R	R	R	R
100	R	R	R	R	R	R	R	R	R
Methanol									
1	R	R	R	R	R	R	R	R	R
5	R	R	R	R	R	R	R	R	R
10	9.7±0.14	8.5±0.07	R	R	R	R	R	R	R
15	**10.2±0.14**	9.7±0.14	R	R	R	R	R	R	R
20	9.5±0.14	9.6±0.28	R	R	R	R	R	R	R
30	R	R	R	R	R	R	R	R	R
40	R	R	R	R	R	R	R	R	R
60	R	R	R	R	R	R	R	R	R
80	R	R	R	R	R	R	R	R	R
100	R	R	R	R	R	R	R	R	R
Petroleum ether									
1	R	R	R	R	R	R	R	R	R
5	R	R	R	R	R	R	R	R	R
10	R	R	R	R	R	R	R	R	R
15	R	R	R	R	R	R	R	R	R
20	R	R	R	R	R	R	R	R	R
30	R	R	R	R	R	R	R	R	R
40	R	R	R	R	R	R	R	R	R
60	R	R	R	R	R	R	R	R	R
80	R	R	R	R	R	R	R	R	R
100	R	R	R	R	R	R	R	R	R
Cefotaxime									
100µg	37.8±0.176a	33±0.71	24.5±0.71	33±0.71	23.5±0.75	31.5±0.70	36.5±0.2	29±0.70	21.5±1.4

R Resistant/ No inhibition zone Data represents the average of three replicates ± S.D., The bold values represent the optimum zone of inhibition formed by the respective plant extract among the tested bacterial strains

other strains were resistant towards *Vicia sativa* extracts (Table 4). No zone of inhibition was found in aqueous and petroleum ether extracts. Valya *et al.* 2011 evaluated the antibacterial potential of *Solanum americanum* Miller against both gram positive and gram negative bacteria by agar well diffusion method. Bacterial strains they tested included *Staphylococcus aureus, Escherichia coli, Bacillus* sp. and *Pseudomonas* sp. Methanolic extract of *Solanum americanum* Miller was active against *Staphylococcus aureus* and *Pseudomonas* sp. only while all other strains were resistant towards methanolic extract. Their aqueous and ether extracts also showed no activity against any bacterial strains. It has been recorded that lower plants belonging to family Leguminosae are rich in phytoalexins, which include flavanone derivatives structurally analogous to the anti-MRSA flavanones and result in the inhibition of methicillin resistant *Staphylococcus aureus* (Tsuchiya *et al.* 1996). *Vicia sativa* being member of Leguminosae family contains flavonoid phytoalexins; this might be the reason for the optimum inhibition of *Vicia sativa* against *Staphylococcus aureus*. As the crude extracts were used, so possibly the bioactive compounds are present in insufficient quantity to be effective against bacterial strains (Taylor *et al.* 2001). Alternatively, the bioactive compound may be present but there could be the other compounds which may have antagonistic effect or cancel out the positive effect of bioactive compound. Lack of activity can only be proved by using purified and high doses of extracts.

In our study, nine different bacterial strains were tested against the polar and non-polar extracts of three weeds used locally in Pakistan as a fodder. One can repeat the same assays by evaluating other bacterial strains in order to verify and examine the broad range antibacterial potential of this plant. As the crude extracts of the selected weeds showed bioactivity against some selected bacterial strains, these extracts can be partitioned and purified and can further be subjected to the isolation of antimicrobial constituents. This can help us to explore pharmacological significance of the investigated plants. The potential for developing antimicrobials from plants appear to be worthwhile at present as it leads to the development of new drugs which is need of hour. These weed extracts open the potential of finding new clinically effective antibacterial compounds. This study significantly supports the usage of weeds as traditional medicines for various bacterial infections.

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Short communication

Herbicide combinations for weed management in transplanted rice

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Rice (*Oryza sativa* L.) is the world's most important food crop catering half of the world's population. Generally, rice is grown in four broad ecosystems namely rainfed upland, rainfed lowland, puddled direct-seeded and puddled transplanted (Sharma, 2007). Among this the transplanting of rice has been the traditional system, where availability of water is in abundance. Weeds are major problem limiting the growth and yield of rice. Transplanted rice faces diverse type of weed flora, consisting of grasses, broad-leaved weeds and sedges. They usually grow faster than rice and absorb available water, nutrient earlier than the rice and suppress rice growth. Effective control of weeds had increased the grain yield by 85.5% (Mukherjee and Singh 2005). Single application of herbicide may provide effective control of weeds, but continuous use of such herbicides leads to the evolution of weeds resistant to several herbicides. Persistence of the herbicides in the field is only up to 30 DAT (Balasubramanian *et al.* 1996) So, single application of pre- and post-emergence herbicide is ineffective in controlling the weed flora in transplanted rice ecosystem. Under such situations, application of herbicide either as mixture or in sequence may be useful for broad-spectrum weed control in transplanted rice. Keeping this in view, a field experiment was carried out to evaluate the effect of herbicide applied in combination as well as in sequence for managing complex weed flora in transplanted rice.

An experiment was conducted during *Rabi* 2012-13 at Agriculture College and Research Institute, Madurai to study the effect of herbicide applied in mixtures and sequence for managing complex weed flora in transplanted rice. The soil of the experimental field was sandy clay loam with a pH of 7.2 and was high in available nitrogen and potassium and medium in available phosphorus.

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A set of 15 treatments was laid out in random block design with three replications (Table 1). The pre-emergence herbicides butachlor, pretilachlor, pyrazosulfuron and bensulfuron-methyl + pretilachlor were applied at 3 DAT. The post–emergence application of bispyribac-Na, metsulfuron-methyl + chlorimuron-ethyl, ethoxysulfuron was done at 25 DAT.

The rice variety *'ADT 49'* was transplanted at a spacing of 20 x 15 cm. Recommended dose of 150 kg N, 50 kg P_2O_5 and 50 kg K_2O NPK/ha was applied to the crop. Entire quantity of phosphorus and one third of the recommended N and K were applied basally at the time of sowing. Remaining two thirds of the recommended N and K was top dressed in three equal splits at 20, 45 and 65 DAT. Bio-fertilizers like azospirillum and phosphobacteria at 1000 g/ha were used for root dipping. All the intercultural practices were carried out as need based. The data on weed counts and dry matter production (DMP) were recorded at 60 DAT and weed control efficiency (WCE) of different treatments was computed using data on weed population. The observations recorded on rice were plant height, number of productive tillers and grain yield.

Weed flora

The predominant weeds of the experimental plot were *Echinochloa crusgalli, Cynodon dactylon, Panicum repens* under grasses, *Cyperus rotundus, Cyperus iria, Cyperus difformis* and *Fimbristylis milliaceae* among sedge and *Sphenoclea zeylanica, Eclipta alba* and *Marselia quadrifoliata* among broad-leaved weeds (BLW). All the weed control treatments caused significant reduction in total weed density and weed DMP when compared to unweeded control.

Effect on weed growth

Density of grassy weeds was significantly reduced to 19.12 /m^2 by tank mixture application of bispyribac-Na and at metsulfuron-methyl + chlorimuron-ethyl at 60 DAT. This was on par with sequential application of pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl at 750/4 g/ha with grass weed density of 19.12/m^2. It was same in the case of sedge and broad-leaved weeds density. In all tank mixture application of bispyribac-Na and metsulfuron-methyl + chlorimuron-ethyl found to be more effective in managing weed population with sedge weed density of 0.84 no./m^2 and BLW density of 3.83 no./m^2. This was comparable with sequential application of pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl. Among the single application of herbicide treatment, bispyribac-Na 25 g/ha was superior in controlling BLW compared to other single application of herbicide treatments.

All the weed control treatments caused significant reduction in total weed density and weed Dry Matter Production (DMP) when compared to unweeded control. Tank mixture application of bispyribac-Na + metsulfuron-methyl + chlorimuron-ethyl g/ha reduced the weed count upto 4.86/m^2 and weed DMP to 7.21 kg/ha and increased the WCE of 92% on 60 DAT. This was at par with the sequential application of pretilachlor *fb* metsulfuron-methyl + chlorimuron-ethyl 750/4 g/ha with the weed count (5.25/m^2), weed DMP (7.80 kg/ha) and WCE (91%) on 60 DAT. This might be due to the fact that the use of two or more herbicide in combination provided broad spectrum of weed control. The next best treatment was sequential application of pre-emergence herbicide pretilachlor and post-emergence application of metsulfuron-methyl + chlorimuron-ethyl on 25 DAT. Pretilachlor as a pre-emergence was effective in controlling weeds during the crop emergence period. The effectiveness of herbicide over weed would be lost after 30 days of its application. Therefore, applying metsulfuron-methyl + chlorimuron-ethyl as post-emergence herbicide at 25 DAT might be effective in controlling weeds that appear during the later stage of the crop. Pre-emergence followed by post-emergence application of almix were found to be on par with hand weeding twice. Sequential application of pre-and post-emergence herbicides and herbicide mixtures provide broad-spectrum of weed control. This is in accordance with those of Muthukrishnan *et al.* (2010). Metsulfuron-methyl + chlorimuron-ethyl as single application might be effective against broad-leaved weeds and sedges at a lower application rate

Table 1. Effect of herbicide combination on weed density, weed control efficiency and weed dry matter at 60 DAT in transplanted rice

Treatment	Weed density (no./m^2)				WCE (%)	Total weed DMP (kg/ha)
	Grasses	Sedges	BLW	Total		
Butachlor alone on 3 DAT as PE	8.86 (78.0)	2.73 (6.98)	4.52 (20.0)	10.27 (105)	66.2	15.29 (233.4)
Pretilachlor alone on 3DAT as PE	9.03 (81.2)	2.96 (8.32)	5.79 (33.0)	11.09 (122)	60.6	16.51 (272.3)
Pyrazosulfuron alone on 3DAT as PE	8.28 (68.2)	2.81 (7.41)	4.42 (19.1)	9.75 (94.7)	69.6	14.52 (210.5)
Bensulfuron-methyl + pretilachlor alone on 3 DAT as PE	5.87 (34.0)	3.03 (8.74)	4.57 (20.4)	7.97 (63.8)	79.7	11.86 (140.4)
Bispyribac-Na alone on 25 DAT as PoE	6.13 (37.1)	2.08 (3.83)	3.88 (14.6)	7.48 (55.5)	82.1	11.13 (123.4)
Metsulfuron-methyl + chlorimuron-ethyl alone on 25 DAT as PoE	5.03 (24.9)	1.63 (2.17)	4.61 (20.8)	6.95 (47.8)	84.6	10.33 (106.4)
Bispyribac-Na + PoE metsulfuron-methyl + chlorimuron-ethyl on 25 DAT as PE	4.42 (19.1)	0.84 (0.22)	2.08 (3.8)	4.86 (23.2)	92.5	7.21 (51.5)
Bispyribac-Na + ethoxysulfuron on 25 DAT as PoE	5.47 (29.4)	1.58 (2.02)	3.32 (10.5)	6.51 (42.0)	86.5	9.68 (93.3)
Pretilachlor + ethoxysulfuron on 25 DAT as PoE	5.39 (28.6)	1.59 (2.03)	3.11 (9.2)	6.35 (39.8)	87.2	9.43 (88.6)
Pretilachlor *fb* PoE metsulfuron-methyl + chlorimuron-ethyl on as PE	4.74 (22.0)	0.84 (0.22)	2.32 (4.9)	5.25 (27.1)	91.3	7.80 (60.4)
Butachlor *fb* PoE metsulfuron-methyl + chlorimuron-ethyl on 25 DAT as PE	5.75 (32.6)	2.18 (4.26)	3.39 (11.0)	6.95 (47.9)	84.6	10.33 (106.4)
Pyrazosulfuron *fb* manual weeding on 25 DAT as PE	5.30 (27.6)	1.01 (0.54)	3.45 (20.2)	6.99 (48.4)	84.4	10.39 (107.6)
Butachlor *fb* manual weeding on 25 DAT as PE	5.55 (30.4)	1.43 (1.57)	3.45 (11.5)	6.62 (43.4)	86.0	9.85 (96.5)
Hand weeding twice at 25 and 45 DAT	4.97 (24.0)	0.92 (0.36)	3.11 (9.2)	6.08 (36.53)	88.3	8.66 (74.5)
Control	12.03 (144)	5.31 (27.8)	11.81 (139)	17.65 (311)	-	32.21 (1037)
LSD (0.05)	0.193	0.14	0.153	0.20	-	0.17

Data subjected to square root transformation; Values in parentheses are original; PE-Pre-emergence, PoE-Post-emergence and was in line with the findings of Mukherjee and Singh (2005). Unweeded control registered the highest weed count (17.65/m^2) and weed DMP 32.21 kg/ha (Table 1) showing greater weed competition.

Effect on rice growth and yield

Maximum plant height was observed in tank mixture application of bispyribac- Na + metsulfuron-methyl + chlorimuron-ethyl at 25/4 g/ha and was significantly superior to the rest of the treatments by recording a plant height of 103.89 cm. Maximum plant DMP (4210 kg/ha) as well as number of productive tillers (361.43/m^2) and LAI (2.72) were recorded during active tillering stage for the above best treatment. This might be due to the better environment provided for the full development of the canopy as a result of an effective weed control achieved by the mixture of herbicides at the early stage of crop weed competition.

The increased grain yield clearly indicated the influence of weed free environment on grain production (Table 2). Herbicide combination of bispyribac-Na and metsulfuron-methyl + chlorimuron-ethyl recorded higher grain yield of 6.3 t/ha. The effective control of weeds starting from the early growth stage might have resulted in better growth and yield of rice. The variation in grain yield (as represented in Table 2) under different treatments was the result of variation in weed density and weed biomass. This is in conformity with the findings of Suganthi *et al.* (2010) and Mukherjee and Maity (2011). All these improved performance of the crop under favorable weed free condition lead to higher grain yield.

Different weed control methods involved different amount of cost which affected the total cost of cultivation of transplanted rice. Hand weeding is laborious and generally more expensive. From the computation of weed control it was observed that the maximum cost of weed control was required for hand weeding twice at 25 and 45 DAT with a B:C ratio of 2.46, which was due to maximum labour requirement. Patra *et al.* (2011) supported this finding with similar result. It was revealed that application of herbicide mixture of bispyribac-Na and metsulfuron-methyl + chlorimuron-ethyl registered lower cost of cultivation with B:C ratio of 3.11 and this increase in B:C ratio was due to increased yield of rice crop resulted from the favorable environment of weed free condition and lesser cost of weeding by the treatments.

Table 2. Effect of herbicide combination applied in mixture and sequence on growth, grain yield and B:C ratio of transplanted rice

Treatment	Plant height (cm)	LAI	No. tillers/ plant (no/m^2)	Plantdry matter (t/ha)	Grain yield (t/ha)	B:C ratio
Butachlor alone on 3 DAT as PE	90.5	1.91	263.9	2.80	5.10	2.62
Pretilachlor alone on 3DAT as PE	85.7	1.86	259.0	2.74	5.00	2.54
Pyrazosulfuron alone on 3DAT as PE	90.6	1.96	276.6	2.99	5.20	2.70
Bensulfuron-methyl + pretilachlor alone on 3 DAT as PE	90.2	2.02	280.1	3.23	5.30	2.59
Bispyribac-Na alone on 25 DAT as PoE	91.4	2.38	297.7	3.54	5.60	2.73
Metsulfuron-methyl + chlorimuron-ethyl alone on 25 DAT as PoE	95.1	2.42	302.1	3.65	5.60	2.89
Bispyribac-Na + PoE metsulfuron-methyl + chlorimuron-ethyl on 25 DAT as PE	103.9	2.72	361.4	4.21	6.30	3.11
Bispyribac-Na + ethoxysulfuron on 25 DAT as PoE	95.1	2.07	289.5	3.43	5.40	2.61
Pretilachlor + ethoxysulfuron on 25 DAT as PoE	92.8	2.19	292.5	3.48	5.50	2.76
Pretilachlor *fb* PoE metsulfuron-methyl + chlorimuron-ethyl on as PE	102.7	2.68	347.2	3.96	6.00	3.03
Butachlor *fb* PoE metsulfuron-methyl + chlorimuron-ethyl on 25 DAT as PE	95.6	2.12	283.2	3.36	5.40	2.72
Pyrazosulfuron *fb* manual weeding on 25 DAT as PE	91.2	2.49	325.2	3.71	5.60	2.69
Butachlor *fb* manual weeding on 25 DAT as PE	101.7	2.52	331.4	3.72	5.70	2.75
Hand weeding twice at 25 and 45 DAT	101.7	2.55	337.2	3.93	5.80	2.46
Control	69.2	1.65	228.0	2.02	3.20	1.76
LSD (0.05)	3.3	0.08	10.7	0.12	0.12	-

PE-Pre-emergence, PoE-Post-emergence

SUMMARY

A field experiment was conducted during 2012-13, to study the effect of herbicides applied in mixture and sequence for managing complex weed flora in transplanted rice. Among the herbicides applied, bispyribac-Na applied in combination with almix as tank mixture recorded the least weed count, weed dry matter and highest WCE. Significantly higher yield attributes, *viz.* number of grains/panicle and grain yield were also recorded when bispyribac-Na and metsulfuron-methyl + chlorimuron-ethyl were applied as tank mixture. Pre-emergence application of pretilachlor *fb* post-emergence application of metsulfuron-methyl + chlorimuron-ethyl and hand weeding twice at 25 and 45 DAT were also equally effective. Application of pre- and post-emergence herbicide alone were found to be less effective in reducing weed density and weed dry matter.

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Short communication

Optimization of suitable weed management practices for aerobic rice

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Key words: Aerobic rice, Hand weeding, Herbicides, Weed control efficiency

Nowadays water is the most critical input in agriculture and future estimate revealed that scarcity of water will become more severe as the share of water to other sector will increase. And all of us know that rice crop water requirement is very high particularly for puddling for transplanting of rice. Therefore new cultivation system *i.e.* aerobic rice should be tested as it requires very less amount of water to reduce future water scarcity problem. The reality is that rice production needs to produce more rice with less water *i.e.* more crop per drop. In aerobic rice, crop is subjected to greater weed competition than transplanted rice. Weeds are one of the major constraints to aerobic rice production systems, as dry tillage, alternate wetting and drying condition are conductive to germination, growth of weeds causing grain yield losses of 50-90 % (Mishra and Singh 2007). This constraint also causes in the way of wider adoption of aerobic rice as weeds and rice seeds germinate at the same time causing serious crop-weed competition.

In recent years, some attempts have been made for developing suitable weed management strategies for rice which are economically viable and practically feasible for general adoption by the average farmers in India. Chemical or mechanical methods of weed management in isolation have also been found effective in many situations of upland rice but these chemical have to be tested especially for aerobic condition. Now, it is the need of hour to find out suitable weed management practice for effective weed management in aerobic rice for increasing crop yield and water use efficiency and to make aerobic rice cultivation more viable. Considering the above facts, a field experiment was conducted to evaluate the efficacy of different weed management practices in managing weeds of aerobic rice.

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A field experiment was carried out at the Agricultural Research Farm, Rajendra Agricultural University, Pusa, Samastipur, Bihar (India), during *Kharif* season of 2012. Geographically, Pusa is located in semi-arid and sub-tropical region at 25^o 59^o N latitude, 85^{o}40'E longitude and at an altitude of 52.1 m above mean sea level. The soil of the experimental field was clay loam in texture. It was moderately fertile being low in organic carbon (0.32%), available nitrogen (249 kg N/ha), phosphorus (16.86 kg P_2O_5/ha) and potassium (120 kg K_2O/ha). The soil was alkaline in reaction (pH 8.4). Rice variety "*Rajendra Suwasani*" was taken as a test crop with recommended dose of fertilizer (RDF) 130-68-58 kg N-P_2O_5-K_2O/ha. The experiment was conducted with 14 weed management treatments *viz.* pretilachlor at 750 g/ha at 1 days after sowing (DAS), pyrazusulfuron at 25 g/ha at 5 DAS; bispyribac sodium at 25 g/ha at 20 DAS; pretilachlor at 750 g/ha at 1 DAS followed by (*fb*) bispyribac sodium at 25 g/ha at 20 DAS; pyrazusulfuron at 25 g/ha at 5 DAS *fb* bispyribac sodium at 25 g/ha at 20 DAS; pretilachlor at 750 g/ha at 1 DAS *fb* one hand weeding at 20 DAS; *sesbania* co-culture at 40 kg/ha *fb* 2,4-D at 800 g/ha at 20 DAS; *sesbania* co-culture at 40 kg/ha *fb* bispyribac sodium at 25 g/ha at 20 DAS; *sesbania* co-culture at 40 kg/ha + pretilachlor at 750 g/ha at 1 DAS *fb* 2,4-D at 800 g/ha at 20 DAS; azimsulfuron at 35 g/ha at 20 DAS; pretilachlor at 750 g/ha at 1 DAS *fb* azimsulfuron at 35 g/ha at 20 DAS; two hand weeding at 15 and 30 DAS; two hand weeding at 20 and 40 DAS; weedy check in RBD replicated thrice. A quadrat of size 0.50 m^2 was placed in the sampling area of each plot and weeds falling within the frames of quadrat were counted and recorded. These weeds were removed, washed free of soil and oven dried at 70 ^{o}C for 72 hours and the weed biomass was recorded. Weed index was calculated by the formula proposed by Gill and Kumar (1969). Since the data on weed density and weed biomass showed high variation, the data were subjected to square root transformation.

Weed growth

The weed management practices significantly influenced the weed density and weed dry weight at different stages of aerobic rice (Table 1). Weed density and weed dry weight were registered significantly lowest under two hand weeding at 20 and 40 DAS at all crop growth stages due to effective management of the first flush of weeds during 20 DAS and second flash of weeds during 40 DAS. This result was similar to that of the experimental findings of Yadav *et al*. (2007).

Weed control efficiency and weed control index

Weed control efficiency varied with different weed management practices in aerobic rice. At 30 DAS, weed control efficiency ranged from 48.24% in bispyribac sodium at 25 g/ha at 20 DAS to 88.02% in hand weeding twice at 20 and 40 DAS (Table 2) indicating the superiority of hand weeding twice at 20 and 40 DAS during critical period of crop weed competition. This finding is in conformity with Walia *et al*. (2008).

All the weed management treatments substantially reduced the competition by weeds for various resources resulting in lower weed control index. Two hand weeding at 20 and 40 DAS recorded the least weed control index (0.00) followed by two hand weeding at 15 and 30 DAS (4.33) and pretilachlor at 750 g/ha at 1 DAS *fb* azimsulfuron at 35 g/ha at 20 DAS (4.66).

Grain and straw yield

Amongst weed management treatments, maximum grain and straw yield were recorded in treatment where hand weeding was done twice either 20 and 40 DAS or 15 and 30 DAS maintained its superiority over rest of the treatments and it was followed by those treatments where pre-emergence application of herbicide followed by post-emergence herbicide. Hand weeding twice at 20 and 40 DAS recorded maximum grain yield of 3.95 t/ha which was 56 % higher over weedy check (1.73 t/ha). Among the various combination of herbicides, application of pretilachlor at 750 g/ha at 1 DAS *fb*

Table 1. Effect of different weed management treatments on weed growth in aerobic rice

Treatment	Weed density (no./m^2)			Weed dry Weight (g/m^2)		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Pretilachlor at 750 g/ha at 1 DAS	136.0 (11.7)	152.7 (12.4)	94.3 (9.8)	13.9 (3.8)	43.5 (6.7)	23.0 (4.9)
Pyrazosulfuron at 25 g/ha at 5 DAS	122.0 (11.1)	149.7 (12.3)	92.3 (9.6)	12.3 (3.6)	37.3 (6.2)	23.0 (4.9)
Bispyribac-sodium at 25 g/ha at 20 DAS	151.0 (12.3)	168.3 (13.0)	105.7 (10.3)	14.9 (4.0)	47.3 (6.9)	27.3 (5.3)
Pretilachlor at 750 g/ha at 1 DAS *fb* bispyribac sodium at 25 g/ha at 20 DAS	59.0 (7.7)	94.3 (9.8)	68.3 (8.3)	5.2 (2.5)	20.3 (4.6)	14.7 (3.9)
Pyrazosulfuron at 25 g/ha at 5 DAS *fb* bispyribac sodium at 25 g/ha at 20 DAS	52.5 (7.3)	66.0 (8.2)	47.0 (6.9)	4.1 (2.2)	14.6 (3.9)	10.7 (3.4)
Pretilachlor at 750 g/ha at 1 DAS *fb* one hand weeding at 20 DAS	54.3 (7.4)	86.3 (9.3)	51.3 (7.2)	4.8 (2.4)	18.5 (4.4)	12.7 (3.7)
Sesbania co-culture at 40 kg/ha *fb* 2,4-D at 800 g/ha at 20 DAS	98.7 (10.0)	135.3 (11.7)	85.3 (9.3)	9.3 (3.2)	34.4 (5.9)	18.2 (4.3)
Sesbania co-culture at 40 kg/ha *fb* bispyribac sodium at 25 g/ha at 20 DAS	80.0 (9.0)	127.0 (11.3)	81.0 (9.0)	8.4 (3.1)	28.4 (5.4)	17.2 (4.2)
Sesbania co-culture at 40 kg/ha + pretilachlor at 750 g/ha at 1 DAS *fb* 2,4-D at 800 g/ha at 20 DAS	119.3 (11.0)	146.7 (12.1)	86.7 (9.4)	10.8 (3.4)	36.1 (6.1)	20.2 (4.6)
Azimsulfuron at 35 g/ha at 20 DAS	66.3 (8.2)	106.7 (10.4)	70.7 (8.5)	7.6 (2.9)	23.5 (4.9)	16.6 (4.2)
Pretilachlor at 750 g/ha at 1 DAS *fb* azimsulfuron at 35 g/ha at 20 DAS	51.3 (7.2)	62.3 (7.9)	43.3 (6.6)	3.7 (2.2)	12.9 (3.7)	9.9 (3.3)
Two hand weeding at 15 and 30 DAS	48.7 (7.0)	58.3 (7.7)	38.7 (6.3)	3.4 (2.1)	9.7 (3.3)	7.1 (2.8)
Two hand weeding at 20 and 40 DAS	35.0 (6.0)	38.3 (6.3)	34.3 (5.9)	2.2 (1.7)	7.1 (2.8)	6.3 (2.7)
Weedy check	136.0 (11.7)	414.4 (20.4)	419.7 (20.5)	28.7 (5.4)	124.3 (11.2)	143.0 (12.0)
LSD (P=0.05)	0.47	0.46	0.39	0.12	0.23	0.21

Figures in parentheses indicate original values

Table 2. Weed control efficiency, weed control index and yield of aerobic rice as influenced by different weed management

Treatment	Weed control efficiency (%)			Weed control index (%)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
	30 DAS	60 DAS	90 DAS				
Pretilachlor at 750 g/ha at 1 DAS	53.4	63.0	77.5	32.3	2.67	3.74	41.7
Pyrazusulfuron at 25 g/ha at 5 DAS	58.4	63.9	77.8	30.8	2.73	3.82	41.7
Bispyribac sodium at 25 g/ha at 20 DAS	48.2	59.2	74.6	37.7	2.46	3.47	41.5
Pretilachlor at 750 g/ha at 1 DAS *fb* bispyribac sodium at 25 g/ha at 20 DAS	79.8	77.2	83.6	8.4	3.62	4.91	42.2
Pyrazusulfuron at 25 g/ha at 5 DAS *fb* bispyribac sodium at 25 g/ha at 20 DAS	82.0	84.0	88.7	6.6	3.69	5.05	42.2
Pretilachlor at 750 g/ha at 1 DAS *fb* one hand weeding at 20 DAS	81.4	79.1	87.7	6.9	3.67	5.03	42.2
Sesbania co-culture at 40 kg/ha *fb* 2,4-D at 800 g/ha at 20 DAS	66.3	67.3	79.6	15.3	3.34	4.61	42.0
Sesbania co-culture at 40 kg/ha *fb* bispyribac sodium at 25 g/ha at 20 DAS	72.6	69.2	80.6	13.2	3.42	4.69	42.2
Sesbania co-culture at 40 kg/ha + pretilachlor at 750 g/ha at 1 DAS *fb* 2,4-D at 800 g/ha at 20 DAS	59.1	64.5	79.3	19.9	3.16	4.39	41.8
Azimsulfuron at 35 g/ha at 20 DAS	77.4	74.2	83.0	11.1	3.51	4.84	42.0
Pretilachlor at 750 g/ha at 1 DAS *fb* azimsulfuron at 35 g/ha at 20 DAS	82.5	84.9	89.6	4.7	3.76	5.15	42.2
Two hand weeding at 15 and 30 DAS	83.3	85.9	90.7	4.3	3.78	5.21	42.0
Two hand weeding at 20 and 40 DAS	88.0	90.7	91.8	0.0	3.95	5.38	42.3
Weedy check	-	-	-	56.1	1.73	2.44	41.5
LSD (P=0.05)					0.40	0.51	NS

azimsulfuron at 35 g/ha at 20 DAS yielded maximum (3.76 t/ha) with 54 % superiority over weedy check. Significantly maximum straw yield (5.38 t/ha) was obtained with hand weeding twice at 20 and 40 DAS which was statistically superior over other treatments except those treatments where pre-emergence application of herbicide was followed either by post-emergence application or hand weeding. The result was in close conformity to those given by Payman and Singh (2008). Different weed management practices have non-significant differences however maximum value of harvest index (42.30%) was recorded with hand weeding twice at 20 and 40 DAS and minimum with weedy check (41.50%).

SUMMARY

A field experiment was carried out at the Agricultural Research Farm, Rajendra Agricultural University, Pusa, Samastipur, Bihar (India), during *Kharif* season of 2012. The experiment involved 14 weed management treatments laid out in randomized block design with three replication. The highest grain yield (3.95 t/ha) was recorded with hand weeding twice at 20 and 40 DAS and lowest under weedy check (1.73 t/ha). Similar trend was observed in straw yield. Among different combination of herbicides, application of pretilachlor at 750 g/ha at 1 DAS *fb* azimsulfuron at 35 g/ha at 20 DAS was the best combination and comparable with hand weeding. Maximum weed control efficiency and weed control index were recorded under treatment hand weeding twice at 20 and 40 DAS and minimum under weedy check. However, weed density and weed dry weight were found maximum under weedy check and minimum with hand weeding twice at 20 and 40 DAS.

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Short communication

Weed management in maize

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Key words: Atrazine, Pendimethalin, Maize, Productivity, *Sesbania aculeata*, Weed managment

Maize (*Zea mays* L.) is the most versatile food crop of global importance. It ranks third most important food grain crop after rice and wheat in India providing food, feed, fodder and also serves as a source of basic raw material for number of industrial products for food (25%), animal feed (12%), poultry feed (49%), starch (12%), brewery (1%) and seed (1%) (Dass *et al.* 2008). It is one of the most efficient crops which gives high biological yield as well as grain yield in a short period of time due to its unique photosynthetic mechanism owing to C_4 mechanism. The average maize yield in the developed countries is more than 7 t/ha while in the developing countries it is only around 3 t/ ha (Dass *et al.* 2008). Amongst various production factors, weed management plays major role in increasing productivity of maize. Unchecked weed growth in crop may results in grain yield losses to the extent of 100% (Sharma 2005). The experiment was designed with the view to find out the effect of herbicides and their combination on productivity of maize.

A field experiment was conducted during rainy seasons of 2014 at research farm of Birsa Agricultural University situated at 23º17' N latitude and longitude of 85º10' E with an altitude of 625 m above mean sea level, to find out the effect of weed control methods on productivity and economics of maize. The experimental soil was poor in nitrogen (210 kg/ha), medium in phosphorus (14.7 kg/ha), potash (123 kg/ ha) and organic carbon (5.2 g/ka soil). The pH of soil was 5.4. The experiment was laid out in a randomized block design with 12 treatments in three replications. The crop variety "*Suwan*" was sown on 26.06.14 at spacing of 60 x 20 cm with fertilizer dose 120:60:40 kg N:P_2O_5:K_2O/ha. Half dose of N and full of P and K were applied as basal. Remaining 50% N was split into two doses, first 25% was applied at knee height stage and second 25% was applied at tasselling stage through top dressing of urea. Crop was harvested on 06.10.14**.** The herbicides as per treatment were applied by knapsack sprayer using 500 liter/ha water. The data on weed species were recorded at 30 and 60 days after sowing. Weed count was expressed as number/m^2. The mean data were subjected to square root transformation ($\sqrt{x + 0.5}$) to normalize their distribution. These samples were dried at 70 ºC till a constant weight was obtained. The dry matter was then computed in terms of g/m^2. Economics was calculated on the basis of prevailing market prices of inputs and produce.

The experimental field was infested with broad-leaved weeds like *Alternenthara sessils*, *Commelina benghalensis*, *Commelina nudifolia*, *Ageratum conyzoides*, *Phyllanthus niruri;* among grassy weeds *Echinochloa colona*, *Echinochloa crusgalli*, *Digitaria sanguinalis*, *Paspalam distichum*, *Dactyloctenium aegyptium* and among sedges *Cyperus rotundus*, *Cyperus iria* and *Fimbristylis milliaceae*.

Application of atrazine + pendimethalin 0.50 + 0.50 kg/ha as PE similar to hand weeding at 20 and 40 DAS as well as atrazin 1.0 kg/ha as PE recorded significantly reduced weed density of narrow-leaf, broad-leaf and sedges at 30 and 60 days after sowing. The extent of reduction was to the tune of 69.8, 96.9 and 85.1% at 30 days and 73.7, 85.7 and 88.2%, respectively at 60 days after sowing as compared to weedy check. In case of dry matter accumulation, application of atrazine + pendimethalin 0.50 + 0.50 kg/ha as pre-emergence (PE) similar to hand weeding at 20 and 40 DAS recorded significantly reduced weed dry matter of all category of weeds at both the growth stages of maize except broad-leaf and sedges at 30 DAS. The extent of reduction was to the tune of 71.4% in case of narrow-leaf at 30 days after sowing and 65.71, 71.74 and 63.64% in case of narrow, broad-leaf and sedges, respectively at 60 days after sowing compared to weedy check (Geetha *et al.* 2013).

Pre-emergence application of atrazine + pendimethalin 0.50+0.50 kg/ha similar to application

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Table 1. Weed density as influenced by weed management methods

Treatment	Weed density (no./m^2)							
	30 DAS				60 DAS			
	NL	BL	S	Total	NL	BL	S	Total
Pretilachlor 0.5 kg/ha PE	6.34 (40)	7.38 (56)	7.55 (57)	12.4 (153)	6.85 (47)	7.42 (55)	6.53 (43)	12.0 (144)
Atrazine 1.0 kg/ha PE	4.88(24)	3.21 (10)	5.35 (31)	7.99 (65)	5.75 (33)	5.83 (37)	4.76 (23)	9.48 (93)
Pendimethalin 1.0 kg /ha PE	5.58(31)	5.51 (32)	5.99 (39)	10.1 (101)	6.43 (43)	6.74 (46)	5.96 (35)	11.1 (124)
Metribuzin 0.35 kg/ha PE	6.91(47)	11.1 (123)	11.6 (135)	17.5 (305)	8.41 (70)	11.1 (122)	11.3 (128)	17.9 (320)
Pretilachlor + metribuzin 0.75 + 0.175 kg/ha PE	5.41 (29)	5.10 (28)	5.88 (36)	9.55 (93)	5.95 (36)	6.37 (41)	5.08 (27)	10.1 (103)
Atrazine + pendimethalin 0.50 + 0.50 kg/ha PE	4.04 (16)	2.39 (5)	4.73 (23)	6.68 (44)	4.47 (20)	4.87 (23)	4.07 (16)	7.73 (60)
Pretilachlor 1.0 kg/ha 15 DAS	5.59 (31)	6.61 (47)	6.66 (44)	11.0 (122)	6.69 (45)	7.20 (51)	6.42 (41)	11.7 (138)
Metribuzin 0.25 kg/ha 15 DAS	5.28 (29)	5.55 (32)	5.99 (39)	9.70 (100)	6.14 (37)	6.61 (43)	5.48 (31)	10.6 (111)
Atrazine + 2,4-D 0.50 + 0.50 kg/ha 30 DAS	6.47 (41)	10.2 (104)	8.77 (80)	15.0 (225)	7.26 (53)	10.7 (113)	9.82 (96)	16.2 (262)
Green manuring *fb* 2,4-D 0.625 kg/ha) 30 DA	6.70 (45)	10.3 (113)	10.2 (104)	16.1 (262)	7.45 (55)	10.8 (116)	10.0 (101)	16.5 (273)
Hand weeding	4.11 (17)	3.12 (9)	5.23 (27)	7.33 (53)	5.53 (31)	5.70 (33)	4.32 (18)	9.04 (82)
Weedy check	7.29 (53)	12.6 (159)	12.4 (154)	19.1 (366)	8.71 (76)	12.7 (161)	11.7 (136)	19.3 (373)
LSD (P=0.05)	1.41	2.79	2.56	2.48	1.58	1.44	1.37	1.67

Table 2. Weed dry matter as influenced by weed management methods

Treatment	Weed dry matter (g/m^2)							
	30 DAS				60 DAS			
	NL	BL	S	Total	NL	BL	S	Total
Pretilachlor 0.5 kg/ha PE	3.81(15)	3.96(18)	4.35(19)	7.04(52.1)	4.46(20)	5.99(36)	5.51(30)	9.28(86)
Atrazine 1.0 kg/ha PE	3.03(9)	3.44(11)	4.02(16)	6.05(36.2)	4.01(16)	4.40(19)	4.68(21)	7.51(56)
Pendimethalin 1.0 kg/ha PE	4.43(20)	4.05(16)	4.36(19)	7.39(54.5)	4.18(17)	4.96(24)	4.97(24)	8.11(65)
Metribuzin 0.35 kg/ha PE	3.34(11)	4.65(21)	4.55(20)	7.27(52.6)	5.12(26)	6.54(42)	6.35(40)	10.41(108)
Pretilachlor + metribuzin 0.75+0.175 kg/ha PE	3.06(9)	3.55(12)	4.12(17)	6.18(38.6)	4.07(16)	4.51(20)	4.69(22)	7.64(58)
Atrazine + pendimethalin 0.50 + 0.50 kg/ha PE	2.48(6)	3.07(9)	3.41(12)	5.19(26.5)	3.57(12)	3.60(13)	4.04(16)	6.44(41)
Pretilachlor 1.0 kg/ha 15 DAS	3.56(13)	4.14(17)	4.36(19)	6.94(47.8)	4.20(17)	5.11(26)	5.17(26)	8.35(69)
Metribuzin 0.25 kg/ha 15 DAS	3.21(10)	3.61(13)	4.29(18)	6.42(41.2)	4.15(17)	4.72(22)	4.76(22)	7.85(61)
Atrazine + 2,4-D 0.50 + 0.50 kg/ha 30 DAS	4.16(18)	4.53(20)	4.46(20)	7.57(57.5)	4.56(21)	6.14(38)	6.11(37)	9.79(96)
Green manuring *fb* 2,4-D 0.625 kg/ha) 30 DA	4.32(18)	4.51(21)	4.48(20)	7.69(58.9)	5.00(25)	6.49(42)	6.21(38)	10.27(105)
Hand weeding	2.87(8)	3.22(10)	3.60(14)	5.65(31.9)	3.87(15)	4.13(17)	4.24(18)	7.04(49)
Weedy check	4.63(21)	4.70(22)	4.73(22)	8.08(65.6)	5.94(35)	6.82(46)	6.66(44)	11.21(125)
LSD (P=0.05)	1.27	NS	NS	1.58	0.81	0.90	0.97	0.62

of atrazine 1.0 kg/ha as PE, pretilachlor + metribuzin 0.75 + 0.175 kg/ha as PE, two hand weeding at 20 and 40 days after sowing recorded 19.5% higher plant height than weedy check. Application of atrazine + pendimethalin 0.50+0.50 kg/ha as PE similar to all weed control treatments except application of pretilachlor 0.5 kg/ha as PE, metribuzin 0.35 kg/ha as PE, *Sesbania aculeata* broadcasted *fb* 2,4-D 0.625 kg/ha at 30 DAS and two hand weeding at 20 and 40 days after sowing recorded 16.8% more number of grains per cobas compared to weedy check. Application of atrazine + pendimethalin 0.50+0.50 kg/ha as PE similar to application of atrazine 1.0 kg/ha as PE and two hand weeding at 20 and 40 days after sowing recorded 31.4% more 100 seed weight as compared to weedy check. It also recorded 65.6% significantly higher grain yield as compared to weedy check while straw yield was similar to hand weeding performed at 20 and 40 DAS and produced 65.7% higher as compared to weedy check.

Pre-emergence application of atrazine + pendimethalin 0.50 + 0.50 kg/ha recorded maximum B:C ratio (3.57) and ₹ 17,728/ha, significantly higher net return compared to hand weeding (₹35,764/ha) performed at 20 and 40 days after sowing and ₹43,274/ha higher compared to weedy check (₹10218/ha). Sidhu *et al.* (2014) also reported pre-emergence tank mix application of atrazine + pendimethalinis economically feasible and cost effective for controlling weeds.

It was concluded that for higher productivity, profitability and effective weed control in maize, atrazine + pendimethalin 0.50 + 0.50 kg/ha as pre-emergence can be applied.

Table 3. Yield attributes and yields of maize as influenced by weed management methods

Treatment	Plant height (cm)	No. of grains/cob	100-seeds weight (g)	Yield (t/ha)	
				Grain	Straw
Pretilachlor 0.5 kg/ha PE	213	371	20.8	2.12	3.17
Atrazine 1.0 kg/ha PE	241	470	23.1	2.94	4.39
Pendimethalin 1.0 kg/ha PE	230	450	21.1	2.32	3.50
Metribuzin 0.35 kg/ha PE	207	412	18.1	1.58	2.37
Pretilachlor + metribuzin 0.75+0.175 kg/ha PE	240	449	21.7	2.57	3.84
Atrazine + pendimethalin 0.50+0.50 kg/ha PE	255	495	24.0	3.80	5.73
Pretilachlor 1.0 kg/ha 15 DAS	214	429	20.2	2.30	3.43
Metribuzin 0.25 kg/ha 15 DAS	238	427	21.1	2.37	3.56
Atrazine + 2,4-D 0.50+0.50 kg/ha 30 DAS	210	444	19.3	1.75	2.65
Green manuring *fb* 2,4-D 0.625 kg/ha) 30 DAS	210	373	19.0	1.75	2.63
Hand weeding	246	415	23.3	3.06	4.59
Weedy check	204	412	16.4	1.31	1.96
LSD (P=0.05)	15	68	2.0	0.71	1.10

Table 4. Economics of maize as influenced by weed management methods

Treatment	Cost of cultivation (x10^3 `/ha)	Gross returns (x10^3 `/ha)	Net returns (x10^3 `/ha)	B:C
Pretilachlor 0.5 kg/ha PE	14.24	38.2	23.95	1.68
Atrazine 1.0 kg/ha PE	14.56	52.86	38.31	2.63
Pendimethalin 1.0 kg/ha PE	15.44	41.82	26.38	1.71
Metribuzin 0.35 kg/ha PE	14.65	28.44	13.79	0.94
Pretilachlor + metribuzin 0.75 + 0.175 kg/ha PE	15.04	46.20	31.15	2.07
Atrazine + pendimethalin 0.50+0.50 kg/ha PE	15.00	68.50	53.49	3.57
Pretilachlor 1.0 kg/ha 15 DAS	14.84	41.30	26.46	1.78
Metribuzin 0.25 kg/ha 15 DAS	14.36	42.68	28.31	1.97
Atrazine + 2,4-D 0.50+0.50 kg/ha 30 DAS	14.60	31.59	17.00	1.16
Green manuring *fb* 2,4-D 0.625 kg/ha) 30 DAS	16.66	31.56	14.89	0.89
Hand weeding	19.34	55.10	35.76	1.85
Weedy check	13.34	23.56	10.22	0.77
LSD (P=0.05)		13.08	13.08	0.90

price of maize grain = ₹ 15/kg and straw= ₹ 2/kg

SUMMARY

A field experiment was conducted on sandy loam soil of Birsa Agricultural University, Ranchi during rainy season of 2014 to evaluate the performance of weed-control methods on weed dynamics and productivity of maize. The experiment was laid out in randomized block design with 12 treatment in three replication. Application of atrazine + pendimethalin 0.50 + 0.50 kg/ha as pre-emergence similar to two hand weeding at 20 and 40 DAS recorded reduced weed density dry matter accumulation compared to weedy check at 30 and 60 days after sowing. These resulted significantly increase in plant height, number of grains per cob, 100-seed weight as well as 65.6% significantly higher grain yield (3.80 t/ha) as compared to weedy check (1.309 t/ha), consequently maximum net return (₹ 53492/ha) and benefit: cost ratio (3.57) than rest of the treatments.

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Short communication

Bioefficacy and phytotoxicity of pre- and post-emergence herbicides in grain sorghum

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Grain sorghum [*Sorghum bicolor* (L.) Moench], an important cereal crop of semi-arid tropical regions of India is traditionally grown for food, animal feed and fodder; but is also used as an industrial feedstock, and for biofuels. Weeds are a major deterrent in increasing the sorghum productivity, especially during rainy season. Grain sorghum seedlings are comparatively small and grow slowly for the first 20-25 days (Vanderlip 1979) and consequently do not compete well with most weeds in the early stage of crop growth, resulting in a yield loss of 15-83% depending on crop cultivars, nature and intensity of weeds, spacing, duration of weeds infestation and environmental conditions (Mishra *et al*. 2012). Planting sorghum in wider rows to facilitate inter-row cultivation further increases the weed problems. Weed control in grain sorghum is a challenge because of the availability of limited number of herbicides to farmers (Fromme *et al*. 2012). Early competition, especially from grasses is critical to control to avoid yield loss.

Sorghum producers in semi-arid tropical regions of India rely on hand weeding and mechanical cultivation to control weeds. However, repeated cultivation can accelerate loss of soil organic matter, increases soil erosion and promotes the emergence of new weed flushes. Scarcity of labour for hand weeding, and high costs are the major limitations of hand weeding. Atrazine (as pre-emergence) is the most widely used herbicide for weed control in grain sorghum. However, the efficacy of pre-emergence herbicides is moisture dependent. Too little or excessive moisture after herbicide application can result in poor weed control (Tapia *et al*. 1997). However, it has a low effectiveness on grasses (Dan *et al*. 2011). Atrazine may also cause carry over effects in subsequent sensitive crops under some conditions, so alternative treatments are needed (Ishaya *et al*. 2007, Keeling *et al*. 2013). Sensitivity of grain sorghum to currently available post-emergence grass herbicides is one of the major concerns to manage grassy weeds that emerge after crop establishment (Archangelo *et al*. 2002). Hence, atrazine may be combined with the grassy herbicides such as pendimethalin, metolachlor or alachlor to broaden the weed control spectrum. Combinations of these products with atrazine as tank mixes or premixes applied as pre-emergence will control most seedling grasses and broadleaf weeds for three to four weeks. In general, controlling grassy weeds that emerge after crop establishment is difficult because post-emergence herbicide options to control grass weeds in grain sorghum are limited (Hennigh *et al*. 2010, Abit and Al-Khatib 2013). Hence, the present investigation was undertaken to evaluate the bio-efficacy and phytotoxicity of new herbicide molecules in grain sorghum during rainy season.

A field experiment was conducted during rainy season of 2014 at the ICAR-Indian Institute of Millets Research, Hyderabad to evaluate weed control and grain sorghum response to herbicides. The climate of the area is semi-arid and tropical, with an average annual rainfall of 618 mm (75-80% of which is received during June-September), minimum temperature of 8-10 ^{0}C in December, and maximum temperature of 40-42 ^{0}C in May. The total rainfall received during cropping season (June-October) was 887 mm. The soil was an Alfisol, Udic Rhodustalf, sandy loam (66% sand, 13% silt and 21% clay), with 7.42 pH, 0.18 dS/m electrical conductivity, 0.39% organic carbon, 1.63 g/cc bulk density, 7.34% available soil moisture; low in available N (163 kg/ha), medium in available P (29 kg P_2O_5/ha) and high in K (360 kg K_2O/ha) content. A randomized complete-block experimental design was used and treatments were replicated three times.

Herbicide treatments (Table 1) were pre-emergence tank mix application of atrazine + pendimethalin, pendimethalin + imazethapyr, ready

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Table 1. Effect of herbicides on weed density, weed dry weight and weed control efficiency in sorghum

Treatment	Weed population at harvest (no./m^2)*				Total weed dry weight (g/m^2)	WCE (%)
	Broad-leaf	Grasses	Sedges	Total		
Atrazine PE (500 g/ha)	1.58 (2)	2.92 (8)	3.35 (5)	3.95 (15)	6.47 (47)	78.3
Atrazine + pendimethalin (tank mix) PE(500+750g/ha)	1.90 (3)	2.35 (5)	3.35 (5)	3.72 (13)	4.93 (33)	84.7
Pendimethalin + imazethapyr (tank mix) PE(750+100g/ha)	4.55 (20)	3.67 (13)	2.92 (8)	6.45 (41)	10.8 (124)	42.8
Penoxsulam PE (25 g/ha)	2.35 (5)	2.12 (4)	2.15 (4)	3.77(13)	4.13 (17)	92.1
Pendimethalin+ imazethapyr ready mix PE (750 + 50 g/ha)	1.91 (3)	1.58 (2)	1.87 (3)	2.96 (8)	2.3 (7)	96.7
Imazethpyr + imazamox ready mix (70 g/ha)	1.59 (2)	2.74 (7)	2.55 (6)	3.98 (15)	5.94 (36)	83.4
Penoxsulam as post-emergence at 15 DAS (25 g/ha)	6.52 (42)	4.75 (22)	3.54 (12)	8.77 (76)	14.3 (207)	4.6
Atrazine as post- emergence at 15 DAS (500 g/ha)	3.94 (15)	4.31 (18)	3.54 (12)	6.74 (45)	11.2 (125)	42.4
Imazethapyr as post- emergence at 15 DAS(100 g/ha)	4.55 (20)	9.41 (70)	4.18 (17)	10.41 (107)	20.1 (405)	0
Imazethpyr + imazamox ready mix at 15 DAS (70 g/ha)	3.95 (15)	7.71 (59)	3.81 (14)	9.41 (88)	18.8 (355)	0
Weedy check	8.69 (75)	5.53 (30)	3.10(9)	10.72 (114)	14.5 (217)	0
LSD (P=0.05)	1.34	1.57	1.45	2.36	4.17	

*Data subjected to square root transformation ($\sqrt{x + 0.5}$). Values in parentheses are original; PE=Pre-emergence (1 DAS); DAS=Days after sowing

mix application of pendimethalin+ imazethapyr, imazethpyr + imazamox, penoxsulam, and post-emergence application of penoxsulam, atrazine, imazethapyr and imazethpyr + imazamox. A non-treated control (weedy check) and standard pre-emergence herbicide atrazine were included for comparison. The sorghum hybrid '*CSH 16*' was sown manually in rows at 45 x 15 cm on 8 July 2014 and was later thinned to one plant per stand at 15 days after sowing (DAS). Herbicides, as per treatments, were applied in 500 l/ha spray volume with knapsack sprayer fitted with flat-fan nozzle. Pre-emergence herbicides were applied next day after sowing and post-emergence herbicides were applied at 15 DAS. Fertilizer (80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha) was applied as recommended for grain sorghum in the area. All the phosphorus as single super phosphate and potassium as muriate of potash were applied as basal on the day of planting. Nitrogen as urea was applied in 2 splits, 50% at sowing and remaining at 35 DAS. Sorghum crop injury was estimated by visual rating on a scale of 0 (no injury) to 100% (crop death) at 2 weeks after post-emergence herbicide application. Sorghum grain was manually harvested from middle 6 rows of each plot, weighed, and grain yield was adjusted to 14% moisture content. Weed count, for estimating weed density, and total weed dry weight were recorded at crop maturity with the help of a quadrate (0.50 m x 0.50 m) placed randomly at four spots in each plot. The data on weed dry weight were subjected to square root transformation ($\sqrt{x+0.5}$) before statistical analysis.

The experimental field was infested with mixed weed flora comprised of broad-leaved, grasses and sedges. The relative density of broad-leaved weeds was higher (65.8%) compared to grasses (26.3%) and sedges (7.9%). The dominant broad-leaf weeds were day flower (*Commelina benghalensis* L.), horse purslane (*Trianthema portulacastrum* L.), tridax daisy (*Tridax procumbens* L.), Indian borage [*Trichodesma indicum* (L.) R. Br.], and Parthenium (*Parthenium hysterophorus* L.); grass weed species include jungle rice [*Echinochloa colona* (L.) Link.], Indian goosegrass [*Eleusine indica* (L.) Gaertn.], viper grass [*Dinebra retroflexa* (Vahl) Panzer], common crab grass [*Digitaria sanguinalis* (L.) Scop.], and crowfoot grass [*Dactyloctenium aegyptium* (L.) Willd.]; and sedges such as rice flatsedge (*Cyperus iria* L.) and purple nutsedge (*Cyperus rotundus* L.).

Application of herbicides except imazethapyr and imazethpyr + imazamox applied at 15 DAS significantly reduced the weed density at harvest as compared to weedy check (Table 1). Post-emergence application of these herbicides caused complete mortality of both sorghum plants and weeds at 2 weeks after herbicide application. However, the second flush of weeds emerged, but no sorghum plants. In absence of competition from crop, weeds germinated in large numbers, grew profusely and accumulated higher dry matter even more than that of weedy check. New herbicide molecules, *viz*. penoxsulam, Pendimethalin+ imazethapyr, and imazethpyr + imazamox were very effective in controlling weeds. Penoxsulam at 15 DAS was less effective in reducing the density and dry weight of weeds as compared to its pre-emergence application. Application of herbicides significantly influenced the growth, yield attributes and yield of grain sorghum (Table 2). Leaf area index was significantly lower in penoxsulam and atrazine when applied at 15 DAS as compared to their pre-emergence applications. Pre-emergence application of imazethpyr + imazamox

Table 2. Effect of herbicides on growth, yield attributes and yields of grain sorghum

Treatment	LAI at 60 DAS	Plant height at harvest (cm)	Number of panicles/m^2	Panicle length (cm)	Grains/ panicle	100-grain weight (g)	Grain yield (t/ha)	Dry fodder yield (t/ha)
Atrazine PE (500 g/ha)	4.72	205	13.93	32.0	1146	3.64	5.81	12.89
Atrazine + pendimethalin (tank mix) PE (500+750g/ha)	5.12	204	12.03	31.3	1595	3.09	5.87	13.33
Pendimethalin + imazethapyr (tank mix) PE (750+100g/ha)	5.20	197	11.83	31.4	1120	3.43	3.72	11.55
Penoxsulam PE (25 g/ha)	4.60	203	13.40	31.9	1152	3.07	4.35	10.22
Pendimethalin+ imazethapyr ready mix) PE(750 + 50 g/ha)	4.60	200	13.11	33.7	1059	3.26	4.72	8.67
Imazethpyr + imazamox ready mix (70 g/ha)	4.37	209	14.52	32.6	631	3.39	3.10	10.67
Penoxsulam (Granite 21.7%)15 DAS(25 g/ha)	3.53	207	13.49	31.5	888	3.63	4.01	8.09
Atrazine 15 DAS (500 g/ha)	3.93	209	12.47	30.3	1012	3.53	4.46	11.55
Imazethapyr 15 DAS (100 g/ha)	0	0	0	0	0	0	0	0
Imazethpyr + imazamox ready-mix at 15 DAS (70 g/ha)	0	0	0	0	0	0	0	0
Weedy check	3.01	209	11.17	31.5	970	3.08	3.70	9.78
LSD (P=0.05)	0.79	11	1.06	2.58	398	0.50	1.06	2.92

*values in parentheses are original

ready mix and post-emergence application of penoxsulam produced the lower number of grains/ panicle as compared to other herbicides. Although pre-emergence application of pendimethalin + imazethapyr ready mix resulted in higher weed control efficiency (96.77%), the maximum grain yield of sorghum (5.87 t/ha) was recorded with tank mix application of atrazine + pendimethalin (500+750 g/ha) applied as pre-emergence. Atrazine as post-emergence produced lower grain yield (4.46 t/ha) as compared to its pre-emergence application (5.81 t/ha) due to lower efficacy on weeds. Tank mix pre-emergence application of pendimethalin + imazethapyr caused significant reduction in plant population (data not shown) and number of panicles/ m^2 compared to atrazine alone. This has resulted in significant reduction in grain yield. Although visual injury on sorghum plants with pre-emergence ready mix application of pendimethalin+ imazethapyr (Velore) and imazethpyr + imazamox (Odessey), and post-emergence application of penoxsulam was less severe and slight yellowing on leaves was observed, which recovered at harvest, but these herbicides produced lower grain yield due to reduction in number of grains/panicle. The lowest grain yield (3.1 t/ha) was recorded with pre-emergence application of imazethpyr + imazamox. Infestation of weeds throughout the cropping season caused 37 % reduction in grain yield. The yield components most reduced by weed competition are number of heads per plant, panicle size, and numbers of seeds per panicle or head (Hwang *et al.*, 2015). Similarly, penoxsulam applied as pre-emergence caused significant reduction in population and dry matter accumulation of weeds and produced higher grain yield as compared to its post-emergence application. Pre-emergence ready mix application of pendimethalin + imazethapyr (750 + 50 g/ha) was more effective in controlling weeds and increasing grain sorghum yield than its tank mix application (750 + 100 g/ha), due to phytotoxicity of higher dose of imazethapyr (100 g) in the tank mix, which resulted in lower plant population (data not shown) and number of panicles/m^2. Lower plant population of sorghum in tank mix application might have allowed more weeds to emerge and accumulate higher dry matter.

The study showed that tank mix application of atrazine + pendimethalin (500 + 750 g/ha) as pre-emergence effectively controlled the weeds and increased grain sorghum yields. New herbicide molecules *viz.*, penoxsulam, pendimethalin+ imazethapyr and imazethpyr+ imazamox, though effectively controlled the weeds but reduced the grain yield due to reduction in number of grains/panicle. Post-emergence application of imazethapyr and odessey was highly phytotoxic to sorghum.

SUMMARY

Bio-efficacy and phytotoxicity of pre-emergence tank mix application of atrazine + pendimethalin, pendimethalin + imazethapyr, ready mix application of pendimethalin+ imazethapyr (Velore), imazethpyr + imazamox (Odessey), penoxsulam, and post-emergence application of penoxsulam, atrazine, imazethapyr and imazethpyr +

imazamox along with standard pre-emergence herbicide atrazine were evaluated at ICAR-Indian Institute of Millet Research, Hyderabad during rainy season of 2014. The field was dominated with broad-leaved weeds (65.8%) followed by grasses (26.3%) and sedges (7.9%). Infestation of weeds throughout the cropping season caused 37 % reduction in grain yield. Post-emergence (15 DAS) application of imazethapyr and velore herbicides was highly phytotoxic and caused complete mortality of both sorghum plants and weeds at 2 weeks after herbicide application. Tank mix application of atrazine + pendimethalin (500 + 750 g/ha) as pre-emergence was safe and most effective in sorghum. Atrazine as post-emergence was less effective than its pre-emergence application. New herbicide molecules *viz*., penoxsulam, velore and odessey, though effectively controlled the weeds but reduced the grain yield due to reduction in number of grains/panicle.

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Short communication

Weed management in rainfed finger millet

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Finger millet (*Eleusine coracana* L. Gaertn) is an important *Kharif* season crop of small millet group cultivated in rainfed tracks of hilly region of Uttarakhand. Initial growth period of finger millet is subjected to heavy weed infestation resulting into higher competition and drastic reduction in yield (Pradhan *et al.* 2012, Patil *et al.* 2013). Finger millet is a high stature crop with slower initial growth which remains under smothering due to the infestation of weeds at early stages of growth. Pradhan *et al.* (2010) reported that weeds caused an appreciable reduction in crop density, dry weight and depletion of nutrients. Information on weed management in finger millet is limited, therefore, present experiment was carried out to study the effect of pre- and post-emergence herbicides and weed wiper on growth, productivity and economics of finger millet.

An experiment was carried out at Hawalbagh Experimental Farm of ICAR–Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora during rainy season of 2014. The soil was medium in available N (262 kg/ha) and P (13 kg/ha), high in available K (296 kg/ha) with pH 6.8. Finger millet cv. '*VL-324*' was sown on 21st June of 2014 at 20 cm wide rows. Half dose of N (20 kg/ha) along with full dose of P_2O_5 and K_2O (20 and 20 kg/ha) were applied as basal, and remaining N (20 kg/ha) was applied as top dressing after 30 days of sowing. Seven treatments involving weedy check, weed free, manual weedings at 20 and 40 days after sowing (DAS) were taken. Pendimethalin at 1.0 kg/ha and 2,4-D at 1.0 kg/ha was applied as pre-emergence (2 DAS) and post-emergence (30 DAS), respectively. Weed wiper (Singh *et al.* 2014), a mechanical tool to control inter-row weeds evaluated at the institute was taken as another treatment. Non-selective herbicide glyphosate at 2.0 l/ha in 400 l of water was used to wipe out weeds in between rows through the weed wiper. Fresh and dry weight of weeds was recorded by putting a quadrate (0.25 m^2) at three random spots in each plot at 60 DAS. Weed index was calculated on the basis of total dry weight of weeds at 60 DAS. Data on growth, yield attributes and economics were recorded and analysed statistically. Weed fresh and dry weight data were subjected to square root transformation and expressed in g/m^2. Gross income was calculated out by taking into account the main product and the byproduct. The prices of different produce per quintal used for calculation were: ₹1550/- for finger millet grains, ₹ 200/- for straw and ₹ 250/- per manday.

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Ageratum conyzoides, *Echinochloa colona* and *Eleusine indica* were found to be dominant weeds across the plots (Table 1). All treatments significantly reduced the weed fresh and dry weight compared to weedy check. Weedy check registered the highest fresh weight for *A. conyzoides* (13.7 g/m^2), *E. colona* (16.3 g/m^2), *E. indica* (7.8 g/m^2) and total fresh weight (23.1 g/m^2). Manual weedings at 20 and 40 DAS was found to be the best treatment in controlling weeds. Similarly, dry matter of weeds also reduced to varying magnitude under different weed management practices. Apart from weed-free plots manual weedings at 20 and 40 DAS resulted in to the lowest total weed dry matter (5.6 g/m^2). Manual weeding at 20 DAS (7.4 g/m^2), pre-emergence application of pendimethalin (8 g/m^2) and weed wiper (7.9 g/m^2) resulted in to total weed dry matter which was on par with each other. Apart from weed free plots, manual weedings at 20 and 40 DAS recorded higher weed index (82.0%) compared to rest of the treatments (Table 1). Glyphosate applied through weed wiper resulted into 63.7% WCI. also been reported by

All weed management practices significantly improved the growth and yield attributes of finger millet over weedy check (Table 2). Apart from weed free plots (2.35 t/ha) two hand weedings at 20 and 40 DAS (2.20 t/ha) resulted in higher grain yield followed by manual weeding at 20 DAS (2.02 t/ha). Herbicide application as pre-emergence, post-emergence and through weed wiper resulted in similar grain yields. Straw yield was highest (4.28 t/ha) in plots received manual weeding at 20 DAS. The

Table 1. Effect of different weed control measures on fresh weight, dry weight and weed control index at 60 DAS of finger millet

Treatment	Fresh weight (g/m^2) *A. conyzoides*	*E. colona*	*E. indica*	Others	Total fresh weight (g/m^2)	Total dry weight (g/m^2)	Total biomass (kg/ha)	WI (%)
Manual weeding at 20 DAS	4.9(24)	8.0(63.2)	7.4(54.2)	5.7(32.4)	13.2(173.8)	7.4(54.3)	41.7(1738)	68.5
Manual weeding at 20 and 40 DAS	0.7(0)	5.4(28.4)	5.9(34.4)	4.3(18)	9.0(80.8)	5.6(31.1)	28.4(808)	82.0
Pre-emergence pendimethalin at 1 kg/ha	5.1(26)	8.1(65.3)	7.3(52.6)	5.2(26.6)	13.1(170.5)	8.0(63.1)	41.3(1705)	63.3
2,4-D at 1.0 kg at 35 DAS	4.5(20)	7.0(48)	8.0(64.3)	5.7(32)	12.8(164.3)	8.3(68.5)	40.5(1643)	60.3
Weed wiper (glyphosate at 2.0 kg/ha) at 20 DAS	6.0(36)	7.9(62)	8.0(63.8)	5.1(26)	13.7(187.8)	7.9(62.6)	43.3(1878)	63.7
Weedy check	13.7(186)	16.3(264)	7.8(60)	4.9(24)	23.1(534)	13.1(172.3)	73.1(5340)	-
Weed free	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	0.7(0)	100.0
LSD (P=0.05)	0.5	0.8	0.6	0.5	1.2	0.7	3.8	-

*Data were transformed through square-root ($\sqrt{(x+0.5)}$) method, Figures in the parentheses are original values.

highest B:C ratio (1.39) was recorded in manual weeding at 20 DAS. Higher cost of cultivation in weed free plots and twice manual weeded plots due to engagement of more labourers for weeding. Weed wiper treated and weedy check plots recorded B:C ratio of 1.1 and 0.52 (Table 2). Similar B:C ratio in finger millet in Uttarakhand was also reported by Pant and Srivastava (2014).

Table 2. Effect of different weed control measures on grain yield and economics of finger millet

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	B:C ratio
Manual weeding at 20 DAS	2.02	4.28	1.39
Manual weeding at 20 and 40 DAS	2.20	4.09	1.30
Pre-emergence Pendimethalin at 1 kg/ha	1.59	3.72	1.29
2,4-D at 1.0 kg at 35 DAS	1.43	3.68	1.16
Weed wiper (glyphosate at 2.0 kg/ha) at 20 DAS	1.45	3.73	1.10
Weedy check	0.62	2.84	0.52
Weed free	2.35	3.99	1.29
LSD (P=0.05)	0.17	0.38	0.1

SUMMARY

A field experiment was conducted during rainy season of 2014 at Experimental Farm, Hawalbagh, Almora, to know the effect of weed management practices on weed index and grain yield of rainfed finger millet. All the weed control measures significantly reduced total weed dry weight and weed index as compared to that of weedy check. Manual weeding at 20 and 40 DAS (5.6 g/m^2) significantly lowered the total weed dry weight followed by manual weeding at 20 DAS (7.4 g/m^2). Weed dry matter recorded in weed wiper treated plots were at par with pre-emergence pendimethalin at 1 kg/ha and post-emergence 2,4-D at 1 kg/ha. Apart from weed free check highest weed index was found in manual weeding at 20 and 40 DAS (82.0%) followed by manual weeding at 20 DAS (68.5%). Grain yield was significantly higher in hand weeding twice (2200 kg/ha) followed by weeding once (2.02 t/ha). The highest B:C ratio was in manual weeding at 20 DAS (1.39).

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Short communication

Post-emergence herbicides for weed control in blackgram

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Key words: Blackgram, Hand weeding, Weed control efficiency, Weed dynamics, Weed index

Blackgram *(Vigna mungo)* is one of the most highly prized pulse crop, cultivated in almost all parts of India. It is the cheapest available source of protein for the poor and vegetarians. Blackgram popularly known as *urdbean* or *urd* has emerged as a potential *Kharif* pulse of Chhattisgarh. It is being grown in an area around 1.81 lakh ha with a production of 5.61 lakh tons which accounts for an average productivity of 315 kg/ha in the year 2008. The major districts growing blackgram in Chhattisgarh are Bastar (41.6% area), Jashpur (30.17%), Sarguja (28.73%) and Raigarh (18.47%) (Anonymous, 2005).

Weeds are major threat in *Kharif* season which adversely affect the yield. The extent of yield reduction depends upon the density of weed species, crop varieties, weather conditions and fertility of the soil. Various methods like cultural, mechanical, biological and chemicals are used for weed control. The chemical weed control method is becoming popular among the farmers.The efficacy of pre-plant incorporated and pre-emergence herbicides for weed control is reduced by various climatic and edaphic factors. The use of post-emergence herbicides alone or in combination may broaden the window of weed management by broad spectrum weed control . Keeping the above points in the present investigation was carried out.

The experiment was carried out during *Kharif* season 2009 in the Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The crop received 999.7 mm of rainfall during the entire growth period. The average monthly maximum temperature for different months varied from 30.7 ^{0}C to 32.3 ^{0}C, while monthly average minimum temperature ranged between 25.1^{0}C to 25.48 ^{0}C. The experiment was done in randomized block design with 14 treatments in three replications (Table 1). Variety *"TU 94-2"* was used in the study. Plant height, no. of leaves and branchs were taken from the five tagged plants from each plot. Weed control efficiency, weed index, harvest index was calculated as per the standard formulae.

Hand weeding twice at 20 and 40 DAS produced significantly taller plants as compared to others, though it was at par to fenoxaprop-p-ethyl at 60 g/ha + chlorimuron-ethyl at 4.0 g/ha and imazethapyr at 25 g/ha. The lowest plant height was recorded in unweeded check plot at all the time interval of observations (Table 1). During initial stage, different weed management practices, failed to show their significant impact. However, at later stage significantly maximum number of leaves/plant was noted with hand weeding twice (20 and 40 DAS), though at 60 DAS, it was at par to fenoxaprop-p-ethyl at 60 g/ha + chlorimuron-ethyl at 4.0 g/ha, imazethapyr at 25 g/ha, chlorimuron-ethyl at 4.0 g/ha and othr treatments

At harvest, the number of branches/plant was significantly higher under hand weeding twice (20 and 40 DAS) than rest of the treatment except imazethapyr at 25 g/ha. The lowest was recorded under unweeded check. At harvest, dry matter accumulation was significantly higher under hand weeding twice (20 and 40 DAS) and lowest under unweeded check followed by rest of the treatments. The number of nodules was increased from 25 to 50 DAS. At 50 DAS, hand weeding twice (20 and 40 DAS) produced significantly the highest number of nodules/plant, though it was at par to herbicde treatments. More nodules count in the above treatments might be due to greater infection of *Rhizobium* in the growing roots. At 50 DAS, hand weeding twice (20 and 40 DAS) gave significantly higher dry weight of nodules, which was at par to fenoxaprop-p-ethyl at 60 g/ha + chlorimuron-ethyl at 4.0 g/ha, imazethapyr at 25 g/ha and pendimethalin at 1.0 kg/ha *fb* quizalofop-p-ethyl at 37.5 g/ha + chlorimuron-ethyl at 4.0 g/ha. Low dry weight of nodule in unweeded check might be due to more crop-weed competition. These results were in agreement with the finding of Raman *et al.* (2005).

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Table 1. Effect of different herbicides on growth parameters of blackgram

Treatment	Dose (g/ha)	Time of application	Plant height at harvest (cm)	No. of leafs/ plant (at harvest)	No. of branches/ plant	Dry matter accumulation at harvest (g)	No. of nodule/ plant (50 DAS)	Dry weight of nodule/ plant (g) (50 DAS)
Pendimethalin	1000	2 DAS	43.6	19.3	5.44	8.99	35.7	30.0
Quizalofop-ethyl	37.5	20 DAS	41.2	18.4	5.33	8.44	34.3	29.0
Chlorimuron-ethyl	4.0	20 DAS	40.1	17.3	5.11	7.68	33.7	27.7
Fenoxaprop-p-ethyl	60.0	20 DAS	41.2	18.9	5.33	8.77	35.0	29.3
Quizalofop-ethyl + chlorimuron-ethyl	37.5+4.0	20 DAS	42.3	20.0	5.66	9.07	37.0	30.3
Fenoxaprop-p-ethyl + chlorimuron-ethyl	60+4.0	20 DAS	45.7	20.5	6.11	9.64	39.1	31.3
Imazethapyr	25	2 DAS	46.3	21.5	6.22	10.04	40.0	31.7
Chlorimuron-ethyl	4.0	1 DBS	42.0	21.0	5.44	9.23	35.3	29.7
Quizalofop-ethyl + chlorimuron-ethyl	37.5+4.0	35 DAS	39.4	16.3	5.11	7.60	33.4	26.0
Fenoxaprop-p-ethyl + chlorimuron-ethyl	60+4.0	35 DAS	41.7	20.3	5.88	9.35	34.0	28.7
Pendimethalin *fb* quizalofop-ethyl + chlorimuron-ethyl	1000 *fb* 37.5+4.0	2 *fb* 35 DAS	43.7	21.1	6.00	9.49	38.2	30.0
Pendimethalin *fb* fenoxaprop-p-ethyl + chlorimuron-ethyl	1000 *fb* 60+4.0	2 *fb* 35 DAS	43.2	17.8	5.00	9.42	37.3	30.7
Unweeded check	-	-	39.0	16.0	5.00	6.83	33.3	21.7
Hand weeding twice	-	20 and 40 DAS	47.0	22.0	6.77	10.66	40.3	31.0
LSD (P=0.05)			3.35	1.98	0.64	1.13	2.67	2.8

DAS = Days after sowing; DBS = Day before sowing, *fb* = Followed by

Significantly higher seed yield was obtained with hand weeding twice (20 and 40 DAS) (0.695 t/ ha) than rest of the treatments and the lowest was recorded under unweeded check (0.343 t/ha). The yield attributes *viz*., number of pods/plant, number of seeds/ plant, number of seeds/pod, 100-seed weight were higher with hand weeding twice (20 and 40 DAS) which contributed towards the higher seeds yield (Table 2) . The increase in yield attributes under hand weeding twice (20 and 40 DAS) was due to weed management from early crop growth and higher dry matter accumulation which resulted in greater translocation of food materials to the reproductive parts and reflected in superiority of yield attributing characters and ultimately to higher yield. The lower weed density and higher weed control efficiency also resulted in higher seed yield. Crop parameters like branch/plant (6.9), pods/plant (40.7), seeds/pod (11.5) was found highest under twice hand weeded treatment. Similar findings were also reported by Gogoi *et al.* (1991) and Raman *et al.* (2005).

Harvest index was significantly influenced by various weed management practices. The maximum harvest index (39.0%) was estimated under hand weeding twice (20 and 40 DAS) due to high economic yield *i.e.* seed yield in proportion to stover yield because of low crop-weed competition. The minimum harvest index (32.86%) was obtained in fenoxaprop-p-ethyl at 60 g/ha and unweeded check due to low seed yield and more crop-weed competition.

Weed index indicate the reduction in yield due to crop-weed competition as compared to hand weeding twice (20 and 40 DAS). The maximum seed yield reduction was found under unweeded check (50.69%) and fenoxaprop-p-ethyl at 60 g/ha due to the fact that there was minimum seed yield. Whereas minimum registered in imazethapyr at 25 g/ha and fenoxaprop-p-ethyl at 60 g/ha + chlorimuron-ethyl at 4.0 g/ha. The maximum weed index was estimated under unweeded check. The weed index was influenced due to all weed management practices. Similar observation was also reported by Yadav *et al.* (1997).

The weed growth rate increased from 20-40 DAS and minimum was noted during 60 DAS-harvest time intervals. During 60 DAS-harvest, application of pendimethalin at 1.0 kg/ha *fb* fenoxaprop-p-ethyl at 60 g/ha + chlorimuron-ethyl at 4.0 g/ha recorded the lowest weed growth rate followed by hand weeding twice (20 and 40 DAS), fenoxaprop-p-ethyl at 60 g/ ha, quizalofop-p-ethyl at 37.5 g/ha + chlorimuron-

Table 2. Effect of different herbicides on weed index, weed control efficiency, harvest index and seed yield on blackgram

Treatment	Dose (g/ha)	Time of application	Weed control efficiency (%)	Weed index	Harvest index	Seed yield (kg/ha)
Pendimethalin	1000	2 DAS	51.8	27.3	34.5	505
Quizalofop-ethyl	37.5	20 DAS	38.3	33.1	35.9	465
Chlorimuron-ethyl	4.0	20 DAS	32.7	44.6	33.9	385
Fenoxaprop-p-ethyl	60.0	20 DAS	46.4	49.6	33.8	350
Quizalofop-ethyl + chlorimuron-ethyl	37.5+4.0	20 DAS	56.5	25.2	34.6	520
Fenoxaprop-p-ethyl + chlorimuron-ethyl	60+4.0	20 DAS	64.4	13.6	37.3	600
Imazethapyr	25	2 DAS	69.6	12.2	37.4	610
Chlorimuron-ethyl	4.0	1 DBS	51.6	35.9	35.7	445
Quizalofop-ethyl + chlorimuron-ethyl	7.5+4.0	35 DAS	31.8	43.2	34.2	395
Fenoxaprop-p-ethyl + chlorimuron-ethyl	60+4.0	35 DAS	55.6	32.6	36.3	468
Pendimethalin *fb* quizalofop-ethyl + chlorimuron-ethyl	1000 *fb* 37.5+4.0	2 *fb* 35 DAS	65.1	18.7	36.9	565
Pendimethalin *fb* fenoxaprop-p-ethyl + hlorimuron-ethyl	*1000fb* 60+4.0	2 *fb* 35 DAS	67.3	16.5	37.3	580
Unweeded check	-	-	-	50.7	32.8	342
Hand weeding twice	-	20&40 DAS	71.4	-	39.0	695
LSD(P=0.05)			-	-	0.67	13

DAS = Days after sowing; DBS = Day before sowing, *fb* = Followed by

ethyl 4.0 g/ha, fenoxaprop-p-ethyl at 60 g/ha + chlorimuron-ethyl at 4.0 g/ha, imazethapyr at 25 g/ha and pendimethalin at 1.0 kg/ha *fb* fenoxaprop-p-ethyl at 60 g/ha + chlorimuron-ethyl at 4.0 g/ha. However, unweeded check gave the highest weed growth rate during all the time intervals.

The highest weed control efficiency, at harvest was witnessed under hand weeding twice (71.45%) followed by imazethapyr at 25 g/ha (69.63%) (Table 2). This was due to less dry matter production and density of weeds which resulted by successfully checking the weed growth in the above treatments. The minimum was found under quizalofop-p-ethyl at 37.5 g/ha + chlorimuron-ethyl at 4.0 g/ha (31.81%).

SUMMARY

Experiment was conducted in the Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during *Kharif* season 2009. The treatment comprised of 14 weed management practices and blackgram variety "*TU 94-2*". The results revealed that higher plant population, plant height, number of leaves, number of branches, dry matter accumulation, number of nodules, dry weight of nodules, crop growth rate, seed yield, weed growth rate, weed control efficiency and harvest index were obtained under hand weeding twice (20 and 40 DAS), followed by imazethapyr at 25 g/ha pre-emergence and minimum was obtained under unweeded check.

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Short communication

Management of complex weed flora in chickpea

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Key words: Chickpea, Herbicides, Metribuzin, Oxyfluorfen, Weed management

Chickpea (*Cicer arietinum* L.) is an important winter season pulse crop and a key source of protein. In India, chickpea is grown over an area of 8.52 million ha with production of 8.83 million tonnes and average productivity of 1.04 t/ha (Anonymous 2014). Among various barriers, poor weed management in chickpea is one of the most important yield limiting factors. Chickpea, being slow in its early growth and short stature plant, is highly susceptible to weed competition and often considerable losses may occur if weeds are not controlled at proper time. Weed infestation in winter pulses has been reported to offer serious competition and causes yield reduction to the extent of 75% in chickpea (Chaudhary *et al*. 2005). A critical period of 30 to 60 days is considered to be the crucial for crop-weed competition in chickpea (Kumar and Singh 2010). Weed management with herbicides is an effective, quick in action, and time saving method. Herbicide treatment gave 50-64% weed control with considerable increase in yield (Bhalla *et al.* 1998). Pendimethalin is extensively used as PE herbicide for weed management in chickpea field, but the efficacy of pendimethalin fluctuates according to the soil type, moisture regime and type of weed flora, and there is no recommended herbicide for chickpea. Therefore, there is a need to study the efficacy of non-recommended pre and PoE herbicides either alone or in combination for efficient weed management in chickpea in Chhattisgarh region.

A field experiment was conducted during *Rabi* season of 2013-14 at the Instructional Cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). The soil of experimental field was clayey in texture, low in nitrogen, medium in phosphorus and high in potassium contents with neutral pH. The experiment was laid out in randomized block design with 11 tratments in three replications. The chickpea variety *'JG-130'* was grown as test crop. The crop was sown on 25th November by seed cum fertilizer drill in rows at 30 cm apart with seed rate of 80 kg/ha and harvested in second week of March. A basal application of 20 kg N, 50 kg P_2O_5 and 30 kg/ha K_2O was given uniformly through DAP and MOP in all the experimental plots. After sowing of the seed immediately a light irrigation was given to the crop for uniform germination. Herbicides were applied as PE, early PoE and PoE by using knapsack sprayer fitted with flat fan nozzle by mixing in 500 liter of water/ha as per treatments. All the growth characters *viz*. plant height, number of branches, dry matter accumulation, number of pods, seed yield and stover yield, harvest index and weed index of chickpea crop were recorded and economics in terms of net return and benefit cost ratio were calculated with prevailing rates. Phytotoxicity of herbicides on chickpea was observed by quantitative visual assessment at 1, 3, 7 and 10 days after spraying of herbicides by using rating scale 0-10. Dehydrogenase activity of experimental field was measured by using UV/VIS Spectrophotometer with the wavelength of 485 nm. The total weed density and total dry matter production by weeds were also recorded and subjected to square root $\sqrt{x+0.5}$ transformation and statistically analyzed.

The dominant weed flora of the experimental field comprised of *Medicago denticulata* (41.9%), *Convolvulus arvensis* (23.7%), *Chenopodium album* (5.1%), *Melilotus indica* (5.0%), *Brachiaria mutica* (12.7%) and some other weeds (11.6%).

Different weed management practices significantly influenced the density and dry matter production of total weeds. Total and species wise weed density and dry matter production of *Medicago denticulata*, *Convolvulus arvensis*, *Chenopodium album, Melilotus indica* and *Brachiaria mutica* and some other weed species were recorded maximum under the control plot and minimum was observed under treatment of hand weeding twice at 25 and 45 DAS, followed by metribuzin at 250 g/ha as post-emergence (PoE) and oxyfluorfen + metribuzin at 125 + 350 g/ha as pre-emergence (PE). Similar results were observed by Patel *et al.* (2006), Kumar

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et al. (2008), Sadiq *et al.* (2011). Minimum weed index was registered under hand weeding twice at 25 and 45 DAS, followed by oxyfluorfen + metribuzin at 125 + 350 g/ha as PE and metribuzin at 250 g/ha as PE and maximum weed index (74.4%) was noticed under control plot (Table 1). Results revealed that the hand weeding twice at 25 and 45 DAS and herbicide combination of oxyfluorfen + metribuzin at 125 + 350 g/ha as PE were most effective in reducing density and dry weight of weeds with the weed control efficiency of 90.4 and 74.3%, respectively.

The significantly higher growth characters *viz.* plant height (cm), number of branches, dry matter accumulation (g/plant) were recorded significantly higher in hand weeding twice at 25 and 45 DAS, followed by the oxyfluorfen + metribuzin at 125 + 350 g/ha as PE and metribuzin at 250 g/ha as PE. Similar findings have been reported by Pedde *et al.* (2013), Tiwari and Meena (2014).

Among the herbicides, PE application of pendimethalin at 1000 g/ha, pendimethalin at 1250 g/ ha, pendimethalin at 1500 g/ha, pendimethalin (extra) at 1000 g/ha, oxyfluorfen at 125 g/ha, metribuzin at 250 g/ha and oxyfluorfen + metribuzin at 125 + 350 g/ha were found to be safe herbicides on chickpea and phytotoxic symptoms were not seen throughout its growth period from germination to harvest. Whereas, oxyfluorfen at 125 g/ha and metribuzin at 250 g/ha when applied as early PoE and PoE, respectively, showed adverse effects on chickpea crop. Light yellow discoloration on leaves was observed in 3 days after spraying of oxyfluorfen at 125 g/ha as early PoE and metribuzin at 250 g/ha as PoE, and scorching was also observed with the spraying of metribuzin at 250 g/ha applied as PoE. However, these symptoms vanished and crop was normal by 20 days after herbicide application.

Yield attributes of chickpea *viz.* number of pods/ plant, number of seeds/pod, 100 seed weight were recorded highest under hand weeding twice at 25 and 45 DAS, followed by oxyfluorfen + metribuzin at 125 + 350 g/ha as PE, but number of seeds/ pod and 100 seed weight did not influence significantly due to various weed management practices.

Significantly highest seed and stover yield registered under the treatment of hand weeding twice at 25 and 45 DAS, however, it was at par with the treatment of oxyfluorfen + metribuzin at 125 + 350 g/ ha as PE and metribuzin at 250 g/ha as PE. The minimum seed yield was recorded under control treatment. Among other herbicidal treatments, combination of oxyfluorfen + metribuzin at 125 + 350

Table 1. Density and dry matter accumulation of total weeds as influenced by different weed management practices at different growth stages

Treatment	Dose (g/ha)	Density of total weeds (no./m^2)			Dry matter of total weeds (g/m^2)			Weed control efficiency (%)
		40 DAS	60 DAS	At harvest	40 DAS	60 DAS	At harvest	
Pendimethalin as pre-emergence	1000	9.83 (96.3)	11.1 (123.0)	12.1 (145.3)	7.10 (49.9)	11. 8 (138.4)	15.8 (249.7)	34.6
Pendimethalin as pre-emergence	1250	8.72 (75.7)	9.82 (96.0)	11.26 (126.3)	6.43 (40.8)	10.9 (118.7)	14.4 (205.8)	46.1
Pendimethalin as pre-emergence	1500	8.45 (71.0)	9.04 (81.3)	10.82 (117.0)	6.02 (35.7)	10.5 (109.6)	13.18 (173.3)	54.6
Pendimethalin (extra) as pre-emergence	1000	10.9 (118.3)	11.5 (133.0)	13.1 (171.3)	7.37 (53.8)	12.6 (158.8)	16.5 (274.1)	28.3
Oxyfluorfen as pre-emergence	125	9.51 (90.0)	10.1 (102.7)	11.7 (137.0)	6.57 (42.9)	11.3 (126.3)	14.94 (223.0)	41.6
Metribuzin as pre-emergence	250	7.95 (62.7)	8.64 (74.3)	9.40 (88.0)	5.28 (27.4)	9.51 (90.1)	12.3 (152.0)	60.2
Oxyfluorfen + metribuzin as pre-emergence	125+350	7.25 (52.3)	7.96 (63.0)	8.52 (72.3)	4.72 (21.8)	7.68 (58.4)	9.91 (98.2)	74.3
Oxyfluorfen as early ost-emerence	125	11.31 (128.0)	12.61 (158.7)	13.8 (192.3)	7.63 (58.1)	12.8 (166.1)	16.7 (278.3)	27.2
Metribuzin as post-emergence	250	7.02 (49.0)	7.77 (60.0)	8.40 (70.0)	4.35 (18.1)	7.76 (58.2)	9.87 (97.0)	74.6
Control	-	13.43 (182.3)	15.2 (233.3)	16.5 (275.3)	10.5 (110.6)	15.8 (250.9)	19.5 (382.2)	-
Hand weeding twice at 25 and 45 DAS	-	3.56 (12.3)	4.49 (19.7)	5.49 (29.6)	2.43 (5.4)	4.22 (17.3)	6.09 (36.6)	90.4
LSD(P=0.05)		1.28	1.52	1.57	0.60	0.70	1.52	-

Figures in the parentheses are original values; data were transformed through $\sqrt{x + 0.5}$ which are given in bold

Table 2. Effect of weed management practices on yield attributes, yield and economics of chickpea

Treatment	Pods/ plant (no.)	100 seed weight (g)	Seed yield (t/ ha)	Stover yield (t/ha)	Harvest index (%)	Weed Index (%)	Net return (x10^3 `/ha)	B :C ratio
Pendimethalin 1000 g/ha as pre-emergence	39.8	25.9	1.09	1.53	41.1	38.1	8.60	1.36
Pendimethalin 1250 g/ha as pre-emergence	40.2	26.1	1.32	1.74	42.3	24.8	15.43	1.63
Pendimethalin 1500 g/ha as pre-emergence	44.1	26.3	1.38	1.79	42.9	21.7	16.76	1.68
Pendimethalin (extra) 38.7% CS at 1000 g/ha as pre-emergence	37.4	26.2	1.08	1.51	40.4	38.7	6.25	1.24
Oxyfluorfen 125 g/ha as pre-emergence	40.0	26.0	1.24	1.69	41.9	29.5	13.64	1.58
Metribuzin 250 g/ha as pre-emergence	45.2	26.4	1.51	1.94	43.2	14.0	22.11	1.95
Oxyfluorfen + metribuzin 125+350 g/ha as pre-emergence	47.8	26.7	1.68	2.12	43.5	4.7	25.88	2.05
Oxyfluorfen 125 g/ha early post-emergence	31.2	25.7	0.82	1.32	38.5	53.2	1.12	1.05
Metribuzin 70 WP at 250 g/ha as post-emergence	27.9	25.2	0.66	1.09	37.9	62.3	-3.38	0.86
Control	25.8	25.2	0.45	0.76	37.3	74.4	-8.87	0.60
Hand weeding twice at 25 and 45 DAS	50.4	27.1	1.76	0.214	43.8	-	25.46	1.93
LSD (P=0.05)	6.0	NS	0.25	0.32	4.1	-	-	-

g/ha as PE recorded 73.10 % higher seed yield over control plot. The maximum harvest index (43.80%) was estimated under hand weeding twice at 25 and 45 DAS, but, it was at par with the treatment of oxyfluorfen + metribuzin at 125 + 350 g/ha as PE, metribuzin at 250 g/ha as PE, pendimethalin at 1500 g/ha as PE, pendimethalin at 1250 g/ha as PE, oxyfluorfen at 250 g/ha as PE, pendimethalin at 1000 g/ha as PE and pendimethalin (extra) at 1000 g/ha as PE, respectively and minimum was recorded under control plot. Similar results were observed by Chaudhary *et al.* (2005), Hassan and Khan (2007) (Table 2).

Dehydrogenase activity (ìg TPF/h/g soil) of chickpea field was influenced significantly due to different weed management practices. At 50 DAS, significantly higher dehydrogenase activity was measured under the treatment of control plot, which was at par with the treatment of hand weeding twice at 25 and 45 DAS, pendimethalin at 1000 g/ha as PE, pendimethalin at 1250 g/ha as PE and pendimethalin (extra) at 1000 g/ha as PE, respectively. At harvest, significantly higher dehydrogenase activity was measured under the treatment of control plot, which was at par with treatment of hand weeding twice at 25 and 45 DAS, pendimethalin at 1000 g/ha as PE, pendimethalin at 1250 g/ha as PE, pendimethalin (extra) at 1000 g/ha as PE, pendimethalin at 1500 g/ha as PE, metribuzin at 250 g/ha as PE, oxyfluorfen at 125 g/ha as PE, oxyfluorfen + metribuzin at 125 + 350 g/ha as PE, respectively. The minimum dehydrogenase activity was measured under oxyfluorfen at 125 g/ha as early PoE followed by metribuzin at 250 g/ha as PoE. The minimum dehydrogenase activity under these treatments might be due to herbicidal toxic effects on microbial population (Table 3).

Table 3. Dehydrogenase activity (ìg TPF/h/g soil) of rhizosphere soil as affected by weed management practices of chickpea

Weed management practices	Dose (g/ha)	Dehydrogenase activity (µg TPF/h/g soil)	
		50 DAS	At harvest
Pendimethalin as PE	1000	62.3	25.9
Pendimethalin as PE	1250	61.1	25.4
Pendimethalin as PE	1500	59.2	24.7
Pendimethalin (extra) as PE	1000	60.6	25.1
Oxyfluorfen as PE	125	57.6	23.9
Metribuzin as PE	250	58.3	24.1
Oxyfluorfen+ Metribuzin as PE	125+350	57.2	23.4
Oxyfluorfen as early PoE	125	52.7	21.4
Metribuzin as PoE	250	53.6	22.1
Control	-	68.3	28.1
Hand weeding twice at 25 and 45 DAS	-	64.4	27.2
LSD (P=0.05)		8.24	4.71

Economics

Economics in terms of net return was recorded highest under oxyfluorfen + metribuzin at 125 + 350 g/ha as PE, followed by hand weeding twice at 25 and 45 DAS and metribuzin at 250 g/ha as PE. The highest benefit: cost ratio (2.05) recorded under the treatment of oxyfluorfen + metribuzin at 125 + 350 g/ ha as PE, followed by metribuzin at 250 g/ha as PE and hand weeding twice at 25 and 45 DAS, respectively. However, minimum gross return, net returns and benefit: cost ratio was obtained under control plot.

It may be concluded that oxyfluorfen + metribuzin at 125 + 350 g/ha as PE would be an appropriate combination of herbicides to achieve higher yield and B:C ratio of chickpea with lower density and dry weight of weeds without any phytotoxic effect on chickpea plant.

SUMMARY

A field experiment was conducted during *Rabi* season of 2013-14 at Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) to find out efficient herbicide combinations for weed management in chickpea. Further, significantly higher growth characters *viz*. plant height, number of branches, dry matter accumulation as well as yield attributes, seed yield, stover yield and harvest index were recorded under hand weeding twice at 25 and 45 DAS, which was at par with tank mix PE application of oxyfluorfen + metribuzin at 125 + 350 g/ha and registered an yield increase of 74.36 and 73.1%, respectively, over control. Metribuzin at 250 g/ha applied at 20 DAS and oxyfluorfen at 125 g/ha applied at 12 DAS showed phytotoxic effects on chickpea plants and recorded reduction in yield of 62.26 and 53.2%, respectively, over hand weeding twice at 25 and 45 DAS. Economics in terms of net return and B:C ratio recorded maximum under oxyfluorfen + metribuzin at 125 + 350 g/ha as PE. Dehydrogenase enzyme activity of experimental field was significantly maximum under control plot, followed by hand weeding twice at 25 and 45 DAS.

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Short communication

Integrated weed management for improved yield of soybean

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Soybean (*Glycine max* (L) Merrill) is one of the important oilseed crops of the Leguminaceae family having subfamily Papiliononaceae and genus *Glycine*. It has revolutionized the agricultural economy with its immense potential for food, fuel and numerous industrial products (Gandhi 2009). It is the cheapest source of protein, therefore it is called as "poor man's meat". The biology of some weeds that occur in soybean makes it difficult to achieve effective weed control with single application of herbicides (PPI or pre- or post-emergence. Hence in order to control weeds for a longer period of crop growth there is need to apply herbicides on sequential basis (Malik *et al.* 2006 and Vijayalaxmi *et al.* 2012). Some studies (Singh *et al.* 2004 and Malik *et al.* 2006) clearly indicated that sequential application of herbicides as pre-emergence followed by post-emergence will provide more consistent weed control than any one (single application) approach. A well planned pre- *fb* post will provide more consistent weed control and helps to solve some of the problems in post-emergence herbicides. New selective post emergence herbicide *viz.*,imazethapyr,fenoxaprop-p-ethyl, propaquizafop- ethyl resulted in less weed biomass and greater yield in soybean (Deore 2008). It has alos been reported that most of the selective herbicide do not control all weeds (Mohod 2002). Therefore integrated approaches of chemical and cultural control may be more feasible and practicable.

A field experiment was conducted during *Kharif* season of 2013-14 at research farm of Phule Krishi Vidyapith; Rahuri during *Kharif*, 2013-2014.The experiment was laid out in randomized block design with eight treatments replicated thrice with combination of pre- and post-emergence herbicide along with hand weeding and hand hoeing.

The soil of experimental field was silty clay with 7.66 pH.The data on weed count and dry weight of weed were analysed using square root $(\sqrt{x+1})$ transformatio.For economy study; prevailing market price was used for different output and inputs.

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Weed flora

Predominant weeds in experiment plot were *Commelina benghalensis*, *Acalypha cilliata*, *Achyranthus aspera*, *Euphorbia geniculata*, *Alternanthera triandra*, *Digera arvensis*, *Merremia emarginata*, *Physalis minima*, *Phyllanthus niruri*, *Parthenium hysteophorus* and *Digetaria arvensis*.

Weed growth

All the treatments resulted in significant reduction in weed density and weed biomass over unweeded control. Weed free check had lowest weed density and biomass. Among combination of herbicide with mechanical method, pre-emergence application of metribuzin at 2 DAS at 525 g/ha + 1 HW at 30 DAS, recorded the lowest weed density and biomass compared to other herbicide treatments, except pre- application of treatment pendimethalin at 2 DAS cs at 677.25 g/ha + 1 HW at 30 DAS, metribuzin at 2 DAS at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl as post-emergence at 20 DAS at 80 + 60 g/ha.

Highest weed control efficiency and lowest weed index were observed in weed free treatment. Among combination of herbicide with mechanical method, pre- application of treatment metribuzin at 2 DAS at 525 g/ha + 1 HW at 30 DAS (Gurjar *et al.* 2001, Kushwah and Vyas 2004) recorded the highest weed control efficiency and lowest weed index percentage over rest of herbicide treatments except pre-application of metribuzin at 2 DAS at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl as post-emeregnce at 20 DAS at 80+60 g/ha.This might be due to pre-emergence application of metribuzin, which prevented emergence of monocot and grassy weeds by inhibiting root and shoot growth while imazethpyr was responsible for inhibition of acetolactate synthases (ALS) or acetohydroxyacide

Table 1. Effect of different weed management practices on weed intensity, dry weight, weed index and weed control efficiency at harvest (pooled mean)

Treatment	Total weed density (number/m^2)	Weed biomass (g/m^2)	Weed index (%)	Weed control efficiency (%)
Pendimethalin pre- at 677.25 g/ha + 1 HW at 30 DAS	4.15 (16.3)	9.31(82.3)	10.9	83.2
Metribuzin post- at 525 g/ha + 1 HW at 30 DAS	3.91 (14.3)	9.04 (80.6)	3.7	85.2
Pendimethalin pre- at 677.25 g/hafb bentazone + fenoxaprop-p-ethyl post- at 1000 + 80 g/ha at 20 DAS	7.16 (50.2)	13.4 (178.6)	36.7	48.2
Metribuzin pre- at 525 g/ha *fb* bentazone + fenoxaprop-p-ethyl post- at 1000 + 80 g/ha at 20 DAS	5.45 (28.7)	9.8 (96.8)	16.2	70.4
Pendimethalin pre at 677.25 g/ha *fb* imazethapyr + propaquizafop-ethyl post- at 80 + 60 g/ha at 20 DAS	5.49 (29.2)	10.1 (100.2)	20.7	69.9
Metribuzin pre at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl post at 80 + 60 g/ha at 20 DAS	4.03 (15.2)	8.73 (75.2)	8.1	84.3
1 Hoeing at 15 DAS and 2 HW at 25 and 45 DAS (weed free)	1.95 (2.8)	2.23 (3.94)	-	97.1
Unweeded control	9.90 (96.9)	22.4 (500.3)	86.3	-
LSD (P=0.05)	0.62	0.95	2.5	9.4

Value given in parentheses are mean of original value, which are transformed to $(\sqrt{x+1})$

Table 2. Effect of weed control treatments on growth, yield attributing charactes, grain, stover yield and economics of soybean

Treatment	Plant height (cm)	No of pod/ plant	No of seed/ plant	Weight of seed/ plant	Test weigh (g)	Seed yeild (t/ha)	Stover yield (t/ha)	Net retun (x10^3 \` /ha)	B:C ratio
Pendimethalin pre- at 677.25 g/ha + 1 HW at 30 DAS	58.4	55.6	152.3	21.6	14.6	2.22	2.40	42.12	2.08
Metribuzin post- at 525 g/ha + 1 HW at 30 DAS	59.6	55.6	158.4	22.9	15.6	2.38	2.56	48.18	2.24
Pendimethalin pre- at 677.25 g/ha *fb* bentazone + fenoxaprop-p-ethyl post- at 1000 + 80 g/ha at 20 DAS	51.7	47.1	133.6	17.8	12.6	1.80	2.07	27.35	1.71
Metribuzin pre- at 525 g/ha *fb* bentazone + fenoxaprop-p-ethyl post- at 1000 + 80 g/ha at 20 DAS	57.2	52.0	148.1	21.0	14.2	2.12	2.32	39.35	2.03
Pendimethalin pre at 677.25 g/ha *fb* imazethapyr + propaquizafop-ethyl post- at 80 + 60 g/ha at 20 DAS	56.7	51.3	147.4	20.6	14.1	2.04	2.22	36.62	1.96
Metribuzin pre at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl post at 80 + 60 g/ha at 20 DAS	60.3	55.6	154.3	21.7	14.6	2.28	2.46	45.74	2.21
1 Hoeing at 15 DAS and 2 HW at 25 and 45 DAS (weed free)	62.6	57.3	161.8	23.5	15.8	2.47	2.60	47.20	2.10
Unweeded control	45.6	41.7	117.2	14.2	11.1	1.32	1.47	14.26	1.42
LSD (P=0.05)	4.9	4.9	13.2	2.4	1.4	0.06	0.06	6.19	0.20

synthesis (AHAS) in broad-leaves which caused destruction of these weeds in 3-4 leaf stage and remaining monocot weeds was control by propaquizafop-ethyl and hand weeding at 30 DAS Which was critical period of soybean crop. Lowest weed control efficiency and highest weed index was observed in unweeded control due to high weed competition for growth and yield factors. One hoeing at 15 DAS and two hand weeding at 25 and 45 DAS recorded highest WCE, lowest weed index, weed dry matter and weed population (Karande 2008).

Crop growth

Integrated weed management significantly affected soybean growth attributing characters and grain yield.One hoeing at 15 DAS and two hand weeding at 25 and 45 DAS as also reported by Sankaranarayan *et al.* (2002), Chintalwar (2004) was found singnifiantly best treatment among all treatments and pre- application of treatment pendimethalin at 2 DAS at 677.25 g/ha + 1 HW at 30 DAS, metribuzin sprayed at 2 DAS at 525 g/ha + 1 HW at 30 DAS, metribuzin at 2 DAS at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl as post- at 20 DAS at 80 + 60 g/ha was at par with it. This might be due to better control of weed in different stages of crop, manual weeding, interculture operation at critical stage of crop reduce crop weed competition and thereby providing better growth (plant height, branches/plant), yield attributing characters (no. of pod/plant, pod weight/plant, no of seed /plant, weight of seed/plant, test weight) and ultimately yield. The highest net monetory returns of ` 48181/ha was obtained in metribuzin at 2 DAS at 525 g/ha + 1 HW at 30 DAS. The highest benefit:cost ratio of 2.24 was observed in metribuzin at 2 DAS at 525 g/ha + 1 HW at 30 DAS,which was followed by metribuzin sprayed at 2 DAS at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl as post-emergence at 20 DAS at 80 + 60 g/ha (2.21) and one hoeing at 15 DAS and two hand weeding at 25 and 45 DAS (2.10). B:C ratio is high for herbicide treatment due to low cost of treatment as compare to mechanical method.It may be concluded that combination of herbicide and mechanical method was most effective for weed control in soybean. Metribuzin sprayed at 2 DAS at 525 g/ha + 1 HW at 30 DAS was found economical viable method of managing weeds in soybean.

SUMMARY

A field experiment was carried out on the silty clay soil at Mahatma Phule Krishi Vidyapith, Rahuri (Maharastra) during *Kharif* 2013-2014. One hoeing at 15 DAS and two hand weeding at 25 and 45 DAS best treatment in respect of growth attributing character and yield attributing characters. The weed dry matter and intensity was also lowest in one hoeing at 15 DAS and two hand weeding at 25 and 45 DAS, which was followed by pre-emergence application of metribuzin at 2 DAS at 525 g/ha + 1 HW at 30 DAS, PE application of treatment pendimethalin at 20 DAS cs at 677.25 g/ha + 1 HW at 30 DAS, metribuzin at 525 g/ha *fb* imazethapyr + propaquizafop-ethyl as post-aplication at 20 DAS at 80 + 60 g/ha. Metribuzin at 525 g/ha + 1 HW at 30 DAS was economic viable due to high B: C ratio and net return.

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Short communication

Efficacy of chlorimuron for controlling weeds in soybean

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Soybean is a crop of multiple qualities as it is both a pulse and oilseed crop. It is third largest oilseed crop of India after rapeseed-mustard and groundnut. In India, it is cultivated in 9.73 million hectares area with the annual production of 9.96 million tonnes. In Madhya Pradesh it is grown over an area of 5.35 million hectares with a production of 6.41 million tonnes which shows the dominance of soybean in M.P. during *Kharif*. Therefore, M.P. is known as soybean state in the country (IIOES 2010). The competition stress between weeds and crop for the nutrients, water, light and space are responsible for poor yield of soybean. One of the major reason for this poor performance is inadequate weed control. The excessive occurrence of weeds, limit the full expression of yield potential of crop, thus an early control of weeds in soybean is very essential and if it is not done, the yield losses may reach up to 43%. Hand weeding is one of the most efficient mean to control weeds in soybean, but it is time consuming and difficult due to unavailability of labours during peak period of demand. The weather-conditions may restrict the manual weed control. Use of mechanical weeding by hand hoe is also popular in the Malwa tract of the state. Secondly, the timing of herbicides application also much concern on weed control efficiency. Therefore, there is need to explore the possibility of pre and post emergence herbicides for effective weed control in soybean.

A field experiment was conducted at Product Testing Unit, Adhartal farm, Jawaharlal Nehru Kirshi Vishwa Vidyalaya, Jabalpur (M.P.) in *Kharif* season of 2012. The field selected for experimentation was fairly infested with location specific weeds representing to this area. Jabalpur is situated at 23^0 9' North latitude and 79^0 58' East longitudes with an altitude of 411.78 meters above the mean sea level. The total rainfall received during the crop season was 1542 mm, which was equally distributed in 54 rainy days from June to third week of November. Minimum and maximum mean temperature ranged from 11 ^{0}C to 32.8 ^{0}C respectively. The relative humidity ranged from 86 to 96% in morning and 24 to 85% in evening. The soil of the experimental field was clayey in texture, neutral in reaction (7.2), medium in organic carbon (0.60%), medium in available N (372 kg/ha), low in available P (16.40 kg P_2O_5/ha) and high in available K (293 kg K_2O/ha). The experiment consisted of nine treatments were laid out on well prepared seed bed in randomized block design with three replications. The herbicide spray solution was prepared by mixing the required quantity of herbicide in water at 500 litre/ha for each plot. Sowing of seed was done manually on July 12th, 2012. Before sowing, the seeds were treated with carbendazim at 2.0 g/kg of seeds followed by inoculation with *Rhizobium japonicum* culture at 5 g/kg of seeds. The rows were opened with the help of pick axe and later sowing was regulated for each plot using a seed rate of 70 kg/ha of *'JS 97-52'* variety of soybean. Sowing of seeds in each plots was done in rows 45 cm apart at the depth of 3-4 cm and then seeds were covered with fine soil and was harvested on 16 November, 2012. Full dose of major plant nutrients (20 kg N + 60 kg P_2O_5 + 20 kg K_2O/ha) was applied as basal application through urea, single super phosphate and murate of potash. The observations on density and dry weight of weeds were recorded at 45 DAS and harvest by quadrate count method. The quadrate of 0.25 m^2 (0.5 x 0.5 m) was randomly placed at four places in each plot and then the species wise and weed count was recorded. The data on weed count and weed biomass were subjected to square root transformation *i.e.* $\sqrt{x + 0.5}$, before carrying out analysis of variance and comparisons were made on transformed values. The net monetary returns (NMR) under each treatment was determined by substracting the cost of cultivation from GMR of the particular treatment.

The dominant weeds associated with soybean in the experimental field were among the monocots, the *Echinochloa colona* (26.27 and 21.18%) was the most dominant weed followed by *Cyperus iria* (11.59

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Table 1. Effect of chlorimuron-ethyl in different doses against weed density and dry weight (m^2) in soybean 45 DAS

Treatment	*Alternanthera philoxiroides*	*Echinoochloa colona*	*Eclipta alba*	*Commelina benghalensis*	*Cyperus iria*	Other weeds
Chlorimuron-ethyl 12 g/ha	2.8 (7.33)	6.52 (42.0)	1.71 (2.44)	1.47 (1.65)	2.84 (7.56)	5.08 (25.3)
Chlorimuron-ethyl 24 g/ha	2.57 (6.13)	5.98 (35.3)	1.53 (1.85)	1.43 (1.55)	2.92 (8.00)	5.38 (28.4)
Chlorimuron-ethyl 36 g/ha	2.55 (6.00)	5.88 (34.1)	1.52 (1.80)	1.42 (1.52)	2.85 (7.65)	5.15 (26.0)
Chlorimuron-ethyl 48 g/ha	2.54 (5.95)	5.71 (32.2)	1.46 (1.65)	1.40 (1.45)	2.72 (6.89)	5.09 (25.4)
Chlorimuron-ethyl 72 g/ha	2.53 (5.90)	5.53 (30.1)	1.38 (1.40)	1.38 (1.40)	2.17 (4.23)	5.05 (25.0)
Hand weeding (20 & 40 DAS)	0.71 (0.00)	2.91 (8.0)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
Mechanical weeding (20 DAS)	2.54 (5.93)	5.82 (33.3)	1.53 (1.85)	1.45 (1.60)	2.66 (6.58)	5.08 (25.3)
Chlorimuron-ethyl 24 g/ha + MW (40 DAS)	2.12 (4.01)	3.17 (9.5)	1.27 (1.11)	1.25 (1.07)	2.15 (4.12)	4.96 (24.1)
Weedy check	6.04 (35.9)	7.69 (58.6)	4.62 (20.80)	3.36 (10.7)	5.14 (25.80)	8.43 (70.6)
LSD(0.05)	0.16	0.13	0.09	0.08	0.11	0.10

Data subjected to $\sqrt{x+0.5}$ transformation and figure in parentheses are original values; DAS- Days after sowing

and 14.70%) and in dicot *Commelina benghalensis* (4.82 and 8.91%) at both the stages due to continuous germination of these weeds from seeds. By the mechanical method of weed control, hand weeding at 20 DAS controlled both monocot and dicot weeds. The application of chloimuron-ethyl at lowest dose 12 g/ha as early post emergence caused marginal reduction in density and dry weight of dicot weeds but reduction was more pronounced (in case of dicot weed only) when chlorimuron-ethyl was applied at highest dose 72 g/ha, but both monocot and dicot weeds effectively controlled when combined application of chlorimuron-ethyl 24 g/ha + mechanical weeding at 40 DAS, was applied. Similar views were also endorsed by several research workers (Halvankar *et al*. 2005). Hand weeding done at 20 and 40 DAS reduced the density including dry weight of weeds to maximum extent over herbicidal treatments due to elimination of short of weeds. Similar views were also endorsed by Veeramani *et al* (2000). The weed free treatment registered maximum weed control efficiency 100 and 97.3% at 45 DAS and harvest respectively than other treatments because of least dry matter production of the weeds over weedy check treatment. Subsequent application of chlorimuron-ethyl 24 g/ha along with mechanical weeding and gave the WCE of 83.0 and 79.2 % at 45 DAS and harvest respectively it was significant superior over other herbicidal treatments. These findings are in agreement with findings of Singh *et al* (2003).

Crop biomass and LAI

Weedy check had significantly lower crop biomass among all the treatments at harvest due to severe competition between crop and weeds for growth resources during critical period of crop growth. The increased crop biomass in plots receiving hand weeding (790.70 g/m^2) at harvest followed by combined application of chlorimuron-ethyl 24 g/ha + mechanical weeding (796.65 g/m^2) at harvest and chlorimuron-ethyl 72 g/ha (780.85 g/m^2) at harvest may be attributed to reduced weed competition as a result of effective control of weeds, which promoted the better growth and development of plants and ultimately produced higher biomass as compared to lower rate of chlorimuron-ethyl 12, 24, 36, 48 g/ha and mechanical weeding. The results are in close conformity with the findings of Singh *et al* (2004). LAI differed significantly due to different treatments at 60 days growth stage. At 60 days stage, maximum LAI was recorded in weed free treatment (6.04) followed by chlorimuron-ethyl 24g/ha + MW (40 DAS) (6.01). This may be because of better growth and development of foliage under weed free environment and consequently resulted in more assimilatory area per unit land area. Almost similar results were obtained by Shivakumar (1978).

Yield attributes, namely number of pods per plant and number of seeds per pod were significantly superior in the weed free treatment (154.06 and 2.67, respectively) than other treatments. Excellent growth and development of soybean plants under weed free environment during critical period of crop growth might have resulted in higher number of pods per plant and seeds per pod under weed free treatment as compared to weedy check, which had severe weed competition right from early growth stages and ultimately resulted in most inferior yield attributes. Combined application of chlorimuron-ethyl 24 g/ha + mechanical weeding as early post-emergence produced higher number of pods per plant and seeds per pod as (151.64 and 2.61), respectively as compared to other treatments on account of

Table 2. Effect of chlorimuron-ethyl in different doses against weeds dry weight (g/m²) in soybean

Treatment	*Alternanthera philoxiroides*		*Echinochloa colona*		*Eclipta alba*		*Commelina benghalensis*		*Cyperus iria*		Other weed	
	Before	Harvest	Before	Harvest	Before	Harvest	Before	Harvest	Before	Harvest	Before	Harvest
Chlorimuron-ethyl 12 g/ha	4.40 (18.8)	3.18 (9.61)	5.38 (28.4)	4.69 (21.5)	3.62 (12.6)	3.22 (9.86)	4.62 (20.9)	3.56 (12.2)	4.51 (19.8)	4.35 (18.4)	5.67 (31.6)	4.33 (18.7)
Chlorimuron-ethyl 24 g/ha	4.32 (18.1)	3.01 (8.59)	5.46 (29.3)	4.63 (20.9)	3.76 (13.6)	2.92 (8.00)	4.63 (20.9)	3.28 (10.3)	4.63 (20.9)	4.10 (16.3)	5.58 (30.7)	4.11 (16.4)
Chlorimuron-ethyl 36 g/ha	4.38 (18.6)	2.83 (7.49)	5.47 (29.6)	4.58 (20.5)	3.67 (13.0)	2.84 (7.60)	4.61 (20.8)	3.28 (10.2)	4.61 (20.8)	3.88 (14.5)	5.65 (31.4)	4.16 (16.8)
Chlorimuron-ethyl 48 g/ha	4.26 (17.6)	2.71 (6.85)	5.35 (28.1)	4.52 (19.9)	3.68 (13.0)	2.74 (7.00)	4.56 (20.3)	3.27 (10.2)	4.53 (20.1)	3.67 (13.0)	5.57 (30.5)	4.04 (15.9)
Chlorimuron-ethyl 72 g/ha	4.16 (16.8)	2.63 (6.40)	5.27 (27.3)	4.50 (19.7)	3.62 (12.6)	2.72 (6.90)	4.47 (19.5)	3.23 (9.93)	4.64 (21.1)	3.60 (12.5)	5.62 (31.0)	3.88 (14.5)
Hand weeding (20 and 40 DAS)	4.24 (17.5)	1.92 (3.20)	5.35 (28.1)	1.32 (1.25)	3.65 (12.5)	1.22 (1.00)	4.53 (20.0)	1.09 (0.70)	4.50 (20.0)	1.41 (1.50)	5.68 (31.8)	1.16 (0.85)
Mechanical weeding (20 DAS)	4.22 (17.3)	2.82 (7.48)	5.32 (27.8)	4.52 (19.9)	3.61 (13.2)	3.00 (8.53)	4.49 (19.7)	3.29 (10.3)	4.63 (20.9)	3.95 (15.1)	5.63 (31.1)	4.16 (16.8)
Chlorimuron-ethyl 24 g/ha + MW (40 DAS)	4.12 (16.5)	2.61 (6.29)	5.43 (29.0)	4.26 (17.7)	3.70 (13.1)	2.64 (6.46)	4.53 (20.0)	3.19 (9.66)	4.54 (20.1)	3.56 (12.2)	5.71 (32.2)	3.80 (14.0)
Weedy check	4.32 (18.2)	7.14 (50.4)	5.34 (28.0)	7.46 (55.2)	3.68 (12.9)	7.12 (50.1)	4.52 (19.9)	6.98 (48.3)	4.54 (20.1)	7.12 (50.2)	5.63 (31.2)	8.12 (65.5)
LSD (P=0.05)	0.17	0.12	0.28	0.09	0.06	0.15	0.14	0.13	0.12	0.16	0.05	0.14

Data subjected to $\sqrt{x+0.5}$ transformation and figure in parenthesis are original values; DAS- Days after sowing

Table 3. Influence of weed control treatments on yield attributes, yield, LAI, weed control efficiency, weed index and economics of soybean

Treatment	Pods/ plant	Seeds/ pod	Crop biomass (g/m²)	Weed control efficiency (%)	Seed yield (t/ha)	Stover yield (t/ha)	LAI at 60 DAS	Weed index	GMR (x10³ `/ha)	NMR (x10³ `/ha)
Chlorimuron-ethyl 12 g/ha	130.9	2.20	746.3	71.9	11.8	2.91	4.45	30.2	28.99	11.13
Chlorimuron-ethyl 24 g/ha	146.6	2.33	758.2	74.8	14.9	3.19	4.75	12.4	35.75	17.87
Chlorimuron-ethyl 36 g/ha	150.4	2.37	767.0	75.8	15.1	3.23	4.85	11	36.43	18.53
Chlorimuron-ethyl 48 g/ha	151.7	2.38	774.7	77.2	15.2	3.24	5.23	10.4	36.71	18.78
Chlorimuron-ethyl 72 g/ha	153.1	2.40	780.8	78.1	15.3	3.26	5.66	9.7	37.05	19.06
Hand weeding (20 and 40 DAS)	154.1	2.67	790.7	97.3	17.0	3.49	6.04	0	41.14	20.01
Mechanical weeding (20 DAS)	147.0	2.45	762.8	75.5	14.9	3.25	5.32	12.2	35.85	15.92
Chlorimuron-ethyl24 g/ha + MW (40 DAS)	151.6	2.61	796.6	79.2	16.1	3.40	6.01	5.3	38.86	20.02
Weedy check	130.9	2.00	719.2	0	10.9	2.7	4.00	36	26.60	9.07
LSD(P=0.05)	0.58	0.46	20.83	-	1.47	0.08	0.05	_		

LAI: Leaf area index; GMR: Gross monetary returns; NMR: Net monetary returns

maximum reduction in weed growth coupled with no inhibitory effects on soybean plants. Almost similar results were obtained by Raghuwanshi *et al.* (2005).

Minimum weed index among herbicidal treatments was recorded under chorimuron-ethyl 24 g/ha + MW (40 DAS) (5.3%) which was almost similar to weed free treatment, closely followed by chlorimuron-ethyl (9.7%). Weed free treatment produced the maximum seed yield (1.70 t/ha) and proved its superiority over all the treatments. Among herbicidal treatments, combined application of 24 g/ha + mechanical weeding resulted in higher seed yield (1.61 t/ha) which was higher to other herbicidal treatment because of relatively low stress and better yield attributes. Application of chlorimuron-ethyl at highest dose 72 and 48 g/ha also produced significantly higher yield (1.53 and 1.52 t/ha respectively) over application of chlorimuron-ethyl 12, 24, 36 g/ha and mechanical weeding. This may be because of selectivity of these herbicides to either monocots or dicots, resulted in poor control of weeds might have failed to arrest the weed growth, this led to record lower yield attributing traits and consequently poor seed yield. Almost similar results were obtained by Singh *et al* (2006). All the treated plots produced significantly higher stover yield than weedy check (2.70 t/ha). Stover yield was increased with the increased application rates of chlorimuron-ethyl 12, 24, 36, 48, 72 g/ha and when combined application of chlorimuron-ethyl 24 g/ha + mechanical weeding was applied stover yield was increases at higher magnitude. However, weed free plots registered the highest stover yield (3.49 t/ha) and was significantly superior to all the treatments.

Highest weed index was recorded under weed free treatment (0.00%). The gross monetary returns (GMR) and net monetary returns were minimum under weedy check because of the lowest seed and stover yields. But it were increased to a maximum level under weed free treatments received two hand weeding closely. The application of combined application of chlorimuron-ethyl 24 g/ha + mechanical weeding and chlorimuron-ethyl at highest dose 72 g/ha, chlorimuron-ethyl 12, 24, 36, 48 g/ha and mechanical weeding also found superior and fetched the greater GMR over weedy check because of increased seed and stover yields of the soybean. Net monetary returns was increased to a maximum level under weed free treatment closely followed by chlorimuron-ethyl 24g/ha + MW (40 DAS) and chlorimuron-ethyl 72g/ha, respectively. The low investment and better seed and stover yields coupled with good economic returns might be the reason for higher NMR over remaining treatments. Pandya *et al* (2005) also reported maximum NMR under hand weeding treatment.

SUMMARY

The field was infested with monocot weeds like *Echinochloa colona, Cyperus iria* whereas dicot weeds *Alternanthera philoxiroides, Eclipta alba, Commelina benghalensis and Phyllanthus niruri* were less dominant in soybean. The application of Chlorimuron-ethyl 24 g/ha as early post-emergence along with mechanical weeding was most effective in paralyzing the weed growth to that of chlorimuron-ethyl (12, 24, 36, 48 and 72 g/ha) and mechanical weeding at 20 DAS. The application of chlorimuron-ethyl herbicide at 24 g/ha as early post-emergence along with mechanical weeding was significant superior for growth parameters, yield attributes and seed yield (1.61 t/ha) of soybean than rest of the treatments without any phytotoxicity on soybean plants and was found more remunerative in terms of NMR (` 20023.8) and B-C ratio (2.06) than application of chlorimuron-ethyl herbicide at 12 g/ha to 72 g/ha, as early post-emergence. Two hand weedings (20 and 40 DAS) proved to be the best in terms of yield (1.69 t/ha grain, 3.49 t/ha stover); however, NMR (` 20011.7/ha) was almost at par to chlorimuron 24 g along with mechanical weeding (` 20023.8/ha).

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Short communication

Effect of weed control on growth and productivity of soybean

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Soybean (*Glycine max* L.) is a "Golden bean" of 21st century mainly due to its high protein (40%) and oil (20%) content and is now making headway in Indian Agriculture. Heavy infestation of weeds with grasses, broad-leaved and sedges poses a big challenge for soybean production. Initial slow growth of this crop coupled with little lateral spread increases opportunity for weeds to easily occupy vacant spaces between rows and offer serious competition with the crop. Good sunshine and intermittent rains during rainy season further provides congenial environment for excessive growth of weeds. Simultaneous emergence and rapid growth of large number of weed species caused severe crop-weed competitions and reduces crop yields to the extent of 30-80% depending on the type of weed flora and weed density (Kurchania *et al*. 2001). The effective and economic weed control may not be possible through manual or mechanical means due to heavy and continuous rainfall in *Kharif,* increasing labour wages and their shortages. Under such circumstances, use of effective weed control treatments may give better and timely weed control.

A field experiment was carried out at research farm of Rajasthan College of Agriculture, Udaipur during *Kharif* 2014. The experimental soil was clay loam, alkaline, medium in nitrogen and phosphorus and high in potassium. The experiment was carried out in randomized block design (RBD) with 14 treatments, *viz*. weedy check, pendimethalin 0.75 kg/ha pre-emergence and in combination with hand weeding 30 DAS, metribuzin 0.75 kg/ha pre-emergence and in combination with hand weeding 30 DAS, fenoxaprop-p-ethyl 0.075 kg/ha, imazethapyr 0.1 kg/ha, sequential application of pendimethalin and metribuzin with fenoxaprop-p-ethyl and imazethapyr, one hand weeding 20 DAS, two hand weeding 15 and 30 DAS and weed free up to 50 days stage of crop and these treatments replicated thrice. Soybean variety 'J*S-9560*' was sown at 30 cm row spacing using 80 kg seed/ha. Sowing was done on 16 July 2014 and crop was sown by using package of practices of south-east Rajasthan. Dominant weed flora of the experiment field was *Amaranthus viridis, Commelina benghalensis, Parthenium hysterophorus, Trianthema portulacastrum, Digera arvensis, Cynodon dactylon, Echinochloa colona* and *Cyperus rotundus*.

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All the growth parameters *viz*. plant height, crop dry matter, leaf area index and branches/plant were significantly influenced by all the weed management treatments. Weed free treatment recorded the maximum plant height, crop dry matter, leaf area index and branches/ at different stages of observation which was closely followed by pre-emergence application of pendimethalin 0.75 kg/ha as pre-emergence + hand weeding 30 DAS and two hand weeding 15 and 30 DAS treatments (Table 1). More dry matter accumulation by the crop under weeded crop seems to be a direct effect of greater penetration of solar radiation in the crop canopy which resulted into greater rate of photosynthesis and subsequently more accumulation of dry matter. Further, in legumes nodulation plays a vital role in fixation of atmospheric nitrogen which is utilized by plants for various enzymatic processes resulting in enhanced carbohydrate and protein contents which are of prime importance for plant growth.

Yield attributing characters *viz*. pods/plant, number of grains per pod, hundred seed weight and pod length were significantly influenced by weed management practices (Table 2). Maximum number of pods/plant, number of grains/pod, hundred seed weight and pod length were observed with weed free treatment which was closely followed by pendimethalin 0.75 kg/ha PE + hand weeding 30 DAS and two hand weeding 15 and 30 DAS treatment. It can be stated from the above finding that, though pods/plant, number of grains/pod, hundred seed weight and pod length is a varietal character but tremendous weed infestation caused stress to the crop plant with respect to nutrient, light, moisture, space and other various aspects related to

Table 1. Effect of weed management treatments on growth parameter of soybean

Treatment	Plant height (cm)			Branches/plant 75 DAS	Dry matter accumulation (g/plant)			Leaf area index		
	50 DAS	75 DAS	At Harvest		50 DAS	75 DAS	At harvest	25 DAS	50 DAS	75 DAS
Weedy check	31.0	44.1	46.3	4.29	7.9	18.1	22.3	1.26	2.68	4.75
Pendimethalin 750 g/ha PE	29.9	43.7	44.7	4.08	7.9	17.4	21.4	1.22	2.60	4.67
Metribuzin 350 g/ha PE	31.3	42.8	43.8	4.11	8.0	18.6	24.6	1.15	2.53	4.53
Fenoxaprop-p-ethyl 75 g/ha POE	31.5	43.9	46.9	4.20	8.0	18.7	23.8	1.26	2.75	4.82
Imazethapyr 100 g/haPOE	41.1	55.3	58.0	5.99	11.3	24.8	31.0	1.20	3.91	6.17
Pendimethalin + HW 30 DAS	39.5	52.9	56.3	4.93	9.8	22.0	29.2	1.18	3.65	5.84
Metribuzin 350 g/ha + HW 30 DAS	38.5	51.6	53.5	4.79	9.8	21.6	27.4	1.51	3.33	5.67
Pendimethalin 750 g/ha+ Fenoxaprop-p-ethyl POE	39.3	52.5	55.2	4.83	9.9	22.2	29.8	1.58	3.49	5.80
Pendimethalin 750 g/ha+ Imazethapyr POE	38.3	50.4	54.4	4.80	9.7	21.4	28.0	1.48	3.43	5.66
Metribuzin 350 g/ha + Fenoxaprop-p-ethyl POE	38.4	52.2	54.9	4.93	9.7	22.0	28.4	1.50	3.31	5.41
Metribuzin 350 g/ha + Imazethapyr POE	28.4	37.6	38.3	3.39	5.8	12.7	15.6	0.95	2.11	3.84
One hand weeding at 20 DAS	36.1	46.2	49.1	4.72	9.1	20.1	25.4	1.39	3.00	4.97
Two hand weeding 15 and 30 DAS	39.7	53.6	56.5	5.32	11.2	23.6	30.6	1.72	3.78	6.04
Weed free	42.3	57.2	59.7	6.33	13.6	27.2	32.2	1.85	4.06	6.78
LSD (P=0.05)	5.7	7.0	8.6	0.4	1.10	2.5	3.5	0.09	0.21	0.34

Table 2. Effect of weed management treatments on yield and economics of soybean

Treatment	Pods /plant	Seeds /pod	Pod length (cm)	Seed index (g)	Weed control efficiency (%)	Yield (t/ha)			Harvest index (%)	Net returns (x10^3 `/ha)	B:C ratio
						Seed	Haulm	Biolo-gical			
Pendimethalin 750 g/ha PE	23.6	2.7	4.53	11.9	57.7	0.91	2.08	30.0	30.5	15.1	1.80
Metribuzin 350 g/ha PE	24.3	2.6	4.59	11.2	58.9	0.83	1.90	2.74	30.4	12.5	1.68
Fenoxaprop-p-ethyl 75 g/ha POE	24.7	2.7	4.72	11.5	59.8	100	2.29	3.29	30.5	18.0	1.94
Imazethapyr 100 g/haPOE	25.6	2.7	4.75	11.8	61.6	1.04	2.38	3.42	30.5	19.2	1.98
Pendimethalin + HW 30 DAS	32.3	3.2	5.00	12.9	76.9	1.38	3.04	4.42	31.1	29.5	2.38
Metribuzin 350 g/ha + HW 30 DAS	27.7	3.0	4.92	12.5	71.0	1.13	2.57	3.70	30.5	21.0	2.00
Pendimethalin 750 g/ha+ Fenoxaprop-p-ethyl POE	26.3	2.9	4.86	12.1	69.7	1.18	2.69	3.87	30.5	23.2	2.12
Pendimethalin 750 g/ha+ Imazethapyr POE	29.0	3.0	4.92	12.8	71.5	1.23	2.79	4.02	30.6	24.7	2.17
Metribuzin 350 g/ha + Fenoxaprop-p-ethyl POE	28.8	2.9	4.89	12.6	70.0	1.13	2.57	3.70	30.5	21.6	2.06
Metribuzin 350 g/ha + Imazethapyr POE	29.2	2.9	4.85	12.0	69.8	1.18	2.71	3.89	30.4	23.4	2.13
One hand weeding at 20 DAS	28.8	2.8	4.83	12.3	66.6	1.12	2.54	3.65	30.5	21.5	2.08
Two hand weeding 15 and 30 DAS	31.7	3.1	4.95	12.9	74.5	1.32	2.90	4.22	31.3	27.2	2.26
Weed free	33.0	3.4	5.05	13.6	92.1	1.42	3.10	4.52	31.4	26.7	2.04
Weedy check	17.9	2.1	4.12	10.5	-	0.52	1.36	1.88	27.7	2.34	1.13
LSD (P=0.05)	1.8	0.20	0.30	0.79	-	0.21	0.40	0.48	NS	-	-

physiological process of crop plant and thus enforced the crop to have the less number of pods per plant and this was highly evident in weedy check treatments.

Data (Table 2) indicated that all the weed control treatments brought about significant improvement in yield of soybean over weedy check. Highest grain (1.42 t/ha) and haulm yields (3.10 t/ha) were recorded in weed free treatment which was followed by pendimethalin 0.75 kg/ha + hand weeding 30 DAS (1.38 t/ha and 3.04 t/ha, respectively). From the result, it is evident that higher weed infestation is responsible for reducing seed yield. Maximum harvest index was recorded under weed free treatment (31.43%), which was closely followed by two hand weeding and pendimethalin 0.75 kg/ha + hand weeding 30 DAS with the respective harvest index value as 31.31 and 31.13%. The lowest yield reported in the weedy check was probably due to fact that crop faced the tremendous competition with vigorous weed infestation. Pendimethalin 0.75 kg/ha + hand weeding 30 DAS was the next best treatment after weed free because emergence of early growth of weeds was inhibited by pre-emergence application of pendimethalin and the late emerging weeds were effectively controlled by hand weeding performed 30 DAS. Consequently, the crop attained luxuriant growth and suppressed the future weed flushes. These results are in close conformity with those reported by Tuti and Das (2011).

Highest net returns and B:C ratio was noted in pendimethalin 0.75 kg/ha + hand weeding 30 DAS owing to higher seed yield and comparatively lower cost under this treatment (Table 2) because pre-emergence application of pendimethalin prevented the seedling growth of grasses in the early stages followed by one hand weeding 30 DAS gave a less or negligible competition to the crop. Though weed free treatment recorded highest yield but it failed to obtain most profitable result with respect to net return and B-C ratio due to higher labour wages. Similar findings were obtained by Verma *et al.* 2013.

SUMMARY

A field experiment was carried out at research farm of Rajasthan College of Agriculture, Udaipur during *Kharif* 2014 in randomized block design (RBD) with 14 treatments pre-emergence application of pendimethalin 0.75 kg/ha + hand weeding 30 DAS resulted broad spectrum of weed control besides gives higher grain yield. This weed management method found to be promising to control weeds of soybean crop and would play an important role in areas where labour is too expensive and time is a constraint.

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Short communication

Weed management with pre- and post-emergence herbicides in linseed

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Key words: Herbicide, Linseed, Pre- and post-emergence, Weed control

India is an important linseed growing country in the world and it contributes 7% to the world linseed pool. At present, linseed is cultivated in about 500 thousand hectares with a contribution of 130 thousand tones to the annual oilseed production of the country. Its average productivity is 260 kg/ha. Madhya Pradesh has largest growing area (1.26 lakh ha) and production (0.48 lakh tones) with 382 kg/ha productivity (Anonymous 2010). The crop is being grown under input starve condition by the resource poor farmers in Indo-Gangatic plain, central and peninsular region of the country. Weeds are one of the major constraints in linseed production and yield losses due to weed infestation in linseed were 36% (Singh *et al.* 1992). Hence, the present study was aimed to find out the efficacy of pre and post emergence herbicides for weed management in linseed.

A field experiment was conducted during 2013-14 at the research farm of College of Agriculture, JNKVV, Tikamgarh (M.P.) on clay loam soil, which was medium in organic carbon, low in available nitrogen and phosphorus but medium in potassium content having neutral pH and normal electrical conductivity. The experiment was laid out in randomized block design with nine treatments, replicated thrice. The linseed variety "*JLT-26*" was sown with seed rate of 30 kg/ha in rows 30 cm apart with fertilizer dose of 80:40:20 kg/ha. Pre-emergence herbicides were applied on next day of sowing and post-emergence herbicides were applied at 2-3 leaf stage of weeds. Weed intensity and dry weight was recorded at 40 DAS of crop growth and weed control efficiency was worked out by dry weight of weeds at harvest.

Weed flora

The prevalence of dicot weeds were found in experimental field constituted the higher relative density (67.7%) as compared to monocot weeds which had only 18.0% relative density. In the dicot weeds, the intensity of *Chenopodium album* was the highest (22.9%) followed by *Convolvulus arvensis* (13.5%) and *Melilotus officinalis* (10.2%) whereas *Cynodon dactylon* was found as dominant monocot weed in the field with relative density of 19.6%.

Weed growth

Density and dry weight of weeds were significantly reduced by all the herbicidal treatments and hand weeding over weedy check (5.04 g/m^2). The significantly lowest weed density and dry weight of weeds was recorded under hand weeding twice at 20 and 40 DAS followed by pendimethalin 1.0 kg/ha + imazethapyr 1.0 kg/ha and pendimethalin 1.0 kg/ha + imazethapyr at 0.75 kg/ha. Application of imazethapyr at 100 g/ha, imazethapyr at 0.75 kg/ha and pendimethalin 1.0 kg/ha registered reduced density and dry weight of weeds over isoproturon at 1.0 kg/ha and clodinafop at 60 g/ha, whereas the highest dry weight of weeds recorded under weedy check (5.04 g/m^2). The highest weed control efficiency was recorded under hand weeding twice at 20 and 40 DAS (87.2%) followed by pendimethalin 1.0 kg/ha+ imazethapyr 1.0 kg/ha (83.41%) and pendimethalin 1.0 kg/ha + imazethapyr 0.75 kg/ha (Table 1).

Yield attributes and economics

The highest yield attributes was recorded under hand weeding twice at 20 and 40 DAS followed by pendimethalin 1.0 kg/ha + imazethapyr 1.0 kg/ha and pendimethalin at 0.75 kg/ha + imazethapyr at 0.75 kg/ha apparently owing to higher weed control efficiency under these treatments.

All the weed control treatments recorded significantly higher seed yield over weedy check (1.37 t/ha), whereas the hand weeding twice at 20 and 40 DAS registered significantly the higher seed yield (2.00 t/ha) among all the treatments and was at par with pendimethalin 1.0 kg/ha + imazethapyr 1.0 kg/ha (1.92 t/ha). The results were in line with the findings of Sharma *et al.* (1997) who reported that hand weeding twice reduced the total weed intensity as compared weedy check in linseed.

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Table 1. Effect of herbicides on weed intensity, weed dry weight, weed control efficiency, yield attributes, seed yield and economics of linseed

Treatment	Weed intensity (no./m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)	Number of capsules/ plant	Number of seeds capsule	Test weight (g)	Seed yield (t/ha)	Net monetary return (x10^3 ` /ha)	B:C ratio
Pendimethalin at 1.0 kg/ha (pre-emergence)	3.63 (12.71)	2.70 (6.83)	69.60	142.53	7.60	6.07	1.69	54.05	4.03
Pendimethalin at 1.0 kg/ha + imazethapyr at 0.75 kg/ha (pre-emergence)	2.85 (7.67)	1.83 (2.85)	82.71	153.53	8.10	6.20	1.85	54.69	2.82
Pendimethalin at 1.0 kg/ha + imazethapyr at 1.0 kg/ha (pre-emergence)	2.65 (6.61)	1.67 (2.30)	83.41	153.67	8.40	6.50	1.92	56.03	2.68
Isoproturon at 1.0 kg/ha at 2-3 leaf stage of weeds	4.43 (19.11)	3.55 (12.13)	61.57	135.33	7.20	6.00	1.63	52.49	4.10
Clodinafop at 60 g/ha at 2-3 leaf stage of weeds	4.80(22.54)	4.13 (16.52)	51.66	127.6	7.00	5.69	1.61	50.87	3.77
Imazethapyr at 75 g/ha at 2-3 leaf stage of weeds	3.63(12.71)	2.52 (5.89)	73.30	142.53	7.60	6.27	1.71	55.43	4.23
Imazethapyr at 100 g/ha at 2-3 leaf stage of weeds	3.49 (11.71)	2.51 (5.84)	77.72	152.6	8.00	6.38	1.75	56.58	4.24
Weedy check	5.76 (32.68)	5.04 (24.86)	0.00	99.33	6.00	5.25	1.37	42.95	3.67
Hand weeding twice at 20 and 40 DAS	2.01 (3.54)	1.25 (1.07)	87.21	155.13	9.10	7.00	2.00	60.93	3.18
LSD (P=0.05)	0.39	0.20	5.27	4.3	0.74	0.91	0.12	-	-

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

Application of pendimethalin + imazethapyr 0.75 kg/ha yielded significantly more than alone application of pre-emergence pendimethalin, post-emergence isoproturon, clodinafop and imazethapyr 75 g/ha but was at par with imazethapyr 100 g/ha. Singh *et al.* (2014) also reported that imazethapyr at 100 g/ha significantly reduced the weed density in linseed. The weed control efficiency of clodinafop and isoproturon as post-emergence was recorded lower (61.6 and 51.7%) than pendimethalin and imazethapyr due to grass weed killers may not able to kill broad leaved weeds which were present in higher density in the field of linseed. These results were in close conformity with Kapur and Singh (1992). The net monetary return was the highest under hand weeding twice (` 60930/ha) followed by imazethapyr at 100 g/ha ( ` 56580/ha) but B:C ratio was maximum under imazethapyr at 100 g/ha (4.24) followed by imazethapyr at 75 g/ha (4.23).

SUMMARY

Field experiment was conducted at Research farm, College of Agriculture, JNKVV, Tikamgarh during *Kharif* 2013-14 to study the effect of herbicides for controlling weeds in linseed. There was prevalence of dicot weeds in experimental field as these weeds constituted the higher relative density (67.8%) at harvest as compared to monocot weeds which had only 18.04% relative density. On the basis of results, it can be concluded that hand weeding twice at 20 and 40 DAS recorded significantly the lowest weed density as well as weed dry weight followed by pre-emergence application of pendimethalin at 1.0 kg + imazethapyr at 1.0 kg/ha. The seed and straw yields of linseed was significantly higher under twice hand weeding at 20 and 40 DAS followed by pre-emergence application of pendimethalin at 1 kg/ha + imazethapyr at 1 kg/ha, pendimethalin at 0.75 kg/ha + imazethapyr at 1.0 kg/ha and post-emergence application of imazethapyr at 100 g/ha. The highest net monetary return obtained with twice hand weeding whereas the B:C ratio was the highest with the application of imazethapyr at 100 g/ha followed by imazethapyr at 75 g/ha.

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Short communication

Chemical weed management in castor

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Key words: Castor, Chlorimuron-ethyl, Pendimethalin, Power operated weeding, Quizalofop-ethyl

Castor (*Ricinus communis L.*) is an important non- edible oilseed crop of India, having immense industrial and commercial value. India is the world leader in castor production followed by China and Brazil. Castor plant is very sensitive to competition with weedy plants. Weeds are able to grow quickly because of slow initial growth of castor. Chlorimuron-ethyl herbicide is selective to castor plants when applied as post-emergence (Sofiatti *et al.* 2012) and this ALS inhibiting herbicide is commonly used only in soybean. Hence the present investigation has been carried out to evaluate post- mergence herbicides namely chlorimuron-ethyl and quizalofop-ethyl in castor over pre-emergence herbicdes, hand weeding and power operated weeding.

A field experiment consisting of nine treatment in three replication was conducted at farmers' field of Yethapur Salem to evaluate suitable integrated weed management practices for improving productivity and profitability in castor hybrid under irrigated condition during Rabi 2013-14. Experimental field was clayey in texture. "*YRCH 1*" castor hybrid was raised at a plant spacing of 1.2 x 1.2 m. Plot size is 7.2 x 7.2 m. Fertilizers were applied at the rate of 90: 45: 45 NPK kg/ha. Pre-calibrated quantity of herbicides has been applied per plot using knapsack sprayer fitted with flat fan nozzle as per the technical programme.

Among the grasses, *Chloris barbata*, *Dactyloctenium aegpytium, Bracharia reptens* and *Panicum flavidum* were predominant. *Cyperus esculentus* was the predominant weed among sedges. Among the broad-leaved weeds, *Boerhaevia diffusa, Digera arvensis, Corchorus olitorius, Cyanotis cucullata, Cleome viscosa, Commelina bengalensis, Croton sparsiflorus* and *Parthenium hysterophorus* were predominant weeds. Total weed density was significantly lowered with pre-emergence application of pendimethalin 1.0 kg/ha at 30 DAS. Since major weed population was broad-leaved weeds, application of chlorimuron-ethyl has recorded lowered weed density at 30 DAS. The same trend was observed at 60 DAS (Table 1).

Pre-emergence application of pendimethalin 1.0 kg/ha followed by mechanical weeding twice at 20 and 40 DAS recorded lower weed density with higher weed control efficiency (84 and 81%) at 30 and 60

Table 1. Effect of weed control treatments on weed density (no/m^2) and weed control efficiency (%) at 30 and 60 DAS during *Rabi'13*- 14

Treatment	Weed density (no./m^2) at 30 DAS			Weed density (no./m^2) at 60 DAS			Weed control efficiency (%)	
	Grasses and sedges	Broad-leaved weeds	Total Weed density	Grasses and sedges	Broad-leaved weeds	Total Weed density	30 DAS	60 DAS
Pendimethalin + HW twice at 20 and 40 DAS as PE	2.83 (7)	2.65 (5)	3.61 (12)	3.16 (9)	3.74 (7)	4.12 (16)	82	80
Pendimethalin + quizalofop-ethyl PE	2.00 (3)	5.74 (32)	6.00 (35)	2.83 (7)	6.93 (47)	7.42 (54)	54	50
Pendimethalin + chlorimuron-ethyl	3.00 (8)	2.65 (6)	3.87 (14)	3.74 (13)	3.00 (8)	4.69 (21)	75	67
Quizalofop-ethyl alone	2.24 (4)	8.48 (71)	8.72 (75)	3.60 (12)	9.22 (84)	9.85 (96)	37	33
Chlorimuron-ethyl alone	5.09 (25)	3.87 (14)	6.32 (39)	5.65 (31)	3.32 (10)	6.48 (41)	52	56
Pendimethalin + MW twice at 20 and 40 DAS as PE	2.83 (7)	2.24 (4)	3.46 (11)	3.16 (9)	2.83 (7)	4.00 (15)	84	81
MW alone twice a t 20 and 40 DAS	3.16 (9)	2.45 (5)	3.87 (14)	3.87 (10)	3.00 (8)	4.36 (18)	77	71
HW twice at 20 and 40 DAS	3.00 (8)	2.65 (6)	3.74 (13)	3.60 (9)	4.00 (8)	4.24 (17)	78	71
Unweeded control	8.00 (61)	10.39 (107)	13.08 (170)	9.38 (87)	11.49 (131)	14.79 (218)	-	-
LSD (P=0.05)	1.29	1.35	1.37	1.21	1.39	1.43		

*Figures in parentheses are original values

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Table 2. Effect of weed management practices on growth and yield of castor

Treatment	Plant height (cm)	Number of nodes per plant	Number of spikes per plant	Kernal yield (t/ha)
Pendimethalin at 1.0 kg/ha + HW twice on 20 and 40 DAS	108	11	14	2.37
Pendimethalin + HW twiceat20 and 40 DAS as PE	87	12	14	2.28
Pendimethalin + quizalofop-ethyl PE	100	12	17	2.47
Pendimethalin + chlorimuron-ethyl	72	11	13	2.20
Quizalofop-ethyl alone	81	10	16	2.43
Chlorimuron-ethyl alone	105	12	15	2.57
Pendimethalin + MW twice at20 and 40 DAS as PE	93	22	13	2.58
MW alone twice at20 and 40 DAS	92	11	14	2.46
HW twice at20 and 40 DAS	47	10	11	1.53
Unweeded control	8.4	NS	NS	0.50
LSD (P=0.05)				

DAS. This treatment was followed by pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding twice at 20 and 40 DAS (82 and 80%). Plant height was significantly higher with pre-emerence application of pendimethalin 1.0 kg/ha + HW twice on 20 and 40 DAS and was followed by pre-emergence application of pendimethalin 1.0 kg/ha + mechanical weeding twice. Mechanical weeding twice (2.58 t/ha), pre-emergence application of pendimethalin followed by mechanical weeding (2.57 t/ha), and post-emergence application of chlorimuron-ethyl 0.01 kg/ha (2.47 t/ha) recorded numerically higher yield (Table 2). Gross returns are higher with pre-emergence application of pendimethalin at 1.0 kg/ha followed by mechanical weeding twice (₹ 1,03,880/ha) and mechanical weeding twice alone (₹ 1,03,280/ha). Pre - emergence application of pendimethalin followed by chlorimuron-ethyl at 0.01 kg/ha has recorded more returns (₹ 98,960/ha) (Table 3). Mechanical weeding twice alone (4.4) and application of chlorimuron ethyl alone (4.4) has recorded higher benefit : cost ratio due to lesser cost of cultivation as well as higher yield over other treatments.

Table 3. Effect of weed management practices on Benefit cost ratio during *Rabi* 13- 14

Treatment	Common cost of cultivation per ha (x10^{3} ` /ha)	Additional cost on weeding (x10^{3} ` /ha)	Total cost of cultivation (x10^{3} ` /ha)	Gross returns (x10^{3} ` /ha)	Net returns (x10^{3} ` /ha)	B:C
Pendimethalin + HW twice at 20 and 40 DAS PE	20.63	11.27	32.29	94.84	62.55	2.9
Pendimethalin + quizalofop-ethyl PE	20.63	6.00	26.61	91.16	64.55	3.4
Pendimethalin + chlorimuron-ethyl PE	20.63	5.10	25.64	98.96	73.32	3.9
Quizalofop-ethyl alone	20.63	2.60	23.23	87.96	64.73	3.8
Chlorimuron-ethyl alone	20.63	1.60	22.26	97.36	75.10	4.4
Pendimethalin + MW twice at 20 and 40 DAS PE	20.63	6.35	26.98	103.88	76.90	3.9
MW alone twice at 20 and 40 DAS	20.63	2.95	23.58	103.28	81.12	4.4
HW twice at 20 and 40 DAS	20.63	8.25	28.88	98.28	69.40	3.4
Unweeded control	20.63	0	20.63	61.32	40.69	3.0

SUMMARY

A field experiment was conducted to study the effect of early post-emergence herbicide namely chlorimuron-ethyl and quizalofop-ethyl on weeds in castor and also to evaluate its weed control efficiency over hand weeding and power operated weeding. It was revealed that pre-emergence application of pendimethalin at 1.0 kg/ha followed by mechanical weeding twice at 20 and 40 DAS has recorded lower weed density with higher weed control efficiency. Mechanical weeding twice, pre-emergence application of pendimethalin followed by chlorimuron-ethyl at 0.01 kg/ha or mechnical weeding twice on 20 and 40 DAS have recorded higher yield and economics. Mechanical weeding twice (2.58 kg/ha), pre emergence application of pendimethalin at 1.0 kg/ha followed by mechanical weeding twice at 20 and 40 DAS (2.57 kg/ha) or post-emergence application of chlorimuron-ethyl at 0.01 kg/ha (2.47 kg/ha) have recorded numerically higher yield and B:C ratio.

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Short communication

Post-emergence herbicides for weed control in sesame

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Sesame [*Sesamum indicum*(L.)] popularly known as til, tilli, gingelly *etc*. is important oilseed crop and belongs to the family *Pedaliaceae*. The area under the crop in India is about 1901 thousand hectares and total production is 810 thousand tonnes (Anonymous 2011-12). In Madhya Pradesh total cultivated area and production of sesame are 295 thousand hectares and 155 thousand tonnes; respectively. Average yield in India and Madhya Pradesh is 426 and 525 kg/ha, respectively (CLRS 2011-12). Severe weed competition is one of the major constraints in lower productivity of sesame. Though the conventional methods of weed control *viz*. hand weeding, hand hoeing *etc*. are very much effective but due to high wages and non-availability of labourers during the critical weeding season (15-30 DAS) and incessant protracted rains, use of herbicides and their combination with cultural practices could be more time saving, economical and efficient to check early crop-weed competition.

The present experiment was conducted at the Research Farm, College of Agriculture, Gwalior during *Kharif* season of 2013-14 under the edaphic and climatic conditions of Gwalior (M.P.). The topography of the field was uniform with proper drainage. The soil of the experimental field was sandy clay loam in texture. The experiment was conducted in randomized block design with and 7 treatments in three replication. The sesame crop variety '*TKG-22*' was sown on 01-07-2013 and was grown with all recommended practices except weed control measures which were applied as per treatments undertaken for investigation. The nutrients were applied at the rate of 60 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha.

Effect on weeds

Weeds are most limiting factor responsible for low yield of sesame. The narrow-leaved weed flora was dominated by species including *Cyperus rotundus* (L.), *Cynodon dactylon* (L.) pers., *Echinochloa crus-galli* (L.) Beauv., *Echinochloa colona* (L.), *Dinebra arabica* (L.), *Digitaria longiflora* (L.) and *Dactylactenium aegyptium* (L.) in the experimental site. Two hand weedings at 20 and 40 DAS gave complete total weed control. followed by propaquizafop 100 g/ha. The highest total weed dry weight was noted under control/ weedy check. Reduced total weed dry weight obtained under different treatments might be due to effective control given by all treatments over control resulted in less population and reduced growth in weedy plants. The highest weed control efficiency (95.50%) was recorded in treatment two hand weeding at 20 and 40 DAS. Followed by treatment was propaquizafop 100 g/ha (73.03%). This may be attributed to better control of weeds under various treatments under investigation which might had provided comparatively stress free environment to crop.

Effect on crop

The weed control practices significantly affected the yield and yield attributes in sesame crop. The highest plant height, number of branches/ plant, number of leaves/plant, number of capsules/ plant, grains/capsule, plant dry weight (g), 1,000-grain weight (g), grain yield/plant (g), grain yield (kg/ha), stalk yield (kg/ha) and harvest index (%) observed in treatment Two hand weeding at 20 and 40 DAS, followed by propaquizafop 50 g/ha. Whereas the application of propaquizafop 100 g/ha gave best weed control result but had phytotoxic effects, *viz.* chlorosis on growth of sesame resulting in decreased yield. The highest weed control efficiency and lowest total weed dry weight were recorded in treatment Two hand weeding at 20 and 40 DAS, followed by propaquizafop 100 g/ha. The results were conformed with (Nadeem *et al.* 2009, Bhadauria *el al.* 2012).

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Table 1. Effect of weed control practices on yield attributing characteristics of sesame

Treatment	Plant height (cm)	No. of branche s/plant	No. of leaves/ plant	No. of capsules/ plant	Number of grains /capsule	Dry weight/ plant (g)	1,000-grain weight (g)	Grain yield/ plant (g)
Propaquizafop 50 g/ha as PoE	149.1	3.60	164.1	24.2	34.5	10.7	2.66	2.23
Propaquizafop 62.5 g/ha as PoE	143.2	2.93	148.6	22.1	33.0	9.9	2.54	1.85
Propaquizafop 100 g/ha as PoE	141.3	2.73	144.1	21.5	32.7	9.6	2.52	1.77
Quizalofop-p-ethyl 50 g/ha as PoE	148.5	3.40	160.9	23.5	34.1	10.5	2.64	2.12
Fenoxaprop-p-ethyl 100 g/ha as PoE	140.6	2.67	142.2	21.1	32.6	9.5	2.50	1.72
Two hand weeding at 20 and 40 DAS	154.3	4.27	175.3	26.9	38.1	12.1	2.75	2.82
Control/weedy check	129.5	1.87	129.4	16.9	24.9	7.9	2.19	0.93
LSD (P=0.05)	4.09	0.40	9.7	1.35	0.95	0.59	0.07	0.21

Table 2. Effect of weed control practices on total weed control efficiency, yield and economics, grain yield, stalk yield, harvest of sesame

Treatment	Total weed dry weight (g/m^2)	Weed control efficiency (%)	Grain yield (kg/ha)	Stalk yield (t/ha)	Harvest index (%)	Net income (x103 `/ha)	B:C Ratio
Propaquizafop 50 g/ha as PoE	69.3	68.3	516	2.58	16.6	36.99	2.76
Propaquizafop 62.5 g/ha as PoE	63.6	70.6	437	2.36	15.6	28.03	2.32
Propaquizafop 100 g/ha as PoE	58.2	73.0	417	2.28	15.5	25.05	2.14
Quizalofop-p-ethyl 50 g/ha as PoE	72.4	64.0	501	2.53	16.6	34.76	2.61
Fenoxaprop-p-ethyl 100 g/ha as PoE	60.9	72.1	409	2.25	15.4	24.19	2.10
Two hand weeding at 20 and 40 DAS	-	95.5	674	2.94	18.6	48.70	2.81
Control/weedy check	180.0	-	208	1.86	10.0	4.06	1.21
LSD (P=0.05)	21.8	-	42	0.18	0.87	-	-

PoE=post-emergence

Economics

All the weed control treatments gave higher income over control/weedy check. The highest net return and B:C ratio were obtained under treatment two hand weeding at 20 and 40 DAS, followed by Propaquizafop 50 g/ha, while lowest B:C ratio with control/weedy check. Under all weed control treatments B:C ratio were found low due to abnormal weather conditions in crop growth and maturity period.

SUMMARY

On the basis of above findings, it may be concluded that treatment Two hand weeding at 20 and 40 DAS, followed by treatment Propaquizafop 10% EC (PoE) 50 g/ha are most effective and remunerative weed control practices for controlling the weeds in sesame under sandy clay loam soils of Northern M.P.. The higher grain yield and net return were obtained from treatment two hand weeding at 20 and 40 DAS.

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Short communication

Energy usage and economic analysis of cotton under various weed management practices

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Key words: Bt cotton, Economical assessment, Energy consumption, Energy intensiveness, Energy productivity, Weed management

The introduction of modern inputs changed the energy scenario of crop production. The main problems facing energy usage are insufficient resources, high production costs, wrong resource allocation and increasing national and international competition in agricultural trade. Agricultural energy requirements can be divided into direct and indirect energy requirements. The direct energy is related to crop production process as land preparation, irrigation, inter-culture, threshing, harvesting, and transportation of agricultural inputs and farm produce. Indirect energy needs are in the form of crop production inputs like seed, fertilizer and plant protection chemicals including biocontrol agents. Efficient use of these energies helps to achieve increased production and productivity and contributes to economy, profitability.

Agricultural practices in many developing countries continue to be based to a large extent on animal and human energy. Mechanical and electrical energy are available for agriculture insufficiently and hence the potential gains in agricultural productivity through the deployment of modern energy services are not being realized. The increase in area under high yielding varieties of various crops has put heavy demand on limited non-renewable energy sources. Renewable energy includes human labor, irrigation water, seeds and non-chemical fertilizers while non-renewable energy is consist of fossil fuels, pesticides, chemical fertilizers and machinery (Mohammadi *et al.* 2008). Cotton is a valuable product traded globally as well as an important employment creator. World widely, more than 100 million farming units are directly involved in cotton production, with many more in its complementary activities (FAO 2005). Major cotton producers and its international traders are China, India, USA, EU and Central Asian and African states. India has the credit of the largest area under cotton (126.55 lakh ha) and ranks second in cotton production (400 lakh bales) during 2014-15. However, the productivity of seed cotton in India is 537 kg/ ha which is below the world average of 790 kg/ ha.

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In Telangana, the cotton crop is being grown in an area of 16.51 lakh ha with the productivity of 515 kg/ha. This crop is mostly grown in alfisols of Southern Telangana agro climatic zone and black soils of Northern Telangana Zone. Since efficient use of the energy resources is vi-tal in terms of increasing production, productivity, competitiveness of agriculture as well as sustainability of rural living. Energy auditing is one of the most common approaches to examining energy efficiency and environmental impact of the production system. Estimating these functional forms is very useful for determining elasticity of inputs on yield and production (Hatirli *et al.* 2006).

Different energy efficiency parameters were determined to evaluate relationship between energy consumption and total output and production per hectare. Energy ratio, specific energy, energy productivity, energy intensiveness and net energy yield were calculated for cotton production under different weed management practices by following equations (Banaeian *et al.* 2010, Ghorbani *et al.* 2011).

Energy ratio = Energy output (MJ/ha)/Energy input (MJ/ha)

Specific energy = Energy input (MJ/ha)/Output (kg/ha)

Energy productivity = Output (kg/ha)/Energy input (MJ/ha)

Energy intensiveness = Energy input (MJ/ha)/Cost of production (Rs/ha)

Net energy yield = Energy output (MJ/ha) – Energy input (MJ/ha).

Energy use efficiency of different weed management practices was evaluated by the energy ratio between output and input. The energy input values for human labor, machinery, diesel fuel, fertilizers, pesticides and seed and the energy output value of cotton yield were used to estimate the energy ratio (Alam *et al.* 2005). Specific energy (MJ/kg) has been widely used in energy analysis to express the quantity of energy invested to produce unit quantity of the product. Energy productivity which measures the quantity of product produced per unit of input energy (kg/MJ) is the inverse of specific energy. This serves as an evaluator of how efficiently energy was utilized in the production system yielding a particular product. Based on the energy equivalents of inputs and output (Table 1) the above calculations were carried out based on experimental results of Bt cotton, conducted at college farm, Professor Jayashankar Telangana State Agricultural university, Rajendranagar during *Kharif* 2014 with 10 weed management practices, *viz.* pendimethalin at 1000 *fb* 2 HW at 20 and 50 DAS: pendimethalin at 1000 *fb* pyrithiobac-sodium at 62.5 g/ha: pendimethalin at 1000 *fb* pyrithiobac-sodium at 62.5 g/ha + quizalofop-p-ethyl at 50.0 g/ha, pyrithiobac-sodium at 62.5 g/ha₊ quizalofop-p-ethyl at 50.0 g/ha, pyrithiobac-sodium at 62.5 g/ha + quizalofop-p-ethyl at 50.0 g/ha *fb* manual weeding at 50 DAS, pyrithiobac-sodium at 62.5 g/ha + quizalofop-p-ethyl at 50.0 g/ha *fb* directed spray of paraquat at 600 g/ha, pyrithiobac-sodium at 62.5 g/ha + quizalofop-p-ethyl at 50.0 g/ha *fb* directed spray of glyphosate at 2000g/ha, pendimethalin at 1000 g/ha *fb* glyphosate at 2000 g/ha directed spray, mechanical weeding thrice at 20,40 and 60 DAS and weedy check and replicated thrice.

Table 1. Energy content of cotton production inputs and outputs and total energy equivalents per unit area

A. Inputs	Energy equivalent (MJ/ unit)	Quantity per unit area (ha)	Total energy equivalent (MJ)
1.Human labour (h)	1.96	165	2587
2.Machinery			
Tractor 50 kW (h)	41.4	6.25	258.75
Plough (h)	22.8	20	456
Sprayer (h)	23.8	15	357
Pump (h)	2.4		
3.Diesel (1)	56.31	23.98	1350.31
4.Chemical fertilizers			
N (kg)	60.60	150	9090
P (kg)	11.1	60	666
K (kg)	6.7	60	402
5. Chemicals			
Insecticides (kg)	278	2	556
Fungicides (kg)	276		
Herbicides (kg)	288		
6.Electricity (kWh)	11.93	24	286.32
7.Water for irrigation (m3)	0.63	24	15.12
8. Seed (kg)	25	1.125	28.12
B. Outputs			
1. Cotton seed yield (kg)	11.8		

Source: Dagistan *et al.* (2009)

Analysis of input-output energy

The results showed that about 1320 h human labor, 41.25 h machinery, 23.98 L diesel fuel, 270 kg chemical fertilizers (including 150 kg nitrogen, 60 kg phosphorus and 60 kg potassium) and 1.125 kg seed were used per hectare cotton production (Table 2). Amount of herbicide used in this study was varied from 0.475 kg to 4.8 kg depending upon the treatments used. Zahedi *et al.* (2014) reported that about 863 h human labor, 25 h machinery, 495 L diesel fuel, 237 kg chemical fertilizers (including 115 kg nitrogen, 69 kg phosphorus and 50 kg potassium) and 5200 kg farmyard manure were used per hectare cotton production in Turky.

In this study, total energy consumption of cotton production under various weed management practice varied in between 16051 MJ/ha to 19575 MJ/ha. Energy output-input ratio shows the efficiency of energy input and also marginal increase of output due to per unit increase in energy input. Higher energy use efficiency of 0.9 was observed with mechanical weeding thrice at 20, 40 and 60 DAS and was followed by pre-emergence application of pendimethalin at 1000 g/ha *fb* 2 HW at 20 and 50 DAS and early post emergence application of pyrithiobac-sodium at 62.5 g/ha + quizalofop-p-ethyl at 50.0 g/ha *fb* manual weeding at 50 DAS. This showed that cotton production under this treatment is not fairly efficient in terms of energy consumption as energy ratio of 2.36 (Dagistan *et al.* 2009) and 4.8 (Canakci *et al.* 2005) were also reported for cotton production.

Interms of specific energy, the lowest amount of energy of 12.9 MJ was invested to produce unit quantity of the seed cotton (kg) in mechanical weeding thrice treatment. This was reflected interms of higher productivity with production of 0.07 kg/MJ of energy with same treatment. The lowest energy intensiveness of 0.5 MJ per rupee was reported in pre emergence application of pendimethalin at 1000 *fb* 2 HW at 20 and 50 DAS as humon labour was engaged to remove the weeds. This treatment was followed by early post emergence application of pyrithiobac-sodium at 62.5 g/ha + quizalofop- p- ethyl at 50.0 g/ha *fb* manual weeding at 50 DAS. However negative net energy yield was obtained in all the treatments due to the less seed cotton yield. In similar way 27.2 MJ $-1, 19.2 MJ /kg, 0.1 kg MJ-1 and -15625.2 MJ ha-1, of energy intensiveness, specific energy, energy productivity and net energy was obtained from cotton production respectively under iran conditions (Zahedi *et al.* 2014)

The energy use efficiency, energy intensiveness, specific energy, energy productivity, net energy and of cotton production system were 0.9, 0.7 MJ/ Rs,

Table 2. Energy input-output relationship for cotton production under various weed management practices

Treatment	Kapas yield kg/ha	CC `/ha	Energy out put (MJ/ha)	Total energy input (MJ/ha)	Energy ratio	Speciifc energy MJ/kg	Energy productivity kg /MJ	Energy intensiveness MJ/`	Net energy yield MJ /ha
Pendimethalin fb 2 HW	1209	32840	14266	17718	0.8	14.6	0.06	0.5	-3452
Pendimethalin *fb* pyrithiobac-sodium	535	27127	6313	17905	0.3	33.4	0.02	0.7	-11592
Pendimethalin *fb* pyrithiobac-sodium + quizalofop- p- ethyl	637	27449	7516	18193	0.4	28.5	0.03	0.7	-10677
Pyrithiobac-sodium + quizalofop- p -ethyl	583	25858	6879	17243	0.4	29.5	0.03	0.7	-10364
Pyrithiobac-sodium + quizalofop- p- ethyl *fb* manual weeding	1019	29608	12024	17046	0.7	16.7	0.05	0.6	-5022
Pyrithiobac -sodium + quizalofop –p- ethyl *fb* directed spray of paraquat	783	26758	9239	17963	0.5	22.9	0.04	0.7	-8724
Pyrithiobac-sodium + quizalofop –p- ethyl *fb* directed spray of glyphosate	806	27809	9510	18625	0.5	23.1	0.04	0.7	-9115
Pendimethalin *fb* glyphosate directed spray	828	27291	9770	19575	0.5	23.6	0.04	0.7	-9805
Mechanical weeding (3)	1427	26750	16838	18550	0.9	12.9	0.07	0.7	-1712
Weedycheck	200	23750	2360	16051	0.1	80	0.01	0.7	-13691
LSD (P=0.05)	231								

12.9 MJ/kg, 0.9 kg/MJ and -1712 MJ /ha respectively. The results indicate that cotton production under this treatment is not efficient enough in terms of energy consumption. Based on the analysis there is a need to increase the cotton output to get more net energy yield in order to increase the energy use efficiency of inputs.

SUMMARY

The objective of energy usage and benefit-cost analysis of Bt cotton was to determine the energy efficiency indices under different weed management practices in Bt cotton. The field experiment was carried out at college farm, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad during *Kharif*, 2014 with ten weed management practices. The inputs in the calculation of energy usage in agro-ecosystems embraced labour, machinery, electricity, diesel oil, fertilizers, herbicides, pesticides, seeds, while seed cotton was included in the output. The results depicted that total input and output energy under different weed management practices were about 16051 to 18550 and 2360 to 16838 MJ/ha, respectively. Out of all the treatments tested the highest energy use efficiency (0.9), energy intensiveness (0.7 MJ/₹), specific energy (12.9 MJ / kg), energy productivity (0.9 kg/MJ), net energy (-1712 MJ/ha) of Bt cotton production system were reported in mechanical weeding thrice at 20, 40 and 60 DAS. However the lowest energy intensiveness of 0.5 MJ per rupee was reported in pre emergence application of pendimethalin at 1000 *fb* 2 HW at 20 and 50 DAS treatment.

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Short communication

Integrated weed management in cumin

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Cumin (*Cuminum cyminum* L) locally known as 'zeera' is an important seed spice crop of western India particularly of Rajashthan, Gujarat and some parts of Madhya Pradesh. Its seed have pleasant aromatic odour and also has medicinal value. India is a major producer, consumer and exporter of spices in the world. Among seed spices cumin occupies first position in term of value and second in terms of production. It is cultivated in an area of 594 thousand hectare with the production of 394 thousand Mt and productivity of 0.7 t/ha in India (NHB 2013).

Being a short stature crop with slow initial growth, the crop is more susceptible to weed competition during the earlier growth period. Herbicides are the most effective and economic measure of weed control. Generally, cumin farmers control weed manually, which is labour intensive and costly. Therefore, the present study was conducted to find out the effective and economical weeding practice in cumin.

An experiment was conducted in winter *(Rabi)* season of 2013-14 at Research Farm, College of Horticulture, Mandsaur (Madhya Pradesh) to find out the effective and economically viable weed management practices for obtaining higher yield of cumin. The soil of experimental field was light black loamy in texture with pH 7.2, EC 0.35 dS/m, low in available nitrogen (243.2 kg/ha), medium in available phosphorus (19.8 kg/ha) and high in available potassium (448.0 kg/ha). The experiment was laid out in randomized block design with 12 treatments using three replications. The cultivar '*GC4'* was used for sowing on 30 October 2013. The crop was sown at a spacing of 30 x 10 cm using recommended dose of fertilizer and cultural practices. Cumin crop was harvested on different dates as per maturity. The data recorded were subjected to statistical analysis using RBD and ANOVA technique suggested by Panse and Sukhatme (1985).

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Effect on growth and yield

Application of herbicides and weed management treatments significantly increased the growth and yield of cumin. Application of oxadiargyl 0.06 kg/ha as pre-emergence *fb* two hand weeding at 40 and 60 DAS significantly improved the plant height at different growth stages, number of branches and reduced the duration of 50% flowering of cumin. Besides weed free treatment, the highest number of umbels/plant (14.4), number of umbellates/plant (84.3), 1000- seed test weight (4.10 g), seed yield (595 kg/ha) and straw yield (900 kg/ha) were recorded with application of oxadiargyl 0.060 kg/ha as *fb* two hand weeding at 40 and 60 DAS. The early flowering (4-7 days) was also observed under oxadiargyl 0.060 kg/ha as PE *fb* 2 hand weeding at 40 and 60 DAS. Higher yield attributes, seed and straw yield under these treatments might be due to effective control of weeds, which in turn reduced crop-weed competition significantly and consequently resulting in better congenial condition for growth and development of the crop. Similar improvement in seed yield, straw yield and harvest index were also recorded by Yadav *et al.*(2005), Mehriya *et al.*(2007), Meena *et al.*(2009) and Yadav *et al.*(2012) in cumin crop.

Effect on weeds

Weed management practices significantly reduced the number of weeds and dry matter of weeds recorded at different growth stages. The dominant weed flora in the experimental field consisted of *Chenopodium album*, *Chenopodium murale*, *Cynodon dactylon*, *Cyperus rotundus*, *Melilotus alba*, *Argemone mexcicana*, *Asphodelus tenuifolius*, *Plantago pumila*, *Rumex dentatus* and *Launea asplenifonifolia*. Application of oxadiargyl 0.06 kg/ha *fb* two hand weeding at 40 and 60 DAS was found more effective in reducing the weed population (6.2/m^2) and resulted in less dry weight of weeds (12.40 g/m^2). Application of oxadiargyl 0.075

Table 1. Growth and yield attributes of cumin under different weed management methods in cumin

Treatment	Plant height (cm.)		Number of branches /plant		Days to 50 % flowering	Number of umbels / plant	1000-seed test weight (g)	Seed yield per plant (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
	60 DAS	At harvest	60 DAS	90 DAS							
Pendimethalin 1.0 kg/ha as PE	15.4	21.5	4.5	4.8	59.0	11.5	3.60	1.29	430	783	35.44
Pendimethalin 1.2 kg/ha as PE *fb* 1 HW at 40 DAS	16.2	22.6	5.0	5.4	56.0	13.5	3.90	1.53	500	850	37.03
Pendimethalin 1.0 kg/ha as PE *fb* 2 HW at 40 and 60 DAS	16.5	22.8	5.3	5.7	55.0	14.0	4.00	1.62	520	880	37.14
Oxyfluorfen.0.15 kg/ha as PE	14.3	20.8	4.1	4.4	59.0	11.0	3.50	1.05	360	730	33.05
Oxyfluorfen 0.30 kg/ha as PE *fb* 1 HW at 40 DAS	14.9	21.1	4.3	4.6	59.0	11.3	3.55	1.38	460	810	36.22
Oxyfluorfen at 0.15 kg/ha as PE *fb* 2 HW at 40 and 60 DAS	15.8	22.3	4.8	5.2	58.0	12.5	3.80	1.42	475	830	36.39
Oxadiargyl at 0.06 kg/ha as PE	15.6	21.8	4.5	4.9	58.0	12.3	3.75	1.35	450	800	36.00
Oxadiargyl at 0.075 kg/ha as PE *fb* 1 HW at 40 DAS	16.3	22.7	5.1	5.6	57.0	13.9	3.95	1.62	520	880	37.14
Oxadiargyl at 0.06 kg/ha as PE *fb* 2 HW at 40 and 60 DAS	17.9	22.9	5.8	6.3	55.0	14.4	4.10	1.71	595	900	39.79
Weed check (control)	11.5	17.4	3.2	3.4	62.0	6.2	3.00	0.45	230	510	31.08
Hand weeding (40 DAS)	13.4	19.2	4.0	4.3	60.0	9.5	3.40	0.87	310	730	30.23
Weed free	19.8	24.7	6.4	7.3	53.0	15.5	4.83	1.87	600	930	39.21
LSD (P=0.05)	1.9	1.8	0.6	0.9	2.7	1.0	0.61	0.23	73	133	5.18

Table 2. Economics of cumin and weeds under different weed management methods in cumin

Treatment	Economics of treatments			Weed dry matter g/m^2				Weed population/m^2			
	Gross returns (x10^3 ₹/ha)	Net returns (x10^3 ₹/ha)	Benefit : cost ratio	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Pendimethalin 1.0 kg/ha as PE	51.60	29.80	1.36	8.7	20.6	40.4	60.0	15.6	20.8	21.3	21.6
Pendimethalin 1.2 kg/ha as PE *fb* 1 HW at 40 DAS	60.00	35.81	1.48	7.4	10.0	22.3	35.2	13.2	10.4	11.2	11.3
Pendimethalin 1.0 kg/ha as PE *fb* 2 HW at 40 and 60 DAS	62.40	36.60	1.41	8.8	10.3	10.0	20.6	15.8	10.6	8.2	8.3
Oxyfluorfen.0.15 kg/ha as PE	43.20	22.00	1.03	12.6	30.1	62.6	90.5	22.5	28.2	29.0	29.5
Oxyfluorfen 0.30 kg/ha as PE *fb* 1 HW at 40 DAS	55.20	30.65	1.24	11.9	10.3	36.3	57.6	21.2	18.3	19.2	19.5
Oxyfluorfen at 0.15 kg/ha as PE *fb* 2 HW at 40 and 60 DAS	57.00	31.80	1.26	12.5	11.2	11.0	25.0	22.3	18.5	15.1	15.3
Oxadiargyl at 0.06 kg/ha as PE	54.00	33.20	1.59	7.2	18.0	36.1	54.3	12.8	17.7	18.1	18.3
Oxadiargyl at 0.075 kg/ha as PE *fb* 1 HW at 40 DAS	62.40	39.55	1.71	6.3	8.5	16.2	27.0	11.2	8.0	9.0	9.5
Oxadiargyl at 0.06 kg/ha as PE *fb* 2 HW at 40 and 60 DAS	71.40	46.55	1.87	7.1	8.1	8.5	12.4	12.6	8.4	6.0	6.2
Weed check (control)	27.60	7.75	0.39	62.3	140.1	220.0	280.0	110.5	130.3	135.8	140.1
Hand weeding (40 DAS)	37.20	15.35	0.70	60.5	70.2	120.8	180.0	108.2	60.3	63.2	64.5
Weed free	72.00	39.15	1.31	1.0	1.2	1.0	1.4	3.0	3.0	2.0	1.0
LSD(P=0.05)	8.70	9.12	0.38	2.08	3.0	5.1	6.6	3.5	3.4	2.4	2.9

kg/ha *fb* one hand weeding at 40 DAS was found equally effective in this respect (Table 1). The highest weed population at harvest was recorded in unweeded control (140.1/m^2). The combined effect of herbicide and hand weeding gave less dry weight of weeds which was responsible for higher weed control efficiency. Further, weeds were effectively controlled under weed free and oxadiargyl 0.06 kg/ha *fb* two hand weeding at 40 and 60 DAS, hence there was no severe competition by weeds for moisture and nutrients which resulted into induced growth and yield of cumin. The findings are in agreement with the results reported by Kumar (2001), Yadav *et al* (2005), Mehriya *et al*(2007), Meena *et al* (2009) and Yadav *et al* (2012).

Economics

Among the different weed management methods, maximum net return (₹ 46550) and benefit : cost ratio of 1.87 were obtained with an application of oxadiargyl 0.06 kg/ha *fb* two hand weeding at 40 and 60 DAS while the minimum net return and benefit :

Table 3. Correlation coefficients and regression lines showing relationship between independent variable (x) and dependent variable (y) under different weed management methods in cumin

Dependent variable (x) in cumin	Independent variable (y)	Correlation coefficient (r)	Regression line (y = a + by (x))
Branches/plant (60 DAS)	Plant height at harvest (cm)	0.941	Y = 2.111x + 11.62
Branches/plant (90 DAS)	Plant height at harvest (cm)	0.935	Y = 1.755x + 12.59
Seed yield (t/ha)	Plant height at harvest (cm)	0.970	Y = 1.734x + 13.80
Seed yield per plant (g)	Plant height at harvest (cm)	0.979	Y = 4.745x + 15.25
No. of umbels per plant	No. of branches/plant (60 DAS)	0.944	Y = 0.321x + 0.855
No. of umbellets per plant	No. of branches/plant (60 DAS)	0.979	Y = 0.039x + 2.496
Plant height at harvest	Weed Population/m2 at harvest	0.913	Y = 0.045x + 22.94
Seed yield (t/ha)	No. of umbels per plant	0.973	Y = 2.283x + 1.811
Seed yield (t/ha)	No. of umbellets per plant	0.963	Y = 19.15x – 29.17
Seed yield per plant (g)	No. of umbels per plant	0.985	Y = 6.265x + 3.694
Seed yield per plant (g)	No. of umbellets	0.945	Y = 51.49x - 11.91
Straw yield (t/ha)	Plant height at harvest (cm)	0.952	Y = 1.633x + 8.534
Harvest index (%)	Seed yield(q/ha)	0.969	Y = 0.370x – 8.669
Harvest index (%)	Seed yield per plant (g)	0.950	Y = 0.133x – 3.417
No. of umbels per plant	No. of branches/plant (90 DAS)	0.931	Y = 0.378x + 0.567
No. of umbellets per plant	No. of branches/plant (90 DAS)	0.965	Y = 0.046x + 2.501
Seed yield (t/ha)	Test weight (g)	0.909	Y = 0.380x + 2.061
Seed yield per plant (g)	Test weight (g)	0.903	Y = 1.025x + 2.400
Harvest index (%)	Plant height at harvest (cm)	0.925	Y = 0.631x – 0.848
Days to 50% flowering	Plant height at harvest (cm)	0.933	Y = 0.714x + 62.76
Straw yield (q/ha)	No. of umbels per plant	0.977	Y = 2.198x – 5.513
Straw yield (q/ha)	No. of umbellets per plant	0.920	Y = 17.56x – 83.54
Weed Population/m^2 at harvest	Plant height at harvest	0.913	Y = 0.045x + 22.94
Weed dry matter g/m^2 at harvest	Weed Population/m2 at harvest	0.980	Y = 0.467x – 4.085
Weed dry matter g/m^2 at harvest	Weed Population/m2 30 DAS	0.939	Y = 0.428x + 0.457
Weed dry matter g/m^2 at harvest	Weed Population/m2 60 DAS	0.976	Y = 0.426x – 2.127
Weed dry matter g/m^2 at harvest	Weed Population/m2 90 DAS	0.981	Y = 0.452x – 3.641

cost ratio was recorded in weedy check (table 2). Correlation coefficients and regression lines showing relationship between independent variable (x) and dependent variable (y) under different weed management methods in cumin is shown (Table 3). Similar trend was also observed by Mehriya *et al* (2007), Meena *et al* (2009) and Yadav *et al* (2012).

SUMMARY

A field experiment was conducted during 2013-14 at Research Farm, College of Horticulture, Mandsaur (Madhya Pradesh) to study the weed management practices in cumin. Twelve weed management treatments were laid in randomized block design with three replications. Weed free treatment recorded significant maximum growth and yield attributes of cumin followed by oxadiargyl at 0.06 kg/ ha (PE) *fb* two hand weeding at 40 and 60 DAS. Similarly, significant maximum seed yield (595 kg/ha), straw yield (900 kg/ha) and harvest index (39.7%) was observed with oxadiargyl at 0.06 kg/ha as pre-emergence *fb* two hand weeding at 40 and 60 DAS. Maximum weed population was measured in case of weedy check, which was followed by hand weeding (40 DAS) at all the growth stages of cumin. It may be concluded that application of oxadiargyl at 0.06 kg/ha as pre-emergence *fb* two hand weeding at 40 and 60 DAS may be use for higher yield of cumin.

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Short communication

Allelopathic effect of some aromatic plants on weed seeds

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Although weed control in modern agriculture primarily relies on use of chemical herbicides, their excessive use causes serious problems as weed resistance (Macías *et al.* 2003), environmental pollution and adverse effects on human and animal health. All this leads to the increasing importance of non-chemical and environmental friendly alternatives in weed management, such as allelopathy. Allelopathy is defined as any direct or indirect harmful or beneficial effect of one plant, fungus or microorganism on the other ones through production of allelochemicals that escape into the environment (Rice 1984). The use of allelopathically active crops against weeds can be utilized in different ways *i.e*. surface mulch, incorporation into the soil, crop rotation, cover crops, intercropping, smothering or water extracts as natural herbicides (Reigosa *et al.* 2001 and Singh *et al.* 2003).

Aromatic plants have been investigated as potential allelopathic plants. Dikic (2005a) reported inhibitory effect of caraway, dill, basil and coriander on germination of hoary cress. Dhima *et al.* (2009) found that water extracts of aboveground mass of basil, coriander and oregano reduced germination and growth of barnyardgrass, while in field experiments reduced plant number of different weed species when incorporated as green manure.The aim of the study was to determine allelopathic potential of aromatic plants coriander, lovage, basil and oregano on weed species hoary cress and scentless mayweed through cogermination.

The experiment was conducted in 2013 at ICAR-National Bureau of Plant Genetic Resources, New Delhi. Seeds of aromatic plants including basil (*Ocimum basilicum* L.), coriander (*Coriandrum sativum* L.), lovage (*Levisticum officinale* Koch) and oregano (*Origanum vulgare* L.) were procured from CIMAP, Lucknow. Weed seeds of hoary cress (*Cardaria draba* (L.) Desv.) and scentless mayweed (*Tripleurospermum inodorum* (L.) C.H. Schultz) were intercepted during 2012 in imported germplasm from different country. All seeds were surface-sterilized for 20 min with 1% NaOCl (4% NaOCl commercial bleach), then rinsed three times with distilled water (Siddiqui *et al.* 2009.).

The effect of cogermination of aromatic crops and weed seeds was investigated according to Dikic (2005a). In each treatment 30 seeds of aromatic crop and 30 seeds of weed species were placed in Petri dishes (9 cm diameter) on top of filter paper soaked in distilled water. Control treatments consisted of 30 seeds of a single weed species per dish. Petridishes were kept at room temperature (22 °C ± 2) for 9 (hoary cress) and 12 (scentless mayweed) days. All treatments had four replications and experiment was conducted twice.

Allelopathic effect of aromatic crops was evaluated at the end of experiment through number, length of root and shoot (cm) and fresh weight (g) of weed seedlings. Germination percentage was calculated for each replication using the formula: G = (Germinated seed/Total seed) x 100. Mean germination time (MGT) was calculated according to the equation of Ellis and Roberts (1981): MGT = " (Dn)/ " n, where *n* is the number of seeds that emerged on day D, and D is number of days counted from the beginning of germination. The collected data were analysed statistically with ANOVA and differences between treatment means were compared using the LSD-test at probability level of 0.05.

Aromatic plants showed various allelopathic effects on germination of weed species hoary cress and scentless mayweed (Fig. 1). Basil and coriander reduced germination of hoary cress for 13.8 and 22.3%, while lovage had the highest inhibitory effect and reduced germination for 27%. On the contrary, germination of scentless mayweed was significantly stimulated for 11.1, 17.3 and 28.4% with coriander, basil and oregano, respectively. The results indicate that allelopathic effect depends on both the allelopathic species and the target species.

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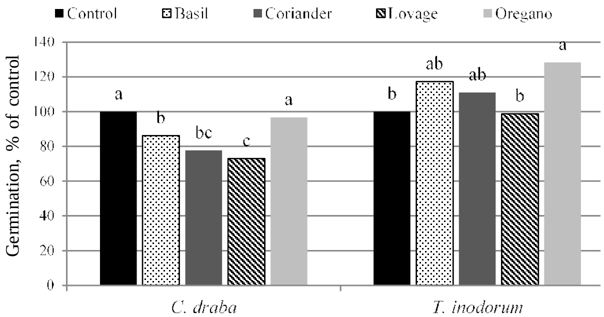
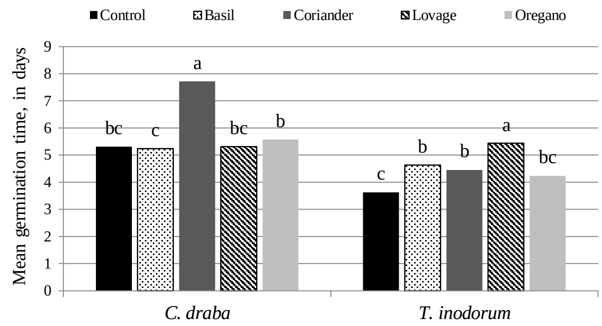


a,b,c - means followed by the same letter within weed species are not significantly different at P<0.05

Fig. 1. The effect of cogermination of aromatic plant and weed seeds on germination (% of control) of weeds



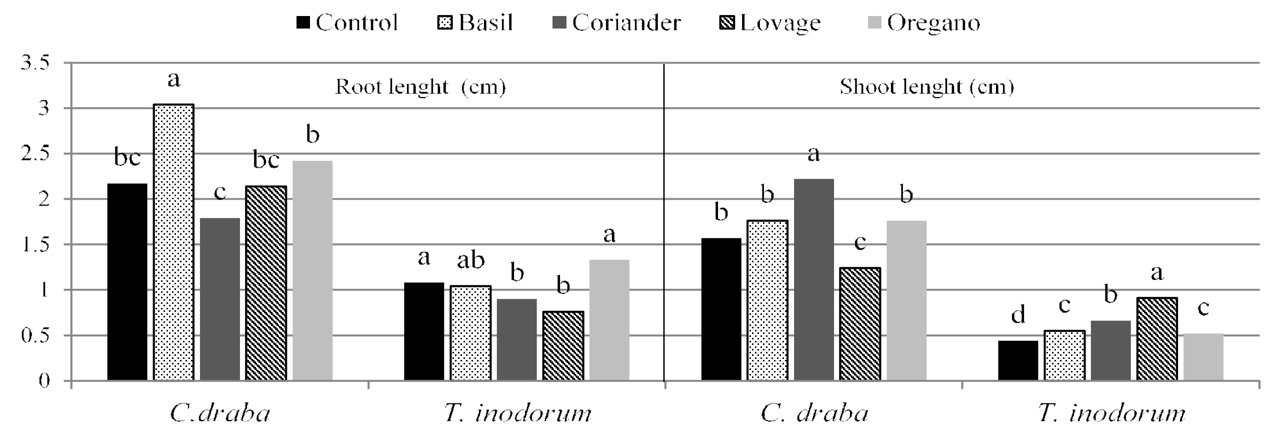
a,b,c - means followed by the same letter within weed species are not significantly different at P<0.05

Fig. 2. The effect of cogermination of aromatic plant and weed seeds on mean germination time (in days) of weeds

Similarly, Dikic (2005a) found that seed germination of hoary cress was reduced when it germinated with seeds of coriander and basil, but germination of quackgrass (*Agropyron repens*) was stimulated.

Mean germination time of hoary cress was only significantly increased in cogermination with coriander and was 7.72 compared to the control which was 5.32 days (Fig. 2). All aromatic plants increased mean germination time of scentless mayweed which ranged from 4.64 to 5.44 days compared to the 3.63 days in control.

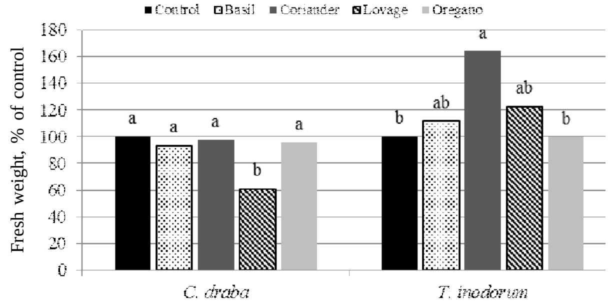
None of the aromatic plants significantly reduced root length of hoary cress, except coriander 17.5% (Fig. 3). Root length of scentless mayweed was reduced with coriander and lovage for 16.5 and 29.3%, respectively. Basil stimulated root length of hoary cress for 42.9%. Lovage reduced shoot growth of hoary cress for 21%, while it greatly stimulated shoot growth of scentless mayweed for 107.7%. All other aromatic plants stimulated the shoot growth of both weeds, especially coriander.



a,b,c - means followed by the same letter within weed species are not significantly different at P<0.05

Fig. 3. The effect of cogermination of aromatic plant and weed seeds on root and shoot length (cm) of weed seedlings

Fresh weight of hoary cress seedlings was significantly influenced in cogermination with lovage and was reduced for 39%, while with basil, coriander and oregano it was only slightly reduced (Fig. 4).Fresh weight of scentless mayweed was stimulated by basil, coriander and lovage for 11.9, 64 and 22.6%, respectively. Dikic (2005a) also reported reduction of hoary cress seedling weight with coriander and basil, but to a greater extent, for 31.3 and 18.3%, respectively.



a,b,c - means followed by the same letter within weed species are not significantly different at P<0.05

Fig. 4. The effect of cogermination of aromatic plant and weed seeds on fresh weight of weed species

The obtained results demonstrated that aromatic plants show allelopathic effect toward germination, root and shoot length and fresh weight of weeds, both inhibitory and stimulatory. The allelopathic effect depended on donor and target species. Lovage showed highest reduction of germination, shoot length and fresh weight of hoary cress, but only root length of scentless mayweed. Coriander reduced germination and root length of hoary cress, but showed high stimulatory effect on shoot length of both weed species and fresh weight of scentless mayweed. Basil reduced germination of hoary cress for 13.8%, but stimulated its root and shoot length and germination and shoot length of scentless mayweed. Oregano showed only stimulatory effect on germination of scentless mayweed.

SUMMARY

Allelopathic effect of cogermination of aromatic plant seeds [basil (*Ocimum basilicum)*, coriander (*Coriandrum sativum*), lovage (*Levisticum officinale*), oregano (*Origanum vulgare*)] and weed seeds [hoary cress (*Cardaria draba*), scentless mayweed (*Tripleurosperum inodorum*)] on germination and early growth of weeds was investigated under laboratory conditions. Basil, coriander and lovage reduced germination of hoary cress from 13.8 to 27%. On the contrary, all aromatic plants, except lovage, had stimulatory effect on germination of scentless mayweed. Coriander decreased root length of hoary cress and scentless mayweed for 17.5 and 16.5%, respectively. Shoot length of scentless mayweed was increased in cogermination with all aromatic plants. Only lovage had significant inhibitory effect on fresh weight of hoary cress, while fresh weight of scentless mayweed was increased by coriander.

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