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Weed management approaches for dry-seeded rice in India: a review

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ABSTRACT

Rice (*Oryza sativa* L.) is an important staple crop in India, where it is mainly grown by manual transplanting of seedlings into puddled soil. Recently, however, there is a trend toward dry-seeded rice (DSR) because of labour and water scarcity. In DSR, weeds are the main biological constraint. Herbicides are used to manage weeds in DSR systems, but the use of herbicides alone does not provide effective and sustainable weed control. Therefore, there is a need to integrate herbicide use with cultural weed management approaches, such as the use of a stale seedbed technique, different tillage systems, weed-competitive cultivars, cultivars capable of emerging under anaerobic conditions, crop residue for mulches, high seeding rates, narrow rows, and optimum time and depth of flooding.

Key words: Direct-seeded rice, Chemical control, Herbicide, Weed management

Rice (*Oryza sativa* L.) is one of the most important crops in India, where it is grown in rice-rice, rice-maize, rice-wheat, *etc*., cropping systems. In irrigated areas, rice is mainly grown by transplanting seedlings into puddled soil. Such a rice production system, however, requires a large amount of water during puddling and transplanting (Chauhan 2012a, Chauhan *et al.* 2012b). In general, rice accounts for 34-43% of the world's irrigation water (Bouman *et al.* 2007). In India, water use for rice has been reported as 1140 mm in Bihar and 1560 mm in Haryana (Gupta *et al.* 2002). Water, however, is becoming an increasingly scarce resource in India (Kumar and Ladha 2011, Mahajan *et al.* 2012). In north-western India, for example, increased use of groundwater for rice cultivation has led to a decline in the water table by up to 1 m per year (Hira 2009, Rodell *et al.* 2009). Therefore, the increasing water scarcity threatens the productivity and sustainability of the irrigated rice system in India.

In addition to the concerns over water scarcity, labour scarcity is also a concern. In the traditional establishment method, both puddling and transplanting operations need a large amount of labour. Because of the increasing demand for labour in non-agricultural sectors and increasing labour costs resulting from the migration of rural labour to the cities, it is difficult to find labour at the critical time of transplanting (Chauhan 2012b). Government policies, for example, 100 days of work in people's home village, are also creating a labour scarcity in some regions, especially where farmers depend on migrant labourers from other states (Mahajan *et al.* 2013). Therefore, farmers in some areas are shifting from traditional transplanted rice to mechanized-sown dry-seeded rice (DSR) in response to the rising production costs and shortages of labour and water. A DSR crop can be sown under zero-till (ZT) conditions or after tillage using a seed drill.

DSR has several advantages over puddled transplanted rice. However, weeds are the main biological constraint to the production of DSR (Chauhan 2012b, Chauhan and Johnson 2010, Chauhan and Opeña 2012, Chauhan *et al.* 2012b). In a recent survey in Punjab, the dominant weed species reported by the farmers in DSR fields were *Cyperus iria* L., *Echinochloa colona* (L.) Link, *Eragrostis* spp., *Leptochloa chinensis* (L.) Nees, *Digitaria sanguinallis* (L.) Scop., *Dactyloctenium aegyptium* (L.) Willd., *Cyperus rotundus* L., and *Eleusine indica* (L.) Gaertn. (Mahajan *et al.* 2013). The main reasons for high weed pressure in DSR are the absence of a weed-suppressive effect of standing water at the time of crop emergence and the absence of a seedling size advantage to suppress newly emerged weed seedlings. Weeds in DSR systems are mainly managed by using herbicides and manual weeding. Manual weeding, however, is becoming less popular because of the labour scarcity and high wages. In the absence of manual weeding, farmers in irrigated areas mainly rely on herbicides to control weeds in DSR systems. The use of herbicides alone may not provide effective and season-long weed control. Because of the increased use of herbicides, the risk of herbicide resistance, and concerns about environmental contamination, there is an interest in integrating herbicide use with cultural weed management approaches (Kumar and Ladha 201, Chauhan 2012b, 2013, Mahajan and Chauhan 2013).

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Some cultural weed management approaches are the use of a stale seedbed technique, different tillage systems, weed-competitive cultivars, cultivars capable of emerging under anaerobic conditions, crop residue for mulches, high seeding rates, narrow crop rows, and optimum time and depth of flooding.

Stale seedbed technique

In the stale seedbed technique, weed seeds are allowed to germinate using a pre-sowing irrigation or after rainfall. After this, emerged weed seedlings are killed using a non-selective herbicide (e.g., paraquat or glyphosate) or cultivation (Chauhan 2012b, Kumar and Ladha 2011). The use of a stale seedbed practice not only reduces the weed population in the crop but also helps to significantly reduce the size of the weed seed bank. In a study, a stale seedbed reduced the weed population by 50% compared with the treatments in which this practice was not used (Singh *et al.* 2007). The success of the stale seedbed practice depends on the weed species, the position of weed seeds relative to the soil surface, and environmental conditions. In general, weed species sensitive to the stale seedbed practice are those that are present in the topsoil layer, have low initial dormancy, and require light to germinate (Chauhan 2012b). Examples of such weed species are *C. iria*, *Digitaria ciliaris* (Retz.) Koel., *Eclipta prostrata* (L.), *L. chinensis*, and *Ludwigia hyssopifolia* (G. Don) Exell. Weed species with high initial dormancy may be difficult to manage using the stale seedbed practice.

In the rice-wheat cropping system in northern India, the success of the stale seedbed practice will mainly depend on environmental conditions, especially temperature and the management practices adopted in the non-rice crop. In ZT wheat, for example, weed seeds shed in the previous rice crop remain near the soil surface and these weed seeds may be more prone to be exhausted by the stale seedbed practice. In conventional tilled wheat, on the other hand, tillage operations may bury weed seeds very deep. Despite the advantage of the stale seedbed practice, the practical importance of this practice should be evaluated by farmers themselves. Such decisions are particularly applicable for areas where the period between the harvesting of the preceding crop and sowing of the DSR crop is short or where farmers use diesel pumps (*i.e*. cost involved) to irrigate their fields.

Tillage systems

As mentioned previously, DSR can be sown under ZT conditions or after thorough land preparation. In continuous ZT systems, most of the weed seeds remain on or near the soil surface after crop planting (Chauhan and Johnson 2009, Chauhan *et al.* 2006, Yenish *et al.* 1992). Such a weed seed bank is prone to rapid desiccation and seed predation (Chauhan *et al.* 2010, Mohler 1993). Furthermore, environmental conditions are more favourable for the germination of weed seeds present on the soil (Banting 1966). These observations suggest that the weed seed bank in ZT systems can be exhausted very easily. However, results may differ in different conditions, especially for wind-disseminated and perennial weed species. Because of a lack of seed burial by tillage, wind-dispersed species have been found dominant in ZT systems (Froud-Williams *et al.* 1981). Similarly, because of the lack of disturbance of the root systems of established weeds, perennial weed species can become dominant in ZT systems (Triplett 1985). In continuous ZT systems, annual weed seeds may also accumulate on or near the soil surface. In such situations, a deep tillage operation can be used to bury most of the seeds below the maximum depth of their emergence (Chauhan and Johnson 2010). Frequent tillage operations may also stimulate weed seed germination by exposing buried weed seeds to light and reduce the weed seed bank in the soil (Mohler 1993). In general, weed response to tillage systems is not well understood in DSR systems, especially in India. Therefore, there is a need to enhance our understanding of the effect of tillage systems on weed management.

Nowadays, different kinds of seeding machines are used for DSR sowing. These machines may have tines or discs, and the thickness of the tines and discs may also differ. In ZT systems, different sowing points are known to cause differential vertical seed distribution (Chauhan *et al.* 2006). Vertical weed seed distribution can affect weed seedling emergence by influencing the conditions for weed seeds. Therefore, there is a need to better understand the effect of different tillage systems on vertical weed seed distribution in DSR systems in India.

Cultivars

The integrated use of rice cultivars with other management practices may help to reduce selection pressure and delay the development of herbicide resistance in weeds. A recent review discussed the role of cultivars in managing weeds in DSR systems (Mahajan and Chauhan 2013). The authors suggested that the traits likely to be most helpful for weed management in DSR included seed germination in anaerobic conditions and tolerance of early submergence for uniform crop emergence, high and early seedling vigour with rapid leaf area development, and cultivars having an allelopathic effect. The significance of allelopathy for weed management is well known for crops such as wheat. However, in rice, the significance of allelopathy will remain conjectural until it is clearly shown that results observed in bioassay studies also occur in fields (Mahajan and Chauhan 2013)

In India, not much work has been done on the development of weed-competitive rice cultivars for DSR systems. In other regions (*e.g.*, Philippines), cultivars, such as '*Apo*' and '*UPLRi-7'*, have been reported with superior weed competitiveness (Zhao 2006) and these could be tested throughout India in the future, where DSR is being promoted. In most of the regions, cultivars bred for transplanted rice are being used in DSR systems. The availability of weed-competitive cultivars might help in curtailing herbicide doses in DSR systems by suppressing weed emergence and growth (Mahajan and Chauhan 2013). In DSR systems, two herbicides (pre- and post-emergence) are usually applied and, in addition, farmers need to perform one hand weeding. The use of weed-competitive cultivars may help to get rid of the hand weeding and reduce herbicide use. Short-duration cultivars and hybrids can also be used to suppress weed growth due to their high vigour and tendency to close the canopy faster. Seedling vigour helps in better crop establishment and it offers successful competition with weeds in favour of the crop (Mahajan and Chauhan 2013). Very little is known about the relative importance of above ground (shoot) and below ground (root) competition of rice cultivars in DSR systems. Breeders and weed scientists should work together to explore different traits in rice-weed competitive interactions in DSR systems.

DSR is a labour-saving establishment method and it has the potential to spread throughout India in the wake of labour scarcity. In some regions, however, the risk of uncertainty of rainfall and possible flooding during crop emergence hinders the large-scale adoption of DSR as cultivars capable of germinating under flooded conditions are not available in India. Work is in progress at the International Rice Research Institute (IRRI) and, very soon, cultivars having tolerance of anaerobic conditions during emergence will be available for farmers. The availability of such cultivars will not only increase the overall area under DSR systems in India but will also provide economical and environmentally friendly weed control as DSR fields will be easily submerged immediately after crop sowing (Chauhan 2012b, Mahajan and Chauhan 2013).

Use of crop residue as mulch

As mentioned in a previous section, DSR can be grown under ZT conditions. Depending on the cropping system (rice-rice, rice-wheat, rice-maize, *etc*.) and farmers' need for crop straw, there may be intact and loose residue on the soil surface. The crop residue present on the soil surface can influence weed and crop growth (Chauhan 2012b, Chauhan and Mahajan 2012, Chauhan and Abugho 2013, Chauhan *et al.* 2012a). In general, crop residue in a normal amount can effectively suppress the emergence of small-seeded weed species. For large-seeded species, a high amount of residue may be needed to substantially affect seedling emergence.

In the rice-wheat cropping system in northern India, wheat residue at 4 t/ha reduced annual and broad-leaved weed densities in DSR compared with no residue (Singh *et al.* 2007). The study also suggested that crop residue can be used as mulch in integrated weed management programmes to reduce herbicide doses. Direct drilling of rice into the anchored and loose residue load of up to 7-8 t/ha has been reported in the rice-wheat system in India (Gupta *et al.* 2006). For sowing in such a high amount of residue, however, there is a need for drills, such as the turbo seeder and disc opener, which can be attached only with four-wheel tractors. In eastern India or where the farm size is very small, there is a need to invest in research and development on different scales of drills, attached with two-wheel as well as four-wheel tractors.

In some countries, cover crops are used to suppress weed emergence and growth. A cover crop can produce residue to create an unfavourable environment for weed germination and crop emergence (Teasdale 1996). In India, too, legume crops such as *Sesbania* and blackgram (mungbean) can be used to reduce weed emergence in DSR crops. The legume crops are then killed by non-selective herbicides before sowing the rice crop. There are numerous advantages of using legume crops; however, farmers may not consider such practices to be economical (Chauhan 2012b). Therefore, there is a need to evaluate such options while working with farmers.

Flooding

Flooding is considered the best weed management option in rice. If irrigation water is plentiful, farmers can submerge their DSR fields immediately after crop emergence. Flooding can suppress the emergence and growth of several weed species (Chauhan and Johnson 2010). Early and continuous flooding at a shallow depth (*e.g.*, 2 cm) can also help to suppress the emergence and growth of problematic weeds, such as *L. chinensis* (Chauhan and Johnson 2008). Because of competition with non-agricultural sectors for water, farmers in India may not be able to flood their rice fields in the future. This may restrict farmers' capacity to use continuous flooding as a weed control mechanism (Chauhan 2012b, Tuong *et al.* 2005). In water-limited environments, farmers should aim for early flooding to make the best use of water to suppress weeds in DSR systems. Flooding after herbicide application or hand weeding could also prevent the further growth of weeds.

Agronomic manipulations

In DSR systems, weeds can also be managed by manipulating agronomic practices. For example, the proper management of fertilizer, especially nitrogen (N), reduces the weed competition and therefore fertilizer should be applied as per the requirement of the crop (Mahajan and Chauhan 2011a). A study in Punjab reported that, when weeds were controlled, the DSR crop responded to a higher N application but, under weedy and partially weedy situations, rice grain yield declined markedly with higher amounts of N fertilization (Mahajan and Timsina 2011). The banding of fertilizer in the soil rather than broadcasting can also help to reduce the weed population in DSR.

DSR in India is grown at seeding rates of 25-30 kg/ha. Farmers who grow hybrid seeds use a seeding rate of 15-20 kg/ha. In some parts, farmers use their own stored seed. In such cases, the seeding rate could be increased not only to suppress weeds but also to compensate for poor seed quality and crop emergence. In some regions of India, there is a chance for poor stand establishment if rain occurs immediately after sowing. Low plant density encourages the growth of weeds if effective weed control measures are not undertaken. A study in DSR systems in India showed that there was no effect of seeding rates, ranging from 15 to 125 kg/ha, on the grain yield of rice grown in weed-free conditions (Chauhan *et al.* 2011). In the presence of weeds, however, maximum grain yield was achieved at 95 to 125 kg seed/ha. Results from various studies in other parts of the world have shown that increasing seeding rates suppresses weed growth and reduces grain losses from weed competition (Zhao 2006, Chauhan *et al.* 2011). Farmers in countries such as Uruguay use very high seeding rates (approximately 165 kg/ha) in DSR, mainly to close the canopy faster.

It is well known that narrow rows improve weed-competitive ability of a crop by closing the canopy faster and allowing less light penetration to the soil surface (Chauhan 2012b, Liebman *et al.* 2001). Because of the availability of suitable seed drills, most farmers in India already plant their DSR crop at a narrow row spacing, that is, 20 cm. However, some farmers (*e.g.* in Tamil Nadu) still use a wider row spacing to accommodate mechanical or hand weeding. The row spacing in the DSR crop can be further reduced to around 15 cm to suppress weeds after herbicide application. In such a narrow row spacing, however, there is a need to evaluate in humid regions whether insect and disease infestations increase. Narrow row spacing results in lower weed biomass than wider row spacing. The yield of some cultivars may be improved by exploring paired-row planting systems. In a study in Punjab, paired-row planting patterns of 15-30-15 cm spacing had a greater influence on weeds than a normal row of 23 cm spacing (Mahajan and Chauhan 2011b). The study suggested that paired-row planting suppressed weeds by maintaining crop plants' dominant position over weeds through a modification in canopy structure. In conclusion, narrow rows and modifying crop geometry can help to suppress weeds through rapid canopy closure.

Herbicides

In DSR systems, herbicide use is must and their use is likely to increase further with the rising labour scarcity. Herbicide use in DSR systems becomes even more important as rice and weed seedlings emerge simultaneously and some weed seedlings (*e.g.*, *Echinochloa* spp.) are morphologically similar to rice seedlings (Chauhan 2012b). Herbicides should not be considered as a replacement for other weed control methods, however, but should be integrated with them.

Various pre- and post-emergence herbicides are used in DSR systems to control weeds (Table 1). Pendimethalin has been found to be superior to oxadiargyl, particularly against *D. aegyptium*, *L. chinensis*, and *Eragrostis* spp., but it requires extra precaution to avoid possibilities of its phytotoxicity (reduced germination), particularly under high soil moisture conditions and when seeds are not properly covered with a thin soil layer. In general, sequential applications of a pre-emergence herbicide (*e.g.*, pendimethalin or oxadiargyl) followed by post-emergence herbicide (*e.g.*, bispyribac-sodium) can provide effective weed control in DSR, if coupled with some other weed management strategies. In future, the combination of two or more herbicides [*e.g.*, bispyribac + pyrazosulfuron, bispyribac + azimsulfuron, bispyribac + ethoxysulfuron, bispyribac + fenoxaprop (with safener), penoxsulam + cyhalofop, pendimethalin followed by bispyribac + pyrazosulfuron, pendimethalin followed by bispyribac + azimsulfuron, pendimethalin followed by bispyribac + ethoxysulfuron, pendimethalin followed by bispyribac + fenoxaprop (with safener)] may become a part of an effective and integrated approach to achieve more satisfactory control of complex weed flora in DSR.

Flooding after the post-emergence herbicide application, for example, could suppress subsequent growth of

Table 1. Different pre- and post-emergence herbicides used in dry-seeded rice

Herbicide	Dose (g/ha)	Application time (days after sowing)
Pendimethalin	1000	1-3
Oxadiargyl	100	1-3
Bispyribac-sodium	25	15-25
Pyrazosulfuron	25	15-25
Penoxsulam	25	15-25
Azimsulfuron	30	15-25
Fenoxaprop (with safener)	60	15-25
Cyhalofop	90	15-25
2,4-D ester or amine	500	15-25
Metsulfuron	4	15-25
Ethoxysulfuron	18.75	15-25
Metsulfuron + chlorimuron	4	15-25

weeds. Because of a lack of continuous standing water in DSR fields, some problematic weed species (*e.g.*, *C. rotundus*) are increasing. Furthermore, because of the continuous use of the same herbicide, there is a shift toward problematic weed species. Bispyribac-sodium, for example, is effective on grasses, but it does not provide effective control of *L. chinensis* and *D. aegyptium* (Gopal *et al.* 2010, Chauhan and Abugho 2012). In such situations, there is a need to evaluate effective tank-mix herbicides.

As mentioned earlier, herbicide use is expected to increase in the future. Therefore, it is important to understand the right application methods for herbicides as improper and ineffective herbicide application methods may result in a waste of chemicals and environmental pollution, damage to non-targeted plants, and harm to human health (Chauhan 2012a). There is a need to use the right nozzles and right spray patterns. Spraying herbicides in a “swinging” way across the field may result in poor weed control. In our view, public-private partnership can greatly help in improving herbicide spray techniques in various parts of India.

Weedy rice

In some countries (*e.g.* Malaysia, Vietnam, and Sri Lanka), the adoption of direct-seeded rice systems has made weedy rice infestation one of the most serious problems. In India, weedy rice may also become a problematic weed with the spread of DSR systems. Selective herbicides to manage weedy rice in cultivated rice are not available and therefore managing weedy rice would be a challenging problem for farmers in India. In the absence of selective herbicides, various cultural approaches may be exploited to reduce the problem of weedy rice. A recent review discussed different strategies (the use of clean seeds and machinery, use of stale seedbed practice, thorough land preparation, rotation of different rice establishment methods, use of high seeding rate and row-seeded crop, use of purple-coloured cultivars, use of flooding, and adoption of crop rotation) to manage weedy rice in Asia (Chauhan 2013).

Conclusion

Weeds are the major constraint in DSR production systems. In this article, we discussed several approaches to managing weeds in DSR systems. The use of any single approach, however, would not provide season-long and sustainable weed control because of the variation in dormancy and growth habits of weeds (Chauhan 2012b). There is a need to integrate as many weed management approaches as possible to achieve effective, sustainable, and long-term weed control in DSR. In India, future research in DSR systems should focus on the integration of appropriate management practices with suitable cultivars and appropriate herbicide application timing and combinations. There is also a need to study weed biology and ecology in DSR systems in different rice ecosystems.

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Integrated weed management practices on growth and yield of direct-seeded lowland rice

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ABSTRACT

Field experiments were conducted to find out the effect of integrated weed management practices on growth and yield of direct seeded rice in Cauvery delta zone. Twelve weed control treatments were tested in randomised block design replicated thrice. The treatments consisted of post-emergence application of metamifop (75, 100, 125 g/ha), pre emergence application of pretilachlor + safener 0.45 kg/ha alone and their combination with one hand weeding at 45 DAS. In addition, post-emergence metamifop 200 g/ha and cyhalofop-butyl 100 g/ha alone was also tested along with two hand weeding at 25 and 45 DAS and unweeded control. The results revealed that two hand weeding was found to be better in terms of weed control and grain yield of rice over other weed management practices. Among the herbicides, the pre-emergence application of pretilachlor + safener 0.45 kg/ha followed by one hand weeding at 45 DAS was effective in controlling all weeds and registered higher yield attributes and yield in wet-seeded rice which was at par with two hand weeding. Greater reduction in grass weed population was observed with post-emergence application of metamifop 100 and 125 g/ha as compared to other herbicides. Pre-emergence application of pretilachlor + safener 0.45 kg/ha followed by one hand weeding at 45 DAS was found to be ideal weed management practice for improving the rice grain yield by eliminating crop-weed competition in wet-seeded rice.

Key words: Growth, Integrated weed control, Weed density, Wet-seeded rice, Yield

Meeting food demand for the increasing population has become a major challenge now than ever before. Agriculture is in the forefront of national and international agenda to assume food security through sound management of natural resources. Cereals play major role in our food economy and it is the most important part of diet throughout the world. Amongst cereals, rice *(Oryza sativa*) is the most important and extensively grown crop in tropical and subtropical regions of the world as it is staple food for more than 60% of the world population.

Rice production systems are undergoing several changes and one of such changes is shift from transplanted rice to direct seeding. Direct seeding offers certain advantages *i.e.* saves labour, faster, easier, timely sowing, less drudgery, early crop maturity by 7–10 days, less water requirements, higher tolerance to water deficit, often higher yield, low production cost, more profit, better soil physical conditions for following crops and less methane emission (Balasubramanian and Hill 2002). Despite several advantages, various production obstacles are also encountered in direct seeded rice (DSR) cultivation.

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The productivity of rice in India is declining due to an array of biotic and abiotic factors. Weeds are the prime yield-limiting biotic constraints that compete with rice for moisture, nutrients, and light. Weed infestation and competition are severe in puddled direct-seeded rice as compared to transplanted rice, because of the simultaneous growth of both crops and weeds. Weed competition reduced the grain yield by 50-60% in direct-seeded low land rice (Subramanian 2011). Any delay in weeding will lead to increased weed biomass which has a negative correlation with yield. Herbicides presently used in rice are mainly pre-emergence and weeds coming at later stages of crop growth are not controlled by these herbicides. No single approach, either uses of herbicides or manual/mechanical weeding is convenient in containing the weed menace. Hence, the present investigation was carried out to study the effect of integrated weed management packages for control of weeds in direct seeded rice.

MATERIALS AND METHODS

Field experiments were conducted at Tamil Nadu Rice Research Institute (Tamil Nadu Agricultural University), Aduthurai during wet seasons of 2011 and 2012 to study the effect of integrated weed management practices for weed control in direct seeded lowland rice in Cauvery Delta Zone of Tamil Nadu. The soil of the experimental field was clay with slightly alkaline pH (8.2), medium in organic carbon (0.52%), low in available nitrogen (161 kg/ha), high in available phosphorus (54.5 kg/ha) and medium in available potassium (206 kg/ha). A total of 12 treatments was tested in a randomized block design replicated thrice. The treatments consisted of post-emergence application of metamifop (75, 100, 125 g/ha), pre-emergence application of pretilachlor + safener 0.45 kg/ha alone and their combination with one hand weeding at 45 DAS. Post-emergence metamifop 200 g/ha and post-emergence cyhalofop-butyl 100 g/ha alone was also tested along with two hand weeding at 25 and 45 DAS and unweeded control for weed control and productivity in direct-seeded rice.

Long duration (155 days) high yielding variety '*CR 1009*' was sown during 11.08.2011 and 15.08.2012 with pre-germinated rice seeds by using drum seeder with inter and intra row spacing of 20 x 7.5-10 cm respectively. The crop was fertilized with recommended dose of 150: 50: 50 kg of N, P_2O_5, K_2O/ha and entire dose of phosphorus was applied as basal in addition to zinc sulphate 25 kg/ha and gypsum 500 kg/ha. Nitrogen and potassium were applied in four equal splits at 21 DAS, active tillering, panicle initiation and heading stages. Pre-emergence herbicide was mixed with sand and applied uniformly in the field on 3 DAS. The post-emergence herbicides were mixed with water at the rate of 500 litres/ha and sprayed at 2-3 leaf stage of weeds by using knapsack sprayer fitted with deflector nozzle. A thin film of water was maintained at the time of pre-emergence herbicide application. Hand weeding was carried out as per the treatment schedule. All other agronomic and plant protection measures were adopted as per the recommended packages.

The data on weed density (30, 60 DAS and harvest) and weed dry weight (60 DAS) were recorded with the help of a quadrate (0.5 x 0.5 m). In case of observation on weeds, normality of distribution was not seen and hence, the values were subjected to square root transformation ($\sqrt{x+0.5}$) prior to statistical analysis to normalize their distribution. Observations on crop growth parameters, *viz.* plant height (harvest), leaf area index (90 DAS) and yield attributes like panicles/m^2, grains per panicle and grain yield were recorded. The weed control efficiency was worked out on the basis of weed dry matter production using the formula suggested by Mani *et al.* (1973) and weed index was calculated by using the formula suggested by Gill and Vijayakumar (1966).

RESULTS AND DISCUSSION

Weed flora

The important weed species observed in the experimental fields were: *Echinochloa crusgalli, Echinochloa colona, Leptochloa chinensis* and *Panicum repens* among grasses; *Cyperus difformis*, *Cyperus iria* and *Fimbristylis miliacea* among sedges; and *Marselia quadrifolia, Eclipta alba, Ammania baccifera, Bergia capensis* and *Ludwigia parviflora* among broad-leaved weeds.

Effect on weeds

The density and dry weight of weeds were significantly influenced by weed control treatments at all stages of observation in both the years of study (Table 1 and 2). The minimum weed density (22.3, 23.3; 26.3, 17.0 and 43.3, 24.7 no./m^2) at 30, 60 DAS and harvest stages and weed dry weight (7.9, 7.6 g/m^2) at 60 DAS were recorded under two hand weeding on 25 and 45 DAS during both years respectively. This was found to be on par with pre-emergence application of pretilachlor + safener 0.45 kg/ha on 3 DAS followed by one hand weeding on 45 DAS and post emergence application of metamifop 100, 125, 200 g/ha followed by one hand weeding on 45 DAS during two years of study at both 60 DAS and harvest. At 30 DAS, the density and dry weight of weeds were lower under two hand weeding over rest of the treatments. These findings were in conformity with Prasad *et al.* (2001) who reported that hand weeding twice resulted in lower weed density and dry weight compared to herbicide application and untreated control. As hand weeding is laborious, tedious, expensive and time consuming method, it can not be practicable at large scale.

Among herbicides, pretilachor + safener was found to be efficient in reducing population of sedges and broad-leaved weeds, but grass weed population was markedly reduced by the application of metamifop. This may be due to the fact that pretilachlor + safener effectively controlled early flushes of weeds and later flushes of weeds by hand weeding. These results were in agreement with the findings of Sangeetha (2009) and Chinnusamy *et al.* (2010). Among different dose of application, metamifop at 100, 125 and 200 g/ha showed higher reduction of grass weed as compared to metamifop at 75 g/ha. The results further revealed that maximum weed density was noticed in untreated plots during both the years. It clearly shows that non adoption of proper weed control measures leads to constant increase in density and dry weight of weeds as a result, crop growth and establishment suffer severely.

At 60 DAS, two hand weeding on 25 and 45 DAS and application of herbicides supplemented with one hand

Table 1. Influence of weed management practices on total weed density (no./m²) in direct-seeded rice

Treatment	30 DAS		60 DAS		Harvest	
	2011	2012	2011	2012	2011	2012
Metamifop 75 g/ha	11.6 (133.3)	12.8 (164.0)	12.7 (161.3)	14.4 (207.3)	13.3 (175.67)	14.1 (197.7)
Metamifop 100 g/ha	11.1 (123.67)	12.1 (147.3)	12.5 (156.0)	13.2 (175.3)	12.5 (156.0)	13.4 (178.7)
Metamifop 125 g/ha	10.7 (113.7)	12.3 (151.0)	12.2 (148.7)	13.3 (176.0)	12.1 (146.0)	13.1 (170.3)
Metamifop 200 g/ha	10.7 (114.0)	12.3 (150.3)	11.9 (142.7)	13.0 (169.3)	12.2 (148.3)	13.0 (170.0)
Pretilachlor + safener 450 g/ha	8.7 (77.3)	9.6 (92.0)	10.9 (118.0)	11.3 (128.0)	11.6 (134.0)	11.1 (124.0)
Cyhalofop-butyl 100 g/ha	11.5 (131.3)	12.7 (162.3)	12.8 (163.7)	14.3 (203.0)	13.1 (172.7)	13.8 (190.7)
Metamifop 75 g/ha + HW 45 DAS	11.1 (121.7)	12.1 (145.3)	5.4 (29.0)	5.4 (28.3)	7.1 (50.7)	6.4 (40.3)
Metamifop 100 g/ha + HW 45 DAS	11.0 (121.7)	12.0 (144.0)	5.5 (30.3)	4.9 (23.3)	7.0 (48.0)	6.0 (35.7)
Metamifop 125 g/ha + HW 45 DAS	11.0 (121.3)	11.9 (142.3)	5.4 (28.7)	4.7 (22.0)	6.3 (39.3)	5.6 (31.0)
Pretilachlor + safener 450 g/ha + HW 45 DAS	8.1 (65.3)	9.3 (85.7)	5.3 (27.7)	4.7 (22.0)	6.6 (42.7)	5.4 (28.33)
Hand weeding twice - 25 and 45 DAS	4.8 (22.3)	4.9 (23.3)	5.2 (26.3)	4.2 (17.0)	6.6 (43.3)	5.0 (24.7)
Unweeded control	13.3 (177.3)	15.1 (227.0)	15.2 (232.0)	16.9 (284.3)	16.7 (280.0)	17.7 (312.0)
LSD (P=0.05)	1.0	0.9	0.9	0.9	0.9	0.8

Figures in parentheses are original values, which were subjected to square root transformation ($\sqrt{x + 0.5}$) before analysis

Table 2. Influence of weed management practices on weed dry weight, weed control efficiency and weed index at 60 DAS in direct-seeded rice

Treatment	Weed dry weight (g/m²)		Weed Index (%)		WCE (%)	
	2011	2012	2011	2012	2011	2012
Metamifop 75 g/ha	10.2(103.3)	10.8 (115.9)	45.2	57.1	58.2	53.4
Metamifop 100 g/ha	9.6 (91.8)	10.1 (101.2)	38.3	51.5	62.8	59.3
Metamifop 125 g/ha	9.3 (87.0)	10.0 (98.8)	35.9	50.0	64.8	60.3
Metamifop 200 g/ha	9.2 (83.8)	9.4 (88.4)	33.6	48.8	66.0	64.5
Pretilachlor + safener 450 g/ha	8.9 (78.5)	8.8 (77.7)	31.3	47.0	68.2	68.8
Cyhalofop-butyl 100 g/ha	10.51(110.2)	10.6 (112.9)	41.5	53.0	55.4	54.6
Metamifop 75 g/ha + HW 45 DAS	3.81 (14.1)	4.4 (18.8)	16.5	16.3	94.3	92.4
Metamifop 100 g/ha + HW 45 DAS	3.65 (12.9)	4.0 (15.3)	9.1	7.1	94.8	93.8
Metamifop 125 g/ha + HW 45 DAS	3.56 (12.2)	4.0(15.7)	8.7	3.4	95.0	93.7
Pretilachlor + safener 450 g/ha+ HW 45 DAS	3.00 (8.5)	2.9 (8.1)	4.0	2.0	96.5	96.7
Hand weeding twice - 25 and 45 DAS	2.87 (7.9)	2.8 (7.6)	0.0	0.0	96.8	96.9
Unweeded control	15.73(246.9)	15.8 (248.8)	63.4	70.5	0.0	0.0
LSD (P=0.05)	0.56	0.70	-	-	-	-

Figures in parentheses are original values, which were subjected to square root transformation ($\sqrt{x + 0.5}$) before analysis weeding at 45 DAS recorded more than 90% weed control efficiency as compared to herbicides application alone which recorded WCE of 53-68%. These observations indicated that weeds in DSR could be kept at low level by integrating chemical and physical methods of weed control. Similar results were also reported by Sinha *et al.* (2006) and Singh *et al.* (2009).

Effect on crop growth

All the weed control treatments brought out a significant effect on plant height and leaf area index (Table 3). Plant height and leaf area index (LAI) were found to be the lowest in weedy check and maximum in two hand weeding on 25 and 45 DAS as reported by Singh *et al.* (2012). Taller rice plants were observed in the plots given with two hand weeding (113.7 and 127.2 cm) which was at par with herbicide application supplemented with one hand weeding at 45 DAS, whereas shorter plants were observed with application of herbicides alone and unweeded check. Maximum LAI of 7.85 and 8.95 were recorded under two hand weeding which was at par with pre-emergence application of pretilachlor + safener 0.45 kg/ha on 3 DAS followed by one hand weeding at 45 DAS and this was found superior over rest of the treatments during both the years. This might be due to effective control of weeds, less crop-weed competition throughout the crop growth period and crop enjoyed favourable conditions with respect to light, space, nutrients, CO_2 *etc.* These results are in conformity with the findings of Subramanian *et al.* (2006) who reported that the weed management practices adopted in wet-seeded rice, improved the growth parameters by eliminating crop-weed competition at critical stages.

Effect on yield

Yield contributing characters like panicles per square metre, grains per panicle and grain yield were significantly influenced by the weed control practices in DSR (Table 3). Among the treatments, two hand weeding registered the highest number of panicles 368 and 409/m^2 during both the year, respectively, which was at par with the pre-emergence application of pretilachlor + safener 0.45 kg/ha on 3 DAS followed by one hand weeding at 45 DAS and metamifop 125 g/ha followed by one hand weeding at 45 DAS.

The highest grain yield of 5.71 and 8.03 t/ha was recorded from two hand weeding during both the years of study. Similar results were also reported by Gill (2008) and Singh *et al.* (2009). Among the herbicides, pretilachlor + safener 0.45 kg/ha on 3 DAS followed by one hand weeding at 45 DAS produced the higher grain yield and it was at par with two hand weeding. Metamifop at 100 and 125 g/ha with one hand weeding at 45 DAS found to be the next best treatments. This might be attributed to better growth of plants on account of reduced crop - weed competition resulting in increased availability of nutrients, water and light. These results were in agreement with the findings of Chinnusamy *et al.* (2010) and Thomas *et al.* (2012). The lowest grain yield (2.09 and 2.37 t/ha) was recorded under unweeded control during both the years of investigation. Without controlling weeds, the loss in grain yield was 63.4% during 2011 and 70.5% during 2012.

It is clearly noted that pre emergence application of pretilachlor + safener 0.45 kg/ha followed by one hand

Table 3. Influence of weed management practices on growth, yield attributes and grain yield of rice

Treatment	Plant height at harvest (cm)		LAI at 90 DAS		Panicles/m^2		Grains/ panicle		Grain yield (t/ha)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Metamifop 75 g/ha	89.9	98.8	4.10	5.80	252	270	117	117	3.12	3.54
Metamifop 100 g/ha	95.1	101.9	4.36	6.21	267	283	119	121	3.52	3.89
Metamifop 125 g/ha	97.5	103.2	4.89	6.09	283	298	120	122	3.65	4.01
Metamifop 200 g/ha	97.9	102.3	5.44	6.35	286	300	119	123	3.79	4.11
Pretilachlor + safener 450 g/ha	98.3	112.1	5.83	6.98	293	306	122	123	3.92	4.25
Cyhalofop-butyl 100 g/ha	92.6	103.3	4.42	6.04	265	279	118	119	3.34	3.77
Metamifop 75 g/ha + HW 45 DAS	107.1	123.9	6.19	7.03	326	344	125	130	4.77	6.72
Metamifop 100 g/ha + HW 45 DAS	110.3	125.4	6.97	7.54	340	374	127	132	5.18	7.46
Metamifop 125 g/ha + HW 45 DAS	111.0	125.6	7.19	8.05	351	386	128	133	5.21	7.75
Pretilachlor + safener 450 g/ha + HW 45 DAS	113.0	126.3	7.55	8.68	354	393	129	135	5.48	7.87
Hand weeding twice - 25 and 45 DAS	116.6	127.2	7.85	8.95	368	409	131	141	5.71	8.03
Unweeded control	84.1	93.4	3.08	4.85	149	182	108	110	2.09	2.37
LSD(P=0.05)	6.6	5.8	0.65	0.63	27	29	8	12	0.38	0.59

weeding at 45 DAS was resulted in significantly higher grain yield in DSR due to better control of weeds leading to lesser nutrient removal by weeds and higher uptake of nutrients by rice. Further, application of post-emergence herbicide metamifop 100 g/ha followed by one hand weeding at 45 DAS was found to be superior wherever the grassy weeds dominated. The results of two hand weeding were significantly better in terms of weed control and rice grain yield, but as it was time consuming and laborious, it cannot be recommended at large scale. Hence, pre-emergence application of pretilachlor + safener 0.45 kg/ha followed by one hand weeding at 45 DAS was found to be the best weed management practice in terms of weed control and higher yield in wet seeded rice cultivation.

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Evaluation of bispyribac-sodium in transplanted rice

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ABSTRACT

Field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai to evaluate herbicide bispyribac-sodium in transplanted rice varieties '*ASD 16'* and '*ADT 37* during 2010 and 2011. Seven treatments were included in a randomized block design and replicated four times. The treatments consisted of pre–emergence application of butachlor 500 g/ha, post-emergence application of bispyribac-sodium 10 SC at 25, 35 and 50 g/ha , weed free, hand weeding twice and unweeded check**.** The results revealed that total weed population and dry weight under bispyribac-sodium at 25 g/ha were at par with the higher doses of bispyribac-sodium at 35 and 50 g/ha during both the years of study. The weed control efficiency and weed index under bispyribac-sodium at lower dose were also comparable with that of higher doses indicating the sufficiency of bispyribac-sodium at 25 g/ha for effective weed management in transplanted rice. The effect of bispyribac-sodium at 25 g/ha on producing tillers and panicles was also at par with that of higher doses and twice hand weeding and significantly superior than butachlor application. Post-emergence application of bispyribac-sodium at 25 g/ha recorded a grain yield of 6.84 and 6.51 t/ha during 2010 and 2011, respectively which were at par with higher doses of bispyribac-sodium, twice hand weeding and weed free and significantly higher than butachlor application. Higher net income and benefit-cost ratio were also associated with the application of bispyribac-sodium at 25 g/ha.

Key words: Bispyribac-sodium, Economics, Grain yield, Rice, Weed

Rice, the most important staple food crop of India is cultivated under various ecosystems, *viz*. transplanted, direct sown and rainfed situations. To meet the future food requirements of ever increasing population and maintain self sufficiency, the estimated rice production in India should be 350 million tonnes by 2020 AD. In transplanted rice, weed infestations not only reduce the grain yield up to 45% but also quality of grain is impaired. The share of weed management cost is higher than other operations in transplanted rice. Though many pre-emergence herbicides are available for controlling weeds, the need for post-emergence herbicide is often realized to combat the weeds emerged during later stages of crop growth. More over, due to increasing problem of labour availability for rice cultivation, use of post-emergence herbicide has greater potential for effective weed management and higher yield. In this context, present study was carried out to evaluate bispyribac-sodium efficacy in transplanted rice.

MATERIALS AND METHODS

Field experiments were conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai to evaluate herbicide bispyribac-sodium in transplanted rice on growth, yield and weed control efficiency in transplanted rice during *Kharif* 2010 and 2011. A total of seven treatments was evaluated in a randomized block design and replicated four times. The treatments consisted of pre–emergence application of butachlor 1500 g/ha at 0-5 days after transplanting (DAT), post-emergence application of bispyribac-sodium 10 SC at 25**,** 35, 50 g/ha at 20 DAT, weed free, two hand weeding and weedy check. The soil of the experimental field was clay loam with a pH of 6.8 and having NPK status of low, medium and high respectively. The rice varieties '*ASD 16'* and '*ADT 37*' were used during 2010 and 2011, respectively with a spacing of 20 x 10 cm. Bispyribac-sodium was applied as foliar spray on 20 DAT in the respective treatments as per schedule while butachlor was applied as broadcasting with sand mixing. Hand weeding was carried out on 20 and 40 DAT and for weed free plot, hand weeding was done as and when required. The data on weed density and dry weight of weeds were recorded at 45 DAT. The weed dry weight was expressed as kg/ha. Weed control efficiency and weed index were computed. The yield attributes and grain yield of rice were recorded and economics was also worked out.

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RESULTS AND DISCUSSION

Total weed density

The total density of weeds decreased with increase in doses of bispyribac-sodium but not significantly (Table 1). The lowest total weed density was observed by weed free plots. However, this was statistically similar with application of all the doses of bispyribac-sodium during both the years. The total weed density under the treatments butachlor application at 1500 g/ha and hand weeding twice were similar and significantly higher than all the doses of bispyribac-sodium. The highest weed density was observed in unweeded control plot. Reduction in weed density due to application of bispyribac-sodium at 15 and 25 DAT in transplanted rice were reported by Yadav *et al.* (2009). Similar effective control of grasses, sedges and broad-leaved weeds in rice fields was documented by Schmidt *et al*, (1999). These results were also in conformity with the findings of Kumaran *et al.* (2012) who registered lower weed density under bispyribac-sodium than other weed management treatments in direct-seeded rice.

Dry weight

Application of bispyribac-sodium at all the doses resulted in significant reduction in total weed dry weight than butachlor application, twice hand weeding and unweeded check (Table 1). However the total weed dry weight under the higher dose of bispyribac-sodium at 50 g/ha was at par with the lower doses of 25 and 35 g/ha indicating the sufficiency of lower dose of 25 g/ha for effective weed management in transplanted rice in both the years. The weed controlling effect of pre-emergence application of butachlor and two hand weeding was lesser than bispyribac-sodium as evident from significantly higher weed dry weight under above two treatments. The highest weed dry weight was registered in unweeded control plot. Post-emergence application of bispyribac-sodium at 15 or 25 DAT significantly decreased the weed dry weight in transplanted rice (Yadav *et al.* 2009). Similar results of lower weed dry weight with the application of bispyribac-sodium at 40 g/ha than butachlor and anilophos in transplanted rice was recorded by Nalini *et al.* (2012). The significant reduction of weed dry weight by bispyribac-sodium at 30 g/ha than pre-emergence herbicide application in dry-seeded rice was also observed by Walia *et al.* (2008).

Weed control efficiency

Among the weed control treatments, application of bispyribac-sodium at 50 g/ha recorded highest weed control efficiency of 98.1 and 98.5% during 2010 and 2011, respectively (Table 1), which was followed by the same herbicide with lower doses of 35 g/ha (97.5 and 97.8%) and 25 g/ha (96.5 and 97.1%) during 2010 and 2011 respectively. The weed control efficiency under hand weeding twice and application of butachlor at 1500 g/ha were lesser than that of all the doses of bispyribac-sodium during both the years. Weed index which indicate the reduction in grain yield was minimum under bispyribac-sodium applied plots. Post-emergence application of bispyribac-sodium at all the doses reduced the grain yield very marginally indicating the superior effect of weed control. Higher weed control efficiency with lower weed index under bispyribac-sodium applied plots were due to effective weed control as evident from lower weed population and lesser weed dry weight than other treatments. Similar result of bispyribac-sodium was registered by Yun *et al.* (2005) and Nalini *et al.* (2012).

Table 1. Effect of bispyribac-sodium on weed growth in transplanted rice

Treatment	Total weed density at 45 DAT (no./m^2)		Total weed DMP (kg/ha)		Weed control efficiency (%)		Weed index	
	2010	2011	2010	2011	2010	2011	2010	2011
Butachlor 1500 g/ha	4.75 (2.29)	33.00 (5.79)	356 (25.09)	307 (17.54)	92.1	91.3	11.23	13.70
Bispyribac-sodium 25 g/ha	1.50 (1.41)	12.00 (3.54)	159 (16.69)	105 (10.27)	96.5	97.1	4.21	4.64
Bispyribac-sodium 35 g/ha	1.25 (1.32)	7.67 (2.86)	112 (14.10)	76 (8.75)	97.5	97.8	3.57	2.99
Bispyribac-sodium 50 g/ha	0.75 (1.11)	5.32 (2.32)	87 (12.38)	53 (7.31)	98.1	98.5	1.75	0.35
Weed-free	0.00 (0.71)	0.00 (0.71)	0 (0.71)	0 (0.71)	100.0	100.0	-	-
Two hand weedings	3.75 (2.06)	16.67 (4.14)	289 (22.62)	128 (11.34)	93.6	96.4	6.30	5.57
Unweeded check	63.75(8.02)	110.68 (10.54)	4511 (90.31)	3541 (59.51)	-	-	44.78	51.28
LSD (P=0.05)	0.28	12.00	3.89	81.60	-	-	-	-

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

Yield attributes

All the yield attributes of rice were significantly influenced by the weed management practices (Table 2). Highest number of panicles/m^2 of 420 and 312 during 2010 and 2011, respectively were recorded by weed free plot which was at par with all the doses of bispyribac-sodium application. Application of bispyribac-sodium at 25 g/ha registerd though numerically lower number of panicles/m^2, its effect on producing tillers was at par that of higher doses and twice hand weeding and significantly higher than butachlor application. Regarding panicle length, weed free plot though recorded higher values, it was at par with all the doess of bispyribac-sodium and hand weeding twice. Similarly, number of grains/panicle were also higher with weed free plot but at par with bispyribac-sodium at 50 g/ha. Post-emergence application of bispyribac-sodium at 25 g/ha registered 129 and 146 number of grains/panicle during 2010 and 2011, respectively which was at par with that of bispyribac-sodium at 50 g/ha (139 and 148) and twice hand weeding (136 and 145) and significantly higher than butachlor application (118 and 125). Similar results of higher yield attributes of transplanted rice under bispyribac-sodium application was reported by Yadav *et al.* (2009).

Grain yield

Significant variation among weed management practices was found and higher yield was associated with bspyribac-sodium applied plots (Table 2). Weed free plot registered highest grain yield of 7.14 and 6.93 t/ha during 2010 and 2011, respectively which was at par with all the doses of bispyribac-sodium. Post-emergence application of bispyribac-sodium at 25 g/ha recorded grain yield of 6.84 and 6.51 t/ha during 2010 and 2011, respectively which was at par with higher doses of bispyribac-sodium and significantly superior than butachlor application. The effect of all the three doses of bispyribac-sodium on grain yield was significantly higher than butachlor application and unweeded control. The per cent yield increment due to application of bispyribac-sodium at the rate of 25 g/ha were 7.9, 2.2 and 73.5 during 2010 and 0.8, 9.4 and 95.7% during 2011 than tiwce hand weeding, butachlor application and unweeded control, respectively. There was 44.8 and 51.3% yield reduction under unweeded plot over weed free plot during 2010 and 2011, respectively. The higher grain yield in bispyribac-sodium applied plots was attributed to lesser weed population and weed dry weight which might have caused lesser weed competition with rice resulted in the production of higher yield attributes which was reflected in higher yield. The results of effective weed control along with higher grain yield by bispyribac-sodium against mixed weed flora in transplanted rice (Yadav *et al.* 2009), wet-seeded rice (Yadav *et al.* 2007) and dry-seeded rice (Walia *et al.* 2008) were in confirmative with the present investigation. Murali *et al.* (2012) obtained similar grain yield of transplanted rice under bispyribac-sodium at both the doses of 50 and 35 g/ha.

Economics

The economic analysis of weed management practices (Table 2) revealed that higher economic benefits were realized under lower doses of bispyribac-sodium application. Post- emergence application of bispyribac-sodium at 25 g/ha registered highest net profit of ₹ 42,452 and ₹ 40,400/ha during 2010 and 2011, respectively followed by bispyribac-sodium at 50 g/ha (₹ 42,086 and ₹ 40,330/ha). Higher benefit-cost ratio was also associated with

Table 2. Effect of bispyribac-sodium application on yield and economics of transplanted rice

Treatment	No. of panicles/m^2		Panicle length (cm)		No. of grains/ panicle		Grain yield (t/ha)		Net profit (x10^3 ₹/ha)		Benefit: cost ratio	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Butachlor 1500 g/ha	380	271	22.6	22.9	118	125	6.34	5.89	38.74	34.72	2.81	2.43
Bispyribac-sodium 25 g/ha	404	297	23.6	24.0	129	146	6.84	6.51	42.45	40.40	2.89	2.61
Bispyribac-sodium 35 g/ha	408	299	24.0	24.2	139	148	6.88	6.62	42.09	40.23	2.81	2.54
Bispyribac-sodium 50 g/ha	415	304	24.3	24.3	142	153	7.01	6.70	42.25	40.33	2.73	2.51
Weed free	420	312	24.9	24.7	149	158	7.14	6.83	40.32	37.77	2.47	2.24
Two hand weeding	401	291	24.2	23.4	136	145	6.69	6.45	38.55	36.47	2.54	2.30
Unweeded check	257	130	18.8	18.1	95	92	3.94	3.33	15.48	10.26	1.78	1.45
LSD (P=0.05)	8.6	7.5	1.12	1.08	3.9	4.2	1.94	1.78	-	-	-	-

bispyribac-sodium at 25 g/ha (2.89 and 2.61) which was followed by bispyribac-sodium at 35 g/ha (2.81 and 2.54). Though higher dose of bispyribac-sodium at 50 g/ha recorded slightly higher grain yield, economically it was inferior to its lower dose of 25 g/ha.

It may be concluded that application of post-emergence herbicide bispyribac-sodium at the rate of 25 g/ha on 20 DAT could be a suitable and economical herbicidal weed management for transplanted rice and higher productivity.

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Sowing time - a tool for weed control in direct-seeded upland rice

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ABSTRACT

A field experiment was conducted to find out the effect of time of sowing and weed control practices on yield and dry weight of weeds during *Kharif* season of 2010 and 2011 at AICRP on weed management, VNMKV, Parbhani. Sowing of direct-seeded rice (DSR) before onset of monsoon produced higher grain yields as compared to sowing after onset of monsoon. Among the different weed control methods, pre-emergence application of butachlor followed by one hand weeding recorded grain yields at par with weed free treatment.

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

Rice is one of the major staples crop grown in India. Transplanting seedlings in puddled and flooded field is the traditional method of rice growing. High losses of water through puddling, surface evaporation and percolation are some of the disadvantages of this method. Growing rice under aerobic environment can reduce water losses to greater extent. Hence, direct seeding instead of conventional transplanting is gaining momentum in India. The productivity of direct-seeded rice is often reported low which has been considered due to increased weed infestation. 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 DSR, 22-36% for modern *'boro'* rice and 16-48% for transplanted *'aman'* rice. Herbicidal weed control methods offer an advantage to save labour and money (Ahmed *et al.* 2000). The time of sowing have noticeable impact on weed intensity and probably on yield also. Delay in sowing results in slow growth of crop and increased infestation of competing weeds. In light of above, the experiment was conducted to test the effect of time of sowing weed control methods on weed intensity and yield of direct-seeded rice.

MATERIALS AND METHODS

A field experiment was conducted at All India Coordinated Research Project on Weed Control, Parbhani during *Kharif* season of 2010 and 2011 in split plot design with three replications. The main plot treatments were two different times of sowing *i.e.* before onset of monsoon and after onset of monsoon, while subplot treatments were for six different weed control methods, *viz.* pretilachlor-S 0.5 kg/ha pre-emergence, butachlor 1.5 kg/ha pre-emergence + 1 hand weeding, post-emergence Almix 4 g/ha, *Sesbania* (broadcast) + 2, 4-D 0.5 kg/ha at 30 DAS, weedy and weed free. The gross and net plot size were 4.5 x 4.5 m and 3.6 x 3.6 m, respectively. The sowing (direct seeding) before onset of monsoon was done on 15 June 2010 and 6 July 2011 during first and second year of experiment, respectively. Sowing after onset of monsoon was done on 1 July 2010 and 18 July 2011 during first and second year of experiment, respectively. The recommended dose of NPK and plant protection schedule was followed as per general recoomodations.

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RESULTS AND DISCUSSION

Crop-weed association

Among broad-leaved weeds, *Ipomoea maxima, Digera arvensis, Parthenium hysterophorus, Euphorbia geniculata, Convolvulus arvensis, Acalypha indica* were found to be dominant species. The dominant grassy weeds were: *Brachiaria eruciformis, Dinebra retraflexa, Cynodon dactylon, Amischophacelus cuculata* and *Heteropogon contortus.*

Significantly lower dry matter of grassy weeds at 30 and 60 DAS was recorded in DSR sown before onset of monsoon than dry weed weight in DSR sown after onset of monsoon during both the years of experimentation. A similar trend was observed in dry weed weight of broad-leaved weeds wherein the significantly lower dry weed weight of broad-leaved weeds at 30 and 60 DAS was observed in paddy crop sown before onset of monsoon than the dry weed weight of weeds in DSR sown after onset of monsoon.

Table 1. Dry weed weight (g/m^2) at 30 and 60 DAS as influenced by different treatments

Treatment	Grassy weeds				Broad-leaved weeds			
	2010		2011		2010		2011	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Time of sowing								
D_1 - Before onset of monsoon	4.95	7.87	5.40	8.10	11.67	15.06	12.20	16.05
D_2 - After onset of monsoon	6.92	10.66	6.80	9.80	13.61	19.39	14.30	18.40
LSD (P=0.05)	1.92	1.77	1.81	1.30	1.89	4.50	1.61	4.30
Weed control								
M_1 - Pretilachlor 0.5 kg/ha PE	6.80	10.00	5.90	9.80	16.11	20.3	15.14	21.14
M_2 - Butachlor 1.5 kg/ha PE + 1 HW	5.13	8.43	3.87	6.34	7.52	11.7	8.25	12.22
M_3 - Fenoxaprop 60 kg/ha POE	6.09	9.37	7.90	8.73	12.05	17.1	12.10	18.10
M_4 - *Sesbnia* (broadcast) + 2,4- D 0.5 kg/ha at 30 DAS	5.87	8.81	6.20	7.18	11.03	15.3	9.30	16.24
M_5 - Weedy check	8.04	12.44	8.40	13.3	23.55	28.5	21.14	25.27
M_6 - Weed free	3.53	6.62	3.40	5.26	6.59	10.3	8.14	8.14
LSD (P=0.05)	1.65	1.81	1.35	1.62	3.38	3.65	3.60	4.10

PE - Pre-emergence, POE - Post-emergence

Dry weed weight

Significant effect of different treatments on dry weed weight of grassy as well as broad-leaved weeds was observed (Table 1). At 30 and 60 DAS, significantly lowest dry weed weight of broad-leaved weeds was recorded in weed free situation which was found at par with the pre-emergence application of butachlor 1.5 kg/ha followed by one hand weeding during 2010 and 2011. Similar trend was observed in case of dry weed weight of grassy weeds.The interaction effect was found to be non significant for grassy and broad-leaved weeds for their dry weed weight at 30 and 60 DAS. Bari (2010) reported lower weed count with butachlor.

Weed control efficiency

The maximum weed control efficiency was observed in crop sown before onset of monsoon as regards grassy and broad-leaved weeds than paddy crop sown after onset of monsoon at both the stages of observations *i.e.* at 30 and at 60 DAS during 2010 as well as 2011.

The maximum weed control efficiency of grassy weeds was observed in weed free situation followed by pre-emergence appliction of butachlor 1.5 kg/ha + 1 HW at 30 and 60 DAS, respectively. Whereas in case of broad-leaved weeds also, maximum weed control efficiency was observed in weed free situation followed by PE- butachlor 1.5 kg/ha + 1 HW at both the stages of observations *i.e.* at 30 and 60 DAS respectively.

Grain yield

Sowing of paddy crop after onset of monsoon reduced the paddy grain yield to the tune of 12% and 15% as compared with paddy crop sown before onset of monsoon during first and second year of the experiment, respectively. The grain yield in crop before onset of monsoon was significantly more than grain yield in the crop sown after onset of monsoon during both the years.

Table 2. Grain yield of direct-seeded rice as influenced by different treatments

Treatment	Grain yield (t/ha)		
	2010	2011	Mean
Time of sowing			
D_1 -	2.26	2.38	2.37
D_2 -	2.12	2.12	2.12
LSD (P=0.05)	NS	0.17	
Weed control			
M_1	1.74	1.66	1.70
M_2	2.68	2.59	2.64
M_3	1.97	2.40	2.18
M_4	2.29	2.30	2.30
M_5	1.56	1.73	1.65
M_6	2.90	2.83	2.87
LSD (P=0.05)	0.30	0.24	

Treatment details are given in Table 1.

The grain yield of direct-seeded rice was found to be influenced significantly due to various weed control treatments. During 2010, highest grain yield (2.83 t/ha) was recorded with weed free situation, which was found at par with PE-butachlor 1.5 kg/ha followed by one hand weeding and was further at par with *Sesbania* (broadcast) + 2,4-D 0.5 kg/ha at 30 DAS. During 2011, highest grain yield pf rice was recorded with weed free situation (2.53 t/ha) which was found at par with grain yield of paddy with PE-butachlor 1.5 kg/ha (2.36 t/ha) followed by one hand weeding and found significantly superior over rest of all the treatments (Table 2). Bari (2010) also reported that highest rice yield was obtained with butachlor as compared to other weed control practices. The interaction effect of time of sowing and weed control methods was found to be non-significant.

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Weed composition and seed bank as affected by different tillage and crop establishment techniques in rice–wheat system

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ABSTRACT

Field experiments were carried out at Krishi Nagar Research Farm, J.N. Krishi Vishwa Vidayalya, Jabalpur, (M.P.) during 2007-08 and 2008-09 to study weed composition and weed seed bank as influenced by tillage and crop establishment techniques in rice–wheat system. Sixteen treatments consisted with 4 tillage and planting management for both crop components under rice-wheat system were tested in strip plot design with 3 replications. Tillage and sowing methods were P_1- direct drilling in dry field, P_2- direct seeding of sprouted seeds through drum seeder in puddled field, P_3- manual transplanting and P_4- transplanting through self propelled transplanter (SPT) for rice cultivar '*Kranti*' and T_1- conventional tillage sowing, T_2- zero till sowing, T_3- strip till sowing and T_4- bed planting for wheat cultivar '*GW-273*'. The total weed density and weed biomass at 30 DAS and maturity stages were significantly greater under direct drilling in dry field (DSR-P_1) than other 3 sowing/planting methods of rice under puddled conditions (P_2-direct seeding of sprouted seeds through drum seeder in puddled field, P_3-manual transplanting and P_4-transplanting through self propelled transplanter). The DSR-P_1 had also higher weed seed counts on top layer of soil than other 3 tillage and sowing methods of rice. In wheat, intensity of grasses, sedges and other minor weeds was enhanced at maturity over their intensity at 30 DAS under conventional till sown wheat, while intensity of broad-leaved weeds (BLWs) declined at maturity over their intensity at 30 DAS. The higher weed seed count (40.9/m^2) at top layer of soil was obtained extensively under zero-till sowing of wheat than conventional till sowing, strip till sowing and bed planting.

Key words: Crop establishment, Rice–wheat system, Seed bank, Tillage, Weed composition

Weeds have a greater genetic diversity than crops. Consequently, if a resource (light, water, nutrients or carbon dioxide) changes within the environment, it is more likely that weeds will show a greater growth and reproductive response. In central part (Madhya Pradesh and Chhattisgarh) of India, rice is grown in variable climatic condition. Tillage operation can have a major impact on the distribution of weed seeds in the soil on survival (Lutman *et al.* 2002). Tillage as a filter or constraints that influences weed species and weed seed distribution in the soil seed bank. The type of tillage implement and concomitant cultivation can significantly impact the weed seed distribution and composition in soil surface. Direct drilling and shallow tillage for example can increase the proportion of weed seed retained near the soil surface, compared to conventional system of sowing in rice–wheat system (Yenish *et al*. 1992). The above conditions have been the impetus for research concerned with the adoption of conservation tillage practices leading to the concept of a conventional tillage effect on weed intensity and seed bank. Keeping these points in views, the present investigation has been undertaken.

MATERIALS AND METHODS

Field experiments were carried out at Krishi Nagar Research Farm, Jawaharlal Nehru Krishi Vishwa Vidayalya, Jabalpur, (M.P.) during 2007-08 and 2008-09. The soil of the experimental field was sandy clay loam in texture and neutral in reaction (7.4) and low in organic C (0.68%) and analyzing medium in available N (250 kg/ha), P (12.5 kg/ha) and medium in available K (308 kg/ha) contents. Sixteen treatments consisted with 4 tillage and planting management for both crop components under rice-wheat system were tested in strip-plot design with 3 replications. Tillage and sowing methods were: P_1- Direct drilling in dry field, P_2- Direct seeding of sprouted seeds through drum seeder in puddled field, P_3- Manual transplanting and P_4- Transplanting through self-propelled transplanter (SPT) for rice cultivar '*Kranti*' and T_1- conventional tillage sowing, T_2 - zero till sowing, T_3- strip till sowing and T_4 - bed

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planting for wheat cultivar '*GW-273*'. Sowing of rice, *viz.* direct drilling in dry field before onset monsoon (P_1), sowing in nursery to get seedlings for transplanting (P_3 and P_4) and soaking of seeds to obtain sprouted seeds under (P_2) was done on the same day. The seed rate 100 kg/ha for direct seeding in dry field and 50 kg/ha for direct seeding of sprouted seeds through drum seeder in puddled field where as seeds as 30 kg/ha were used only for both manual transplanting and transplanting through self propelled transplanter. Tillage operations in direct seeding in dry field were once with cultivator, twice harrow followed by planking and for transplanting methods and direct seeding of sprouted seeds through drum seeder in puddle soil consisted of one cultivator, 2 puddling and 1 planking. Twenty one days old seedlings were used for manual transplanting and transplanting through SPT. The seedlings were raised on mat type nursery for transplanting through self-propelled transplater.

Butachlor 1.5 kg/ha was applied as pre-emergence for weed control in rice. This was supplemented with hand weeding twice at 20 and 40 days in direct seeding in dry field plots whereas one hand weeding was done at 40 days after in puddled condition field. All the direct-seeded plots received frequent irrigation to keep the soil wet. For transplanting under both methods and direct seeding of sprouted seeds through drum seeder in puddled soil, irrigation was applied for puddling, thereafter, uniform irrigation were applied to all the treatments. Sowing of wheat was done by different methods immediately after harvesting of preceding rice grown under different methods of tillage and sowing. After harvesting of rice, a pre-sowing irrigation was given to all plots to ensure optimum moisture for sowing of wheat. Sowing of wheat was done by conventional, zero till, strip till and bed planter. The conventional sowing in wheat involved 1 cultivator, 2 harrows and one planking. Under zero till, strip till and bed plating, sowing of wheat was done directly without land preparation. For weed control in wheat, isoproturon 1 kg + 2,4-D 0.5 kg/ha was sprayed after 35 days of sowing. A uniform dose (120 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha) of fertilizers was applied to both crops along with other agronomic practices. Soil samples of 0.5 kg by weight were taken with the help of core auger at 3 soil depths, *viz.* 0-5, 5-10 and 10-15 cm from each treatment plot before sowing of both crop components under a fixed rice-wheat system.

The existing seed bed conditions before sowing of each crop was taken into consideration to decide the time of sampling. Collected soil samples were well labelled with tags and allowed to sun-drying. After proper sun-drying, these samples were grounded into fine particles with help of mortar and pistal. Then, these samples spread on the Peteriplates separately in almost homogeneous and uniform layer. The Peteriplates were marked for each treatment separately with glass pencil. After this, regular watering was done upto 15 days with the help of water cane uniformly in all Peteriplates. The number of germinated weed seedlings was counted under each treatment at 15 days after regular watering. Finally, weed seed counts/kg soil was worked out for each treatment. The observations on weed density and dry weight (species wise and total) were recorded at 30 DAS/DAT and harvesting stages by using a quadrat of 0.25 m^2 size at 4 places in each plot and then species wise total weeds intensity and dry matter/m^2 were determined.

Weight of grains and straw yield per plot recorded under each treatment for both crops. Rice equivalent yield (REY) was determined for each treatment. For this purpose, grain yield of wheat was converted in to rice yield with the help of existing market value of both crops. After this, the wheat yields converted in to rice yields were added in the preceding rice yields of the same treatment.

RESULTS AND DISCUSSION

Weed dynamics and weed seed bank in rice

While considering the existence of weeds in cropped lands with rice, total 30 weed species consisting of 10 grasses, 6 sedges, 13 BLWs and 1 fern groups were observed in rice. The dominating weed species were identified as *Echinochloa colona* (L.) Link., *E. glabrescens* Murno ex Hook. f., *E. crusgalli* (L.) Beauv., *Eleusine indica* (L.) Gaertner., *Panicum repens* L., *Digitaria sanguinalis* L. (Scop.), *Dactyloctenium aegyptium* (L.) Willd., *Paspalum distichum* L., *Ischaemum rugosum* Salisb. and *Eragrastis japonica* among the grasses; *Cyperus iria* L., *C. difformis* L., *C. rotundus* L., *Fimbristylis miliaceae* (L.) Vahl., *Scirpus lateriflorus* Gmel. and *Eriocaulon quinquangulare* L. among the sedges; and *Caesulia axillaries* Roxb., *Eclipta alba* (L.) Hassk., *Ammania baccifera* L., *Cynotis axillaries* Schult.f., *Commelina communis* L *Alternanthera philoxeroides* (Mart.) Griseb., *Alternanthera sessilis* (L.) DC., *Monochoria vaginalis* (Burm f.) Kunth., *Lindernia crustacea* (L.) F. Muell., *Hydrolea zeylanica* Vahl., *Ludwigia octovalvis* (Jacq.) Raven., *Oldenlendia dichotoma* Hook f. and *Spilanthus calva* DC. among the broad-leaved weeds (BLWs). The presence of a fern-*Marsilia quadrifoliata* was also noted during advanced stage of rice only under the treatments associated with transplanted rice in wet lands. Besides these weeds, several other minor weeds also found in negligible density, hence their identification was not made individually.

The relative density of grasses, sedges, BLWs and other minor weeds was 46, 24, 25 and 5, 41, 15, 40 and 4, 35, 17, 45 and 3 and 35, 16, 44 and 5% under P_1- direct drilling in dry field, P_2-direct seeding of sprouted seeds through drum seeder in puddled field, P_3- manual transplanting and P_4- transplanting through self propelled transplanter tillage and sowing methods of rice, respectively at 30 DAS/DAT. But infestation of these groups of weeds changed as 37, 21, 30 and 12, 28, 24, 38 and 10, 27, 23, 38 and 10, 29, 23, 37 and 9% under P_1- direct drilling in dry field, P_2- direct seeding of sprouted seeds through drum seeder in puddled field, P_3- manual transplanting and P_4-transplanting through self propelled transplanter methods of rice establishment, respectively at maturity stage. The presence of fern *Marsilia quadrifoliata* having relative density of 2% was also noted under P_3- manual transplanting and P_4- transplanting rice establishment only at maturity stage.

It was obvious that the existence and spread of different weeds varied due to different tillage and sowing methods of rice at early growth as well as maturity stages under DSR- P_1 in dry fields. The intensity of *Echinochloa colona*, *E. crusgalli* and *Dactyloctenium aegyptium* reduced at maturity stage over their intensity at 30 DAS, while the intensity of *Eleusine indica*, *Panicum repens, Digitaria sanguinalis* and *Paspalum distichum* was higher at 30 DAS. The presence of *E. glabrescens*, *Ischaemum rugosum and Eragrstis japonica* was noted only at maturity stage under DSR. Among the sedges, the intensity of *Cyperus iria* was lesser at maturity stage over 30 DAS, while *C. rotundus* showed reverse trend only after 30 DAS under DSR- P_1. Simalrly, the severity of *Ammania baccifera* and *Oldenlendia dichotoma* was lesser at maturity as compared to other BLWs. Remaining minor weeds showed their presence during advanced growth stage after 30 DAS. It is remarkable that *Commelina communis*, *Monochoria vaginalis, Hydrolea zeylanica,* and *Marsilia quadrifoliata* were absent under DSR due to aerobic conditions in the field. Under direct-seeding of sprouted rice seeds in puddle fields- P_2, the intensity of grasses and sedge were less at 30 DAS than DSR-P_1 but intensity of BLWs showed their reversed trend at this stage because of wet land agro-ecosystem developed for growing rice under P_2. The weeds which found absent under DSR-P_1. as described above had shown their presence under P_2- direct seeding of sprouted seeds through drum seeder in puddled field due to puddled conditions developed for sowing of sprouted seeds.

The agro-ecosystem of rice plants under transplanted rice manually (P_3) or by SPT (P_4) was almost similar to that of under P_2. Therefore, the intensity of grassy weeds was lesser under transplanted rice (P_3 and P_4) rice than P_1 and it further reduced at maturity over their intensity recorded at 30 DAT. But infestation of other group of weeds was higher under transplanted rice at 30 DAT than under P_1 at maturity stage. The agro-ecosystem of rice plants under transplanted rice manually (P_3) or by SPT (P_4) was almost similar to that of under P_2. Therefore, the intensity of grassy weeds was lesser under transplanted rice (P_3 and P_4) rice than P_1 and it further reduced at maturity over their intensity recorded at 30 DAT. But infestation of other group of weeds was higher under transplanted rice at 30 DAT than under P_1 at maturity stage.

While studying the effect of weed seed counts/kg of soil at varying depths (0-5, 5-10 and 10-15 cm) before final seedbed preparation for sowing/planting of rice, it was observed that weed seeds were greater in number on top layer (0-5 cm) of soil, which orderly reduced in subsequent deeper layers (5-10 and 10-15 cm). The DSR-P_1 had higher weed seed counts on top layer of soil than other 3 tillage and sowing methods of rice, because of turning up of top layer to lower layer during puddling of lands. The zero till sown preceding wheat had greater seed count at each layer of soil than other 3 tillage and sowing methods of wheat (Table 1).

Consequence upon the above facts, total weed density/m^2 and total weed biomass/ha were significantly greater under DSR- P_1 than other 3 sowing/planting methods of rice under puddle conditions (P_2- direct seeding of sprouted seeds through drum seeder in puddled field, P_3- manual transplanting and P_4- transplanting through self propelled transplanter) at maturity stage (Table 2). Since the intensity of all weeds were maximum under DSR -P_1 among all sowing methods at 30 DAS and remained continuously higher at maturity, hence it could be said that DSR-P_1 needs more emphasis on control on weeds to realize the potential grain yields. It is also remarkable from the present investigation that long-term continuous cropping of direct seeded rice followed by zero-till sown wheat under rice might have given excellent opportunity to build up more severe weed infestation. Therefore, it would be good to change direct seeding of rice or zero till sowing of wheat into other tillage and sowing methods at an interval of 2 or 3 years to overcome this problem. Singh *et al.* (2008) and Gangwar *et al.* (2009) agreed with these findings from their studies under rice-wheat cropping system at other locations of India also.

Weed composition and weed seed bank in wheat

The existence and spread of different weed flora in wheat grown under different tillage and sowing methods at 30 DAS and maturity stages were 2,1 and 13/m^2 for grasses, sedgs and BLWs, respectively. Among the grassy weeds, *Phalaris minor* Retz. and *Avena fatua* L. were present. Only *C. rotundus* among the sedges and *Medicago* spp. *(M. denticulata* and *M. hispida* Willd), *Trifolium fragiferum* L., *Chenopodium album* L., *Melilotus* spp. (*Melilotus indica* (L.) All. and *Melilotus alba* Medikus.), *Rumex dentatus* L., *Fumaria parviflora* Lamk., *Spergula arvensis* L., *Anagallis arvensis, Vicia sativa* L. *Lathyrus aphaca* L. and *Portulaca oleracea* L. among the BLWs had also shown their presence.

It is remarkable that relative composition of weeds varied between early (30 DAS) and maturity stages of wheat under all tillage and sowing methods. The relative composition of grasses, sedges, BLWS and other minor weeds were 7, 7, 83 and 3%, respectively at 30 DAS under conventional till sown wheat, which changed as 10, 5, 79 and 5%, respectively at maturity stage. Thus, it is obvious that intensity of grasses, sedges and other minor weeds enhanced at maturity over their intensity at 30 DAS under conventional till sown wheat, while intensity of BLWs declined at maturity over their intensity at 30 DAS. Other tillage and sowing methods of wheat, *viz.* zero till sowing (T_2), strip till sowing (T_3) and bed planting (T_4) had similar trend of weed composition at both the growth stages as were with conventional till sowing (T_2). Although the composition of different weeds was similar in wheat grown under different tillage and sowing methods at both the growth stages, but total weed intensity/m^2

Table 1. Weed seed count/kg soil at varying depth as affected by different tillage and sowing methods in rice-wheat system before sowing of rice

Treatment	Depth of soil								
	0-5 cm			5-10 cm			10-15 cm		
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
Sowing methods of rice									
P_1- Direct seeding	53.3	57	55.2	31.3	33.8	32.6	21.7	24.7	23.2
P_2- Seeding of sprouted seeds	36.7	40.6	38.7	42.2	45.7	44.0	29.3	30.9	30.1
P_3- Manual transplanting	35.4	39.4	37.4	40.5	41.6	41.1	28.3	26.9	27.6
P_4- Transplanting by SPT	34.0	37.3	35.6	40.4	41.5	41.0	27.6	27.2	27.4
LSD (P=0.05)	4.3	5.2	4.6	4.3	2.7	3.6	2.4	3.2	2.7
Sowing methods of wheat									
T_1 - Conventional till sowing	39.1	42.6	40.9	38.1	40.3	39.2	26.9	27.5	27.2
T_2 - Zero till sowing	40.5	43.9	42.3	38.9	40.4	39.7	26.5	27.9	27.2
T_3 - Strip till sowing	40.1	43.6	41.9	38.2	40.8	39.5	26.4	27.3	26.9
T_4 - Bed planting	39.0	43.9	41.5	39.3	41	40.2	27.7	27.0	27.4
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Mean weed density and weed dry weight as affected by different tillage and sowing methods in rice-wheat system in rice

Sowing method	Total weed density/m^2						Weed dry weight at maturity (kg/ha)		
	At 30 DAS/DAT			At maturity					
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
Rice									
P_1	126.0	140.0	133.0	209.0	238.0	223.5	555	598	570
P_2	95.0	105.0	100.0	196.0	211.0	203.5	508	525	517
P_3	89.0	98.0	93.5	184.0	205.0	195.0	453	498	475
P_4	85.0	92.0	88.5	179.0	188.0	183.5	449	489	469
LSD (P=0.05)	10.1	17.8	15.6	12.3	13.7	12.8	009	017	012
Wheat									
T_1	98.0	108.0	103.0	190.0	209.0	199.5	490	523	507
T_2	101.0	112.0	106.5	194.0	213.0	203.5	494	529	512
T_3	97.0	107.0	102.0	190.0	208.0	199.0	487	522	505
T_4	99.0	109.0	104.0	193.0	211.0	202.0	491	526	509
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Treatment details are given in Table 1.

was significantly higher with zero till sowing (T_2) than other 3 tillage and sowing methods. Among the tillage and sowing methods of wheat, strip till sown wheat had the lowest weed intensity/m^2. The higher weed seed counts/m^2 at top layer of soil were more extensively under zero till sowing of wheat (Table 3) resulted in to greater weed infestation than other sowing methods. The weed seed counts/kg of soil was almost similar before sowing of wheat with other 3 methods (conventional till sowing (T_1), strip till sowing (T_3) and bed planting (T_4). Numerically, strip till sowing of wheat– T_3 had the lowest weed seed counts/kg of soil on top layer of soil, which might be the reason for the lowest total weed intensity (Table 4). Consequent upon the above points, zero-till sowing (T_2) had maximum weed dry weight/ha at both growth stages of wheat, while strip till sowing (T_3) had the lowest weed dry weight/ha.

While going through the overall picture of weed dynamics in rice-wheat cropping system with varying tillage and sowing methods, it was evident that T_2 offered more severe weed infestation and it further aggravated when zero till sowing of wheat was associated with direct seeding of rice in dry field (P_1). Similar results have been reported by other workers also (Dhiman *et a.* 2003, Mishra *et al.* 2005, Brar *et al.* 2007 and Jha *et al.* 2008)

Table 3. Weed seed count/kg soil at varying depth as affected by different tillage and sowing methods in rice-wheat system before sowing of wheat

Sowing method	Depth of soil								
	0-5 cm			5-10 cm			10-15 cm		
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
Rice									
P_1	32.7	33.3	33.0	19.0	18.3	18.6	11.1	12.0	11.6
P_2	31.2	32.1	31.7	18.0	18.2	18.1	10.4	11.2	10.8
P_3	30.7	32.5	31.6	17.8	18.5	18.1	10.3	11.0	10.7
P_4	31.4	31.9	31.7	17.7	18.7	18.2	9.9	10.9	10.4
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wheat									
T_1	25.2	26.2	25.7	22.8	21.5	22.1	14.8	16.4	15.6
T_2	40.4	41.4	40.9	13.9	15.3	14.6	7.7	8.4	8.1
T_3	26.4	27.5	27.0	20.2	20.2	20.2	10.7	10.7	10.7
T_4	34.1	34.5	34.3	15.6	16.6	16.1	8.5	9.4	9.0
LSD (P=0.05)	5.4	6.4	5.8	4.2	4.5	4.1	3.6	3.4	3.6

Treatment details are given in Table 1.

Table 4. Mean weed density and weed dry weight as affected by different tillage and sowing methods in rice-wheat system in wheat

Sowing method	Total weed density/m^2						Total weed dry weight at maturity (kg/ha)		
	At 30 DAS/DAT			At maturity					
	2007	2008	Mean	2007	2008	Mean	2007	2008	Mean
Rice									
P_1	101.0	112.0	106.5	69.0	72.0	70.5	388	386	387
P_2	99.0	109.0	104.0	68.0	71.0	69.5	382	382	382
P_3	98.0	111.0	104.5	68.0	68.0	68.0	368	382	375
P_4	98.0	110.0	104.0	67.0	69.0	68.0	364	378	371
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wheat									
T_1	98.0	110.0	97.0	65.0	69.0	65.0	364	355	359
T_2	121.0	139.0	130.0	96.0	100.0	98.0	445	469	457
T_3	82.0	84.0	83.0	48.0	46.0	47.0	325	345	335
T_4	95.0	108.0	101.5	58.0	66.0	62.0	367	362	364
LSD (P=0.05)	6.8	10.5	3.9	6.4	5.3	6.4	011	009	006

Treatment details are given in Table 1.

System productivity

Grain yield of unhusked rice were affected significantly by various crop-establishment methods in rice (Table 5). The highest pooled yield (5.7 t/ha) was recorded with drum seeding (puddle bed), followed by direct seeding under dry field and mechanical transplanting- puddle conditions than manual transplanting in puddle conditions. The more grain yield under drum/direct seeding rice was mainly due to good weed management practices adopted under direct seeding rice in dry field (Gopal *et al.* 2010). The grain yield of wheat were influenced significantly due to different conservation establishment methods applied in preceding rice (Table 5). The grain yields were recorded to be significantly higher when wheat was grown after direct seeding of rice in dry field than after direct seeding of sprouted rice and both transplanted rice under puddle condition. This was mainly attributable to relatively greater compaction of soil under direct seeding of sprouted rice, manual and mechanical transplanted rice (puddled) and its carry over effect on succeeding wheat, which demonstrated the disadvantage of puddling on succeeding crops (Gangwar *et al.* 2009). Irrespective of the various methods in rice, sowing of wheat by strip till drill increased grain yield as well as straw yield significantly higher over other three methods. The possible reason for higher yields because of strip till sowing of wheat provided better germination of seeds and further establishment of seedlings because of good tilth at the time of sowing. Total productivity of rice-wheat system as a whole was determined in terms of rice equivalent yields (REYs) for all treatments.

Table 5. Total productivity of rice-wheat system as affected by different tillage and sowing management (mean of 2007 to 2008)

Sowing method	Rice		Wheat		Rice equivalent yield (t/ha)
	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	
Rice					
P_1	5.32	7.22	4.26	6.28	11.25
P_2	5.70	7.58	4.10	6.18	11.46
P_3	5.11	6.94	4.02	6.20	10.96
P_4	5.21	7.03	4.08	6.12	11.05
LSD (P=0.05)	0.04	0.05	0.02	NS	
Wheat					
T_1	4.23	6.98	4.13	6.14	11.15
T_2	4.22	6.88	4.08	6.02	11.08
T_3	4.25	6.97	4.56	6.64	11.88
T_4	4.33	6.92	3.82	5.69	10.65
LSD (P=0.05)	NS	NS	0.07	0.04	

Direct seeding of sprouted rice gave the highest system productivity (11.26 t/ha/yr) and proved significantly better than other tow methods of establishment (Table 5). The next best treatment was direct seeding in dry field which gave (11.25 t/ha/yr). Strip till sowing produced significantly maximum REYs (11.88 tha/yr) among all sowing methods, while bed planting – T_4 led to record minimum REYs (10.65 t/ha/yr). The REYs were comparable with conventional till sowing -T_1 (11.20 t/ha/yr) and zero till sowing-T_2 (11.02 t/ha/yr). Similar findings have been reported by several workers from their studies in different rice– wheat growing areas of the country (Gill *et al.* 2006)

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Integrated weed management in wheat with new molecules

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ABSTRACT

A field experiment was carried out at Instructional Farm, Department of Agronomy, Junagadh Agricultural University, Junagadh (Gujarat) during *Rabi* of 2008-09 and 2009-10. The weed free treatment recorded significant improvement in yield attributes, *viz*. number of effective tillers, spikelets per spike and grain weight per plant, followed by pendimethalin 0.9 kg/ha as pre-emergence followed by one hand weeding at 35- 40 DAS. Integration of pendimethalin as pre-emergence with clodinafop, metsulfuron-methyl and 2,4-D amine salt as post-emergence with or without hand weeding proved effective in reducing weed density and dry weight of weeds. All the weed control treatments significantly influenced the grain and straw yield of wheat excluding unweeded control. The pre-emergence application of pendimethalin controlled monocot and dicot weeds, while clodinafop controlled monocot and metsulfuron-methyl controlled dicot weeds. Integrated weed management practices also produced increased nutrient uptake by crop and minimized nutrient due to weeds.

Key words: Growth, Herbicides, Nutrient uptake, Wheat, Yield

Wheat (*Triticum* spp.) is one of the most important grain crops which is grown in approximately 225 million ha world wide, about half of which is in developing countries. India is the second largest producer of wheat in the world contributing about 80.6 million tones of grains with productivity of 2.8 t/ha from the area of 28.4 million hectares (Anonymous 2013). Weed problem is one of the major barrier responsible for low productivity of wheat. The weeds in India cause about ₹16,500 million loss in terms of production (Joshi 2002). In agriculture, weeds causes more damage compared to insects, pests and diseases but due to hidden loss by weeds in crop production, it has not drawn much attention of agriculturists.

The use of herbicides have revolutionized weed control due to non-availability and high cot of labours. The integrated weed management approach is advantageous because one technique rarely achieve complete and effective control of all weeds during crop season and even a relatively few surviving weeds can produce sufficient number of seeds to perpetuate the species (Walia *et al.* 1997, Nayak 2006). Therefore, the present investigation was undertaken to provide appropriate options to farmers for effective weed management in wheat.

MATERIALS AND METHODS

An experiment was conducted during *Rabi* season of 2008 and 2009 at Junagadh Agricultural University, Junagadh (Gujarat, India). The soil of the experimental field was clay, low in available nitrogen and medium in available phosphorus and potash and slightly alkaline in reaction with pH 8.05 and EC 0.26/dsm. Total 12 treatments (T_1- pendimethalin 0.9 kg/ha as pre-emergence, T_2- Pendimethalin 0.9 kg/ha as pre-emergence + 1 HW at 40 DAS, T_3- metsulfuron-methyl 6 g/ha as post-emergence at 25-30 DAS, T_4- 2,4-D amine salt 0.75 kg/ha post-emergence at 25-30 DAS, T_5- clodinafop 60 g/ha as post-emergence at 25-30 DAS, T_6- pendimethalin 0.9 kg/ha as pre-emergence + metsulfuron-methyl 6 g/ha as post-emergence at 35-40 DAS, T_7- pendimethalin 0.9 kg/ha as pre-emergence + 2,4-D amine salt 0.75 kg/ha post-emergence at 25-30 DAS, T_8- pendimethalin 0.9 kg/ha pre-emergence + clodinafop 60 g/ha as post-emergence at 35-40 DAS, T_9- 1 HW at 20 DAS, T_{10}- 2 HW at 20 and 40 DAS, T_{11}- weed free and T_{12}- unweeded control) were assigned in randomized block design with three replications. The wheat variety '*GW- 366*' was sown at 22.5 cm row spacing at 120 kg seed/ha on November 17 and harvested on February 27. Pendimethalin was sprayed next DAS (days after sowing) and metsulfuron-methyl, 2,4-D amine salt and clodinafop were sprayed on 30 and 40 DAS at spray volume of 500 l/ha. Spraying was done by manually operated knapsack sprayer. The crop was grown with standard package of practices for the region. The weed index was calculated by following the formula given by Gill and Kumar (1969).The weed control efficiency was calculated by using the following formula (Mani *et al*. 1981).

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RESULTS AND DISCUSSION

Effect on growth and yield

Growth parameter like plant height affected significantly due to weed free conditions (Table 1) over unweeded control. Significantly higher number of effective tillers, spikelets per spike and grain weight per plant were recorded under weed free conditions over unweeded control which was closely followed by treatment pendimethalin 0.9 kg/ha as pre-emergence (T_1).

The maximum seed yield (4.40 t/ha) and straw yield (5.02 t/ha) were recorded under weed free conditions. The improved grain and straw yield under weed free treatment was closely followed by pendimethalin 0.9 kg/ha pre- emergence + 1 HW at 40 DAS (4.31 t/ha) which was statistically at par with pendimethalin 0.9 kg/ha as pre-emergence + metsulfuron-methyl 6 g/ha as post-emergence at 35- 40 DAS, pendimethalin 0.9 kg/ha as pre-emergence + 2,4-D amine salt 0.75 kg/ha as post-emergence at 35-40 DAS, pendimethalin 0.9 kg/ha pre-emergence + clodinafop 60 g/ha as post-emergence at 35-40 DAS and 2 HW at 20 and 40 DAS. The higher yields under these treatments could be ascribed to better control of weeds which favoured higher uptake of nutrients and water resulting optimum growth characters, *viz*. plant height, effective tillers, spikelets per spike, grain weight per plant and test weight. These growth and yield attributes evidently reflected in higher grain and straw yields under these treatments.

Significantly lowest grain and straw yields were recorded under unweeded control. These findings were in close conformity with Singh and Singh (2004) who reported highest grain yield with pendimethalin 0.9 kg/ha pre-emergence supplemented by one hand weeding. They observed maximum grain yield of wheat with post-emergence application of 2,4-D. Similarly, application of metsulfuron methyl at 3 to 5 g/ha and 2,4-D at 0.75 kg/ha recorded significantly higher grain and straw yields (Singh and Ali 2004, Maninder *et al.* 2007).

Effects on weeds

The predominant weed flora at experimental site were: *Brachiaria* spp. and *Echinochloa colona* among grasses; *Amaranthus viridis, Digera arvensis Chenopodium album* and *Euphorbia hirta* among dicot weeds; and *Cyperus rotundus* among sedges.

Among herbicides treatments, pre-emergence pendimethalin resulted efficient control of monocot and dicot weeds, whereas post-emergence application of clodinafop resulted excellent control of monocot weeds and post-emergence application of metsulfuron-methyl and 2,4-D amine salt controlled dicot weeds efficiently. However, integration of one hand weeding with pendimethalin 0.9 kg/ha pre-emergence, pendimethalin 0.9 kg/ha pre-emergence + clodinafop 60 g/ha as post-emergence at 35-40, pendimethalin 0.9 kg/ha as pre-emergence + metsulfuron-methyl 6 g/ha as post-emergence and pendimethalin 0.9 kg/ha as pre-emergence + 2,4-D amine

Table 1. Effect of different weed control treatments on growth and yield of wheat at harvest (pooled data of two years)

Treatment	Plant height at harvest (cm)	Tillers/m		Spikelets per spike	Grain weight/ plant (g)	Grain yield (t/ha)	Straw yield (t/ha)
		Effective	Non-effective				
Pendimethalin	75.00	45.87	4.53	14.60	1.82	3.72	4.38
Pendimethalin + 1 HW at 40 DAS	79.20	46.93	3.30	15.39	2.00	4.31	4.89
Metsulfuron-methyl	75.00	42.60	4.57	13.63	1.74	3.49	3.70
2,4-D amine salt	74.87	42.33	4.70	13.40	1.74	3.46	3.68
Clodinafop	74.83	44.63	4.43	13.83	1.73	3.52	3.89
Pendimethalin. + metsulfuron-methyl	76.00	46.40	3.40	15.00	1.96	4.07	4.65
Pendimethalin + 2,4-D amine salt	77.53	46.33	3.83	14.80	1.95	4.05	4.51
Pendimethalin + clodinafop	77.67	46.43	3.27	15.07	1.97	4.16	4.78
1 HW at 20 DAS	76.80	45.63	4.43	14.57	1.80	3.62	4.11
2 HW at 20 and 40 DAS	79.13	46.67	3.73	15.27	1.99	4.28	4.78
Weed free	80.70	47.07	2.23	15.57	2.03	4.40	5.02
Unweeded control	68.90	36.53	5.38	13.00	1.65	2.70	2.96
LSD (P=0.05)	5.89	5.94	0.59	1.63	0.22	0.64	0.72

salt 0.75 kg/ha post-emergence at 35-40 DAS proved more effective in reducing the weed density at harvest in comparison to herbicides applied alone. Pendimethalin 0.9 kg/ha pre-emergence + 1 HW at 40 DAS proved superior to rest of the treatments by recording minimum dry weight of weeds (Table 2) and remained at par with pendimethalin 0.9 kg/ha pre-emergence + clodinafop 60 g/ha as post-emergence at 35-40 DAS, 2 HW at 20 and 40 DAS, pendimethalin 0.9 kg/ha pre-emergence + metsulfuron-methyl 6 g/ha as post-emergence at 35-40 DAS and pendimethalin 0.9 kg/ha as pre-emergence + 2,4-D amine salt 0.75 kg/ha post-emergence at 35-40 DAS and gave higher weed control efficiencies of 90.7, 88.1, 87.9, 87.5 and 86.5%, respectively. Integrated treatments also recorded lower weed index as compared to sole herbicides, one hand weeding and unweeded control (Table 2). This might be due to the efficient control of weeds during initial stage by pre-emergence application and control of latter weeds through hand weeding. The lowest weed control efficiency was observed under unweeded control (T_{12}), because of better weed competition stress. Superiority of combination of metsulfuron-methyl with 2,4-D have been reported by Kurchania *et al*. (2000) and Nayak *et al*. (2003).

Table 2. Effect of different treatments on weed growth and weed control efficiency (pooled data of two years)

Treatment	Monocot weeds/m^2		Dicot weeds/m^2		Dry weight of weeds (kg/ha)	Weed index (%)	Weed control efficiency (%)
	60 DAS	At harvest	60 DAS	At harvest			
Pendimethalin	1.9 (3.3)	3.3 (10.3)	2.5 (6.0)	3.6 (12.3)	224.8	15.0	84.4
Pendimethalin + 1 HW at 40 DAS	2.0 (3.3)	1.8 (2.7)	2.7 (6.7)	2.4 (5.00)	133.7	1.3	90.7
Metsulfuron-methyl	4.7 (22.0)	6.0 (35.7)	1.8 (3.0)	2.7 (6.7)	424.6	20.0	70.6
2,4-D amine salt	4.7 (21.7)	6.1 (36.3)	1.7 (2.7)	2.6 (6.7)	446.4	20.5	69.1
Clodinafop	1.2 (1.0)	2.1 (4.0)	4.5 (20.0)	5.5 (29.3)	358.2	19.8	75.2
Pendimethalin + metsulfuron-methyl	1.7 (2.3)	3.0 (8.3)	2.5 (6.0)	1.8 (3.0)	180.6	7.0	87.5
Pendimethalin + 2,4-D amine salt	1.8 (2.7)	2.9 (8.3)	2.6 (6.3)	1.9 (3.3)	196.3	8.4	86.5
Pendimethalin + clodinafop	1.6 (2.0)	1.7 (2.3)	2.6 (6.3)	3.5 (12.0)	171.8	5.1	88.1
1 HW at 20 DAS	1.3 (1.3)	3.3 (10.3)	2.0 (3.3)	3.2 (10.0)	297.5	17.5	79.4
2 HW at 20 and 40 DAS	1.6 (2.0)	2.1 (4.0)	1.9 (3.3)	2.0 (3.7)	175.6	2.2	87.9
Weed-free	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.0	0.0	100.0
Unweeded control	5.1 (25.7)	6.2 (38.3)	5.4 (28.7)	6.2 (38.0)	1452.0	38.3	0.0
LSD (P=0.05)	0.51	0.61	0.66	0.54	69.8	-	-

$\sqrt{x + 0.5}$ transformation. Figures in parentheses are original values

Table 3. Influence of weed control treatments on N, P and K uptake by crop and weeds (pooled data of two years)

Treatment	Nutrient uptake by crop (kg/ha)			Nutrient uptake by weeds (kg/ha)		
	N	P	K	N	P	K
Pendimethalin	73.0	17.1	62.2	3.15	0.68	3.02
Pendimethalin + 1 HW at 40 DAS	84.1	18.7	66.4	1.74	0.37	1.85
Metsulfuron-methyl	62.3	15.4	58.1	6.84	1.35	5.10
2,4-D amine salt	58.2	15.0	56.1	7.11	1.22	5.60
Clodinafop	66.1	16.0	59.8	5.92	0.93	4.28
Pendimethalin + metsulfuron-methyl	79.0	18.1	65.0	2.61	0.49	2.27
Pendimethalin + 2,4-D amine salt	77.5	17.8	64.1	2.81	0.50	2.27
Pendimethalin + clodinafop	81.9	18.5	65.1	2.50	0.50	1.98
1 HW at 20 DAS	69.7	16.4	61.3	4.62	0.81	3.44
2 HW at 20 and 40 DAS	82.4	18.7	65.7	2.52	0.47	2.20
Weed-free	86.1	19.1	68.7	0.00	0.00	0.00
Unweeded control	49.9	11.3	40.0	24.43	4.38	20.67
LSD (P=0.05)	5.8	3.7	8.5	1.13	0.25	0.95

Nutrient uptake by crop and weeds

The weed free treatment recorded significantly highest uptake of N, P and K (Table 3) by crop (86.1, 19.1, 68.7/ kg) and lower N, P, K uptake by weeds which was closely followed by pendimethalin 0.9 kg/ha pre-emergence + 1 HW at 40 DAS and at par with treatments pendimethalin 0.9 kg/ha as pre-emergence + metsulfuron-methyl 6 g/ha as post-emergence at 35- 40 DAS (T_6), pendimethalin 0.9 kg/ha as pre-emergence + 2,4-D amine salt 0.75 kg/ha post-emergence at 35- 40 DAS (T_7), pendimethalin 0.9 kg/ha pre-emergence + clodinafop 60 g/ha as post-emergence at 35- 40 DAS (T_8) and 2 HW at 20 and 40 DAS (T_{10}). There were more loss of N, P, K by weeds from unweeded control plots. It can be explained in the light of the facts that these treatments controlled the weeds effectively, might have made more nutrients available to crop and consequently encouraged higher concentration of nutrients and more yield and thereby higher uptake of nutrients. These findings corroborated the reports of Jat *et al*. (2004) and Kanojia and Nepalia (2006).

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Herbicide combinations for broad-spectrum weed control in wheat

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ABSTRACT

Ten treatments, *viz.* clodinafop 60 g/ha, sulfosulfuron 25 g/ha, metribuzin 175 g/ha, pinoxaden 50 g/ha, clodinafop 60 + metribuzin 105 and 122.5 g/ha, sulfosulfuron 25 + metribuzin 105 g/ha, sulfosulfuron 25 + pinoxaden + 40 g/ha, weed free and unweeded check were tested during the *Rabi* season of 2010-11 and 2011-12 at Palampur. Grassy weeds (*Phalaris minor*, *Avena ludoviciana*, *Poa annua* and *Lolium temulentum*) constituted 90% of the total weed flora. All the weed control treatments were significantly superior to weedy check in curtailing dry weight of *Phalaris*, *Avena* and *Vicia sativa*. Metribuzin remaining at par with sulfosulfuron effectively reduced the dry weight of *Poa annua*. Clodinafop alone was least effective against *Poa annua*. Weed free, clodinafop, pinoxaden, clodinafop + metribuzin resulted in significant reduction in the dry weight of *L. temulentum*. Clodinafop 60 g/ha + metribuzin 122.5 g/ha, clodinafop 60 g/ha + metribuzin 105 g/ha, pinoxaden 50 g/ha and weed free resulted in significantly higher grain yield of wheat. Weeds reduced grain yield of wheat by 59.3%. Grain yield was negatively associated with weed count and weed biomass and positively associated with plant height, spike length, spikelets/spike and effective tillers. With every 1 g/m^2 increase in weed dry weight, the grain yield of wheat was expected to fall by 41.55 kg/ha. The economic threshold levels (number of weeds/unit area) with weed management practices varied between 2.6-45.4/m^2. Clodinafop 60 g/ha + metribuzin 122.5 g/ha resulted in highest weed control efficiency, crop resistance index and efficiency index. It gave lowest weed persistence index and weed index. Clodinafop 60 g/ha + metribuzin 122.5 g/ha resulted in highest net return due to weed control. Metribuzin 175 g/ha resulted in the highest marginal benefit: cost ratio.

Key words: Clodinafop, Combinations, Metribuzin, Pinoxaden, Sulfosulfuron, Weeds, Wheat

Wheat is an important winter cereal of Himachal Pradesh. Weeds are the major bottlenecks in realizing potential yield of wheat. Uncontrolled weeds are reported to cause upto 66% reduction in wheat grain yield (Angiras *et al.* 2008, Kumar *et al.* 2009, Kumar *et al.* 2011) or even more depending upon the weed densities, type of weed flora and duration of infestation. Chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding especially in broadcast wheat. Combination of isoproturon and 2,4-D as tank mixture have been recommended against complex weed flora. This combination has been found promising in the situation where isoproturon was effective against *Phalaris minor*. But against complex weed flora dominated by *Avena ludoviciana*, *Lolium temulentum* and *Poa annua,* this combination was not so effective. Under such situation, a suitable combination of clodinafop or pinoxaden with some broad-spectrum herbicides like sulfosulfuron and metribuzin was needed. Hence, the present investigation was carried out to evaluate the efficacy of metribuzin in combination with recommended post-emergence herbicides clodinafop, sulfosulfuron and pinoxaden against mixed weed flora in wheat.

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MATERIALS AND METHODS

A field experiment was conducted during *Rabi* season of 2010-11 and 2011-12 at Palampur. The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.6) and medium in available N (310 kg N/ha), P (18.2 kg/ha) and K (266.2 kg/ha). The experiment comprised of 10 treatments, *viz.* clodinafop 60 g/ha, sulfosulfuron 25 g/ha, metribuzin 175 g/ha, pinoxaden 50 g/ha, clodinafop 60 g + metribuzin 105 and 122.5 g/ha, sulfosulfuron 25 g + metribuzin 105 g/ha, sulfosulfuron 25 + pinoxaden + 40 g/ha, weed free (three hand weedings) and unweeded check were tested in randomized block design with three replications. Wheat variety *'HPW 155'* was sown on 12 November. Except weed control, the crop was raised in accordance with the recommended package of practices. The crop was fertilized with 60 kg

N, 60 kg P_2O_5 and 40 kg K_2O/ha as basal dose. Remaining half dose of nitrogen (60 kg/ha) was applied in two equal splits. The herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using 700 liter of water per hectare after 40-45 days of sowing. Weed count and dry weight were recorded at 90 DAS and at harvest from two randomly selected spots (0.25 m^2) in each plot and expressed as no./m^2 and g/m^2, respectively. The data on count and dry weight of weeds were subjected to $\sqrt{x+1}$ (square root transformation). Yields were harvested from net plot. Economics of treatments was computed based upon prevalent market prices. The economic threshold (=economic injury levels), the weed density at which the cost of treatment equals the economic benefit obtained from that treatment, was calculated after modifying the formula presented by Uygur and Mennan (1995) as well as those given by Stone and Pedigo (1972) as below

Uygur and Mennan:

$$Y= [\{(100/He \times Hc) + A_C\}/(Gp \times Yg)] \times 100$$

Where, Y is per cent yield losses at a different weed density; He, herbicide efficiency; Hc, herbicide cost; Ac, application cost of herbicide; Gp, grain price and Yg, yield of weed free.

Stone and Pedigo:

Economic threshold = Gain threshold/Regression coefficient

Where, gain threshold = Cost of weed control (Hc+Ac)/Price of produce (Gp), and regression coefficient (b) is the outcome of simple linear relationship between yield (Y) and weed density/biomass (x), Y = a + bx.

The different impact indices were worked out after Walia (2003).

RESULTS AND DISCUSSION

Effect on weeds

The weed flora of the experimental field was mainly composed of grassy weeds. They constituted 88.9 and 91.2% of the total weed flora at 90 DAS and at harvest, respectively. *Phalaris minor* (25.8 and 31% at 90 DAS and at harvest, respectively), *Avena ludoviciana* (31.4 and 18.6 at 90 DAS and harvest, respectively), *Lolium temulentum (*14.3 and 22.1%) and *Poa annua* (17.4 and

Table 1. Effect of treatments on species-wise weed dry weight (g/m^2) at maximum dry matter stage in wheat

Treatment	Dosage (g/ha)	*Phalaris* at 90 DAS		*Avena* at 90 DAS		*Poa* at harvest		*Lolium* at harvest		*Vicia* at harvest	
		2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1 - Clodinafop	60	2.2 (4.0)	2.2 (6.7)	2.2 (3.7)	1.0 (0.0)	2.9 (7.7)	2.5 (5.3)	1.0 (0.0)	1.7 (2.3)	1.3 (1.0)	1.4 (1.3)
T_2 - Sulfosulfuron	25	2.2 (3.7)	3.6 (12.0)	2.0 (3.0)	2.6 (5.9)	1.8 (2.7)	1.5 (1.3)	2.1 (4.0)	3.4 (11.9)	1.3 (1.0)	1.0 (0.0)
T_3 - Metribuzin	175	2.0 (3.0)	2.9 (9.6)	2.1 (3.3)	2.6 (6.0)	1.4 (1.3)	1.6 (2.4)	2.1 (4.0)	2.7 (7.6)	1.0 (0.0)	1.2 (0.7)
T_4 - Pinoxaden	50	1.7 (2.0)	1.5 (2.0)	1.7 (2.0)	1.0 (0.0)	2.5 (5.3)	2.1 (3.5)	2.0 (3.3)	1.0 (0.0)	1.3 (1.0)	1.6 (1.7)
T_5 - Clodinafop + metribuzin	60+105	1.3 (1.0)	1.4 (1.3)	1.7 (2.0)	1.5 (1.9)	2.2 (4.0)	1.5 (1.3)	1.4 (1.3)	1.2 (0.5)	1.3 (1.0)	1.8 (2.5)
T_6 - Clodinafop + metribuzin	60+122.5	2.0 (3.0)	1.0 (0.0)	1.4 (1.3)	1.4 (1.2)	2.2 (4.0)	1.5 (1.2)	1.0 (0.0)	1.4 (1.2)	1.3 (1.0)	1.7 (1.9)
T_7 - Sulfosulfuron + metribuzin	25+105	2.0 (3.0)	1.4 (1.2)	2.0 (3.0)	2.4 (4.5)	2.2 (4.0)	1.3 (0.8)	1.8 (2.7)	2.8 (6.8)	1.0 (0.0)	1.0 (0.0)
T_8 - Sulfosulfuron + pinoxaden	25 + 40	2.0 (3.0)	2.5 (5.6)	1.3 (1.0)	3.4 (13.3)	2.2 (4.0)	1.4 (1.2)	2.3 (4.3)	1.6 (1.5)	2.0 (3.0)	1.0 (0.0)
T_9 - Weed free	-	1.3 (1.0)	1.6 (1.9)	1.3 (1.0)	1.8 (3.3)	2.2 (4.0)	1.0 (0.0)	1.8 (2.7)	1.0 (0.0)	2.5 (5.3)	1.0 (0.0)
T_{10} - Weedy check	-	4.2 (17.3)	3.7 (12.6)	4.1 (16.0)	4.5 (19.1)	4.8 (22.3)	2.5 (5.7)	3.1 (8.7)	3.3 (10.1)	3.7 (12.7)	1.6 (1.5)
LSD (P=0.05)	-	0.8	1.5	0.9	1.6	0.6	NS	1.1	1.2	0.7	NS

Values given in the parentheses are the original means, DAS= Days after sowing

19.5%) were the important grassy weeds. *Vicia sativa* (5.5 and 8.8%) and *Coronopus didymus* (5.5% at 90 DAS) were important broad-leaved weeds. *Spergulla arvensis, Stellaria media* and *Alopecurous myosuriodes* also showed their presence but their occurrence was negligible in the experimental field.

Weed control treatments brought about significant variation in the dry weight of *Phalaris minor* and *Avena luduviciana* at maximum weed dry weight stage (Table 1). All the weed control treatments were significantly superior to weedy check in curtailing their dry weight during 2011. However, sulfosulfuron and sulfosulfuron + pinoxaden did not significantly influence their dry weight over weedy check during 2012. The effectiveness of sulfosulfuron against *Phalaris minor* and *Avena ludoviciana* has been well documented (Chhokar and Malik 2002, Chhokar *et al.* 2008, Chhokar *et al.* 2011). Dry weight of *Phalaris* and *Avena* was effectively reduced under weed free treatment. However, except sulfosulfuron 25 g/ha, clodinafop 60 g/ha and sulfosulfuron + pinoxaden, all other treatments were comparable to weed free in influencing the dry weight of *Phalaris* and *Avena.*

All treatments brought about significant reduction in the dry weight of *Poa annua* at harvest during 2011 (Table 1). Metribuzin remaining at par with sulfosulfuron effectively reduced the dry weight of *Poa annua* at harvest. Clodinafop alone was least effective against *Poa annua*. Weed free, clodinafop, pinoxaden, clodinafop + metribuzin resulted in significant reduction in the dry weight of *Lolium temulentum* at harvest during both the years. There was significant reduction in the dry weight of *Vicia sativa* under all the treatments at harvest during 2011. All the weed control treatments except sulfosulfuron + pinoxaden resulted in significantly lower dry weight of *Vicia sativa* over weed free.

Owing to species-wise reduction in the count and dry weight, all treatments resulted in significantly lower total weed count and total weed dry weight over unweeded check (Table 2). Weed free resulted in significantly lower total weed count and total weed dry weight at 90 DAS during 2011 and at harvest during 2012. However other treatments except sulfosulfuron 25 g/ha and clodinafop 60 g/ha were comparable to weed free in influencing the total weed count and total weed dry weight at other stages.

Effect on crop

Clodinafop 60 g + metribuzin 122.5 g/ha resulted in significantly higher grain yield of wheat. However, clodinafop + metribuzin (60 + 105 g/ha), pinoxaden 50 g/ha, and weed free were as good as clodinafop + metribuzin (60 + 122.5 g/ha). Higher grain yield of wheat was owing to effective control of weeds and higher growth and yield attributes of wheat. However, plant height during 2012, spike length during 2011 and 1000-seed weight during both the years were not affected significantly due to treatments under study. Weeds in unweeded check reduced the grain yield of wheat by 59.3% over clodinafop + metribuzin (60 + 122.5 g/ha) (Table 3).

The grain yield was negatively associated with total weed count (r= -0.856**, significant at 1% level of significance) and total weed dry weight (r= -0.935**) and positively associated with plant height (r= 0.729**), spike length (r= 0.877**), spikelets/spike (r= 0.867**) and ef-

Table 2. Effect of different treatments on total weed count and dry weight in wheat

Treatment	Total weed count (no./m^2)				Total weed dry weight (g/m^2)			
	90 DAS		At harvest		90 DAS		At harvest	
	2011	2012	2011	2012	2011	2012	2011	2012
T_1	8.1 (65.3)	4.6 (22.7)	7.8 (60.0)	7.3 (53.3)	4.1 (16.0)	4.3 (19.9)	5.7 (31.7)	3.7 (12.8)
T_2	7.3 (52.7)	7.1 (50.7)	6.9 (46.7)	6.6 (44.7)	4.3 (17.7)	6.0 (35.2)	4.5 (19.7)	6.0 (37.2)
T_3	5.6 (30.7)	4.9 (24.0)	4.8 (22.7)	5.6 (30.7)	3.5 (11.7)	4.9 (24.8)	3.8 (13.3)	4.9 (24.4)
T_4	7.0 (48.0)	5.9 (34.7)	6.1 (38.7)	5.5 (29.3)	3.9 (14.7)	3.5 (11.6)	4.8 (22.3)	2.6 (5.9)
T_5	5.2 (26.7)	5.3 (30.7)	6.0 (36.0)	5.3 (28.0)	3.0 (8.0)	3.2 (9.7)	3.9 (14.3)	3.0 (7.7)
T_6	5.9 (33.7)	4.5 (20.0)	5.2 (26.7)	5.2 (26.7)	3.7 (13.0)	3.8 (13.7)	3.5 (11.7)	2.5 (5.2)
T_7	5.8 (33.3)	4.9 (24.0)	6.1 (37.3)	6.0 (36.0)	3.5 (11.7)	3.2 (9.6)	4.0 (14.7)	4.2(17.1)
T_8	6.0 (34.7)	5.7 (32.0)	6.8 (45.3)	5.7 (32.0)	3.6 (12.3)	4.5 (20.3)	4.9 (22.7)	2.7 (6.5)
T_9	3.3 (10.7)	4.7 (21.3)	5.1 (25.3)	1.0 (0.0)	2.0 (5.0)	3.1 (8.7)	4.4 (18.7)	1.0 (0.0)
T_{10}	11.7(136.7)	7.1 (49.3)	9.8 (96.0)	7.4 (54.7)	7.3 (52.7)	6.8 (45.7)	9.3 (84.7)	5.7 (31.8)
LSD (P=0.05)	1.9	1.4	1.9	1.4	1.0	1.7	1.1	1.4

Treatment details are given in Table 1; Values given in the parentheses are the original means.

Table 3. Effect of treatments on plant height, yield attributes and yield of wheat

Treatment	Plant height (cm)		Spike length (cm)		Spikelets/ spike		Effective tillers (no./m^2)		1000-grain weight (g)		Grain yield (t/ha)		
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	Mean
T_1	100	108	9.7	11.2	20.1	29.6	200	129	47.8	46.7	3.18	3.17	3.18
T_2	99	108	9.8	11.2	20.3	24.9	196	109	46.8	47.3	3.17	2.12	2.64
T_3	100	106	9.7	10.5	20.2	28.1	199	114	46.5	46.0	3.26	2.78	3.02
T_4	100	109	9.9	11.6	19.8	28.9	196	120	46.4	46.3	3.12	3.84	3.48
T_5	102	109	10.1	11.8	20.9	30.1	207	101	46.8	45.7	3.48	3.39	3.44
T_6	101	106	10.2	12.1	20.8	28.0	202	132	47.1	45.3	3.48	4.05	3.76
T_7	99	110	9.9	10.1	19.9	28.9	200	92	46.8	46.7	3.37	1.98	2.67
T_8	100	103	9.8	11.2	20.1	29.4	200	107	47.2	47.0	3.32	3.07	3.19
T_9	100	107	10.6	12.1	20.3	31.6	201	135	46.8	45.7	3.46	3.84	3.65
T_{10}	88	108	8.8	10.5	17.9	24.5	153	100	45.8	46.0	1.22	1.85	1.53
LSD (P=0.05)	7	NS	NS	0.9	1.7	4.2	28	27	NS	NS	0.38	0.80	0.51

Treatment details are given in Table 1; Values given in the parentheses are the original means.

Table 4. Impact assessment indices, economics and economic thresholds

Treatment	WCE	WPI	CRI	EI	WI	CWC	NRwc (x10^3 ₹/ha)	MBCR	Gt	Et	
										SP	UM
T_1	61.8	0.81	5.42	2.80	13.0	1605	26.37	16.43	128	4.9	5.0
T_2	51.2	0.88	3.53	1.48	27.6	1036	17.86	17.25	83	3.2	3.4
T_3	67.6	1.10	6.08	2.99	17.3	830	24.50	29.53	66	2.6	2.2
T_4	75.8	0.54	9.37	5.24	4.7	2280	30.89	13.55	182	7.0	6.3
T_5	81.1	0.61	11.86	6.56	5.9	1815	30.59	16.86	145	5.6	4.7
T_6	85.5	0.50	16.91	10.02	-3.1	1849	36.17	19.56	148	5.7	4.6
T_7	72.7	0.89	6.38	2.72	26.8	1246	18.16	14.58	100	3.8	3.4
T_8	74.9	0.70	8.31	4.32	12.5	2476	25.82	10.43	198	7.6	6.9
T_9	83.9	0.93	14.82	8.59	0.0	14760	21.31	1.44	1181	45.4	38.5
T_{10}	-	1.00	1.00	0.00	58.0	-	-				
LSD (P=0.05)											

Treatment details are given in Table 1. WCE, weed control efficiency (%); WPI, weed persistence index; CRI, crop resistance index; EI, efficiency index; WI, weed index. CWC, cost of weed control (₹/ha); NRwc, net returns due to weed control (/ha); MBCR, Marginal benefit: cost ratio; Gt, gain threshold; Et, economic threshold; SP, after Stone and Pedigo (1972); UM, after Uygur & Mennan (1995).

fective tillers (r= 0.922**). The linear relationship between weed count/weed dry weight (x) and grain yield (Y) of wheat is given hereas under,

Weed count

$$Y= 4074 - 26.02\,x \qquad (R^2= 0.734)\ldots\ldots(i)$$

Weed weight

$$Y= 3893 - 41.55\,x \qquad (R^2= 0.875)\ldots\ldots(ii)$$

The equation (i) explains that 73.4% variation in yield due to weed count could be explained by the regression equation. The further analysis indicated that decrease in yield per unit increase in weed count (1 weed/m^2) is estimated to be 26.02 kg/ha. Similarly from the equation (ii) it may be inferred that 87.5% of variation in grain yield of wheat due to weed dry weight could be explained by the regression equation. With every 1 g/m^2 increase in weed dry weight, the grain yield of wheat was expected to fall by 41.55 kg/ha.

The economic threshold levels of weeds at the current prices of treatment application and the crop production on the basis of weed infestation (population) in wheat are given in Table 4. The economic threshold levels (number of weeds/unit area) with the weed management practices studied varied between 2.6 - 45.4/m^2 when determined after Pedigo and Stone (1972) and 2.2 - 38.5/m^2 after Uygur and Mennan (1995). The trend was almost similar under the methods of determination. It was clearly indicated that any increase in the cost of treatment would lead to higher values of economic threshold, whereas an increase in price of crop produce would result in lowering the economic threshold.

Clodinafop 60 g/ha+ metribuzin 122.5 g/ha resulted in highest weed control efficiency, crop resistance index and efficiency index. This was followed by weed free and clodinafop *fb* metribuzin 105 g/ha. Weed persistence index and weed index were lowest under clodinafop + metribuzin 122.5 g/ha which was followed by pinoxaden 50 g/ha and clodinafop + metribuzin 105 g/ha.

Herbicidal treatments had only 0.06-0.17 times of application cost than that under weed free (hand weeding thrice). Due to higher grain and straw yield owing to effective weed control, clodinafop 60 g/ha + metribuzin 122.5 g/ha resulted in highest net return. This was followed by pinoxaden 50 g/ha, clodinafop 60 g/ha + metribuzin 105 g/ha. Due to lower cost, herbicidal treatments resulted in 7.2 - 20.4 times higher marginal benefit cost ratio than weed free. Metribuzin 175 g/ha resulted in highest marginal benefit cost ratio followed by clodinafop + metribuzin 122.5 g/ha and sulfosulfuron 25 g/ha.

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Influence of herbicides on soybean yield, soil microflora and urease enzyme activity

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ABSTRACT

An experiment was done during *Kharif* 2008 and 2009 at BCKV, Kalyani to study the weed control efficiency of herbicide as well as its effect on soil microorganisms including urease enzyme in Soybean crop field. Dominent weeds were: *Echinochloa colona, Eleusine indica, Dactyloctenium aegyptium, Digitaria sanguinalis, Cyperus rotundus, Euphorbia hirta, Digera arvensis, Physalis minima, Phyllanthus niruri, Alternanthera philoxeroides* and *Amaranthus viridis*. The treatment UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha was found best for efficient weed control as well as safe use for soil microflora including urease enzyme activity among all the treatments even in comparison to hand weeding treatment.

Key words: Seed yield, Soil microflora, Soybean, Urease enzyme activity

Soybean contains 43.2% protein, 20% fat, 31.3% carbohydrate and 432 Calories per 100 g (Kundu *et al.* 2011). Soybean oil can be used as edible oil as well as vegetable oil. Soybean forage and protein also provide excellent nutritive feed for livestock and poultry. Being a leguminous crop, it restores the fertility of soil also. Soybean is grown mostly in *Kharif* season as rainfed crop. In this season, The problem of weed is much more than other season crop causing reduction in yield. To overcome this problem, an effective method which is less costly and environmentally safe in comparison to costly hand weeding method was attempted.

MATERIALS AND METHODS

An experiment was done during *Kharif* 2008 and 2009 at Farm (latitude: 22°57'E, longitude: 88°20'N and altitude: 9.75 m) of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India to study the weed control efficiency of herbicide as well as its effect on soil microorganisms including urease enzyme in Soybean crop field. The experimental soil was well drained, alluvial in nature and sandy loam in texture (sand 63%, silt 21%, clay 16%), having pH 6.86, organic carbon 0.58%, available nitrogen 236.3 kg/ha, available phosphorus 20.0 kg/ha and available potassium 178.6 kg/ha.

The experiment consisted twelve treatments and replicated thrice in RBD was conducted during *Kharif* sea son of 2008 and 2009 in Soybean crop with variety PK-327. The treatments were: T_1- UPH-203 60 g/ha, T_2- UPH-203 80 g/ha, T_3- UPH-203 100 g/ha, T_4-UPH-203 60 g/ha + Na-acifluorfen 10% SL 123.7 g/ha, T_5-UPH-203 80 g/ha + Na-acifluorfen 10% SL 165 g/ha, T_6- UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha, T_7- Na-acifluorfen 10% SL 123.7 g/ha, T_8-Na-acifluorfen 10% SL 165 g/ha, T_9- Na-acifluorfen 10%SL 206.2 g/ha, T_{10}- imazethapyr 10% SL 1000 g/ha, T_{11}- hand weeding twice (15 and 30 DAS) and T_{12}- untreated control. First two herbicides were sprayed at 23 days after sowing whereas imazethapyr was spreyed at 10 DAS.

To count the weed population/m^2 in different plots, quadrate of 0.5 x 0.5 m was thrown at four random places in each plot at 30 DAS, 60 DAS and at harvest.

The enumeration of the microbial population was done on agar plates containing appropriate media following serial dilution technique and pour plate method (Pramer and Schmidt 1965). Plates were incubated at 30^{0}C. The counts were taken at 5th day of incubation. The results were recorded as number of cells per gram of soil. For counting total number of viable bacteria, Thornton's agar medium was used. Jensen's agar medium was used for counting aerobic non-symbiotic nitrogen fixing bacteria. Total number of phosphate solubilizing microorganisms was estimated in Pikovskaia's agar medium. Martin's rose Bengal streptomycin agar medium of the following composition was used for counting total fungi. Soil samples were collected from the rhizosphere of soybean before spraying, 15 days after application of herbicide and at harvest.

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The method was based on determination of ammonia released after the incubation of soil samples with urea solution for 2 hours at 37^{0}C (Tabatabai and Bremner 1972).

RESULTS AND DISCUSSION

Weed flora

Grasses: *Echinochloa colona Digitaria sanguinalis, Dactyloctenium aegyptium,Eleusine indica Cynodon dactylon, Leersia hexandra, Echinochloa crus-galli etc.* Sedges: *Cyperus rotundus, Cyperus difformis, Fimbristylis littoralis*; and broad-leaved weeds: *Digera arvensis, Physalis minima, Phylanthus niruri, Alternanthera philoxeroides, Amaranthus viridis, Euphorbia hirta, Cleome viscosa, Stellaria media* and *Spilanthus paniculata.* Similar findings were reported by Norsworthy (2008).

Hand weeding twice at 15 and 30 DAS recorded significantly lowest weed density (27.3) than all other treatments (Table 1). The highest weed density (120) was recorded in weedy check. UPH-203 100 g/ha + Na-acifluorfen10% SL 206.2 g/ha recorded significantly lowest weed population at all the stages than the sole application of UPH-203 and Na-acifluorfen 10% SL. Again imazethapyr 10% SL 1000 g/ha treatment was statistically at par with UPH-203 60 g/ha+ Na-acifluorfen 10% SL 123.7 g/ha, UPH-203 80 g/ha + Na-acifluorfen 10% SL 165 g/ha and UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha in this respect.

Soybean yield

Highest grain yield (2.35 t/ha) was recorded (Table 1) in the treatment of hand weeding twice, which gave significantly higher seed yield of soybean over all other treatments. Again the treatments UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha (2.16 t/ha) and imazethapyr 10% SL 1000 g/ha (2.04 t/ha) were statistically at par among themselves and showed their best performance in this respect among the chemical treatments. Herbicide UPH-203 as single chemical gave good results and recorded significantly higher seed yield over unweeded control but lower than hand weeding treatment. On the other hand, Na-acifluorfen 10% SL at different doses though at par among themselves with respect to seed yield but gave significantly lower yields when they were compared with combined chemical treatments of UPH-203 and Na-acifluorfen10% SL. Among all the treatments, unweeded control resulted lowest seed yield (1.12 t/ha). Similar results were recorded by Bhattacharya *et al.* 1(998) and Pandey *et al.* (2007).

In respect of net present value (NPV), the highest value was obtained with the treatment T_6 (UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha) (1.15) which was closely followed by the treatment T_{11} (twice hand weeding at 15 and 30 DAS) (T_{11}:1.10) and T_{10} (imazethapyr 10% SL 1000.0 g/ha) (0.99). Hand weeding treatment (T_{11}) showed lower NPV value in comparison to T_6 due to higher expenditure on labour wages. On the contrary, lowest value of cost: benefit ratio was obtained in unweeded control (0.18).

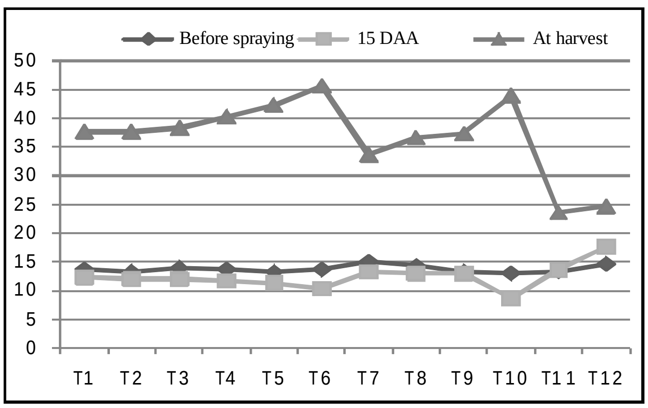
Non-symbiotic N_2-fixing bacteria

Before spraying, population of aerobic non-symbiotic nitrogen fixing bacteria did not differ signifi-

Table 1. Effect of treatments on total weed density and soybean yield (pooled data)

Treatment	Weed density (no./m^2)			Seed yield (t/ha)	NPV
	30 DAS	60 DAS	At harvest		
T_1- UPH-203 60 g/ha	75.3	114.3	135.0	1.68	0.74
T_2- UPH-203 80 g/ha	74.6	105.0	139.7	1.69	0.74
T_3- UPH-203 100 g/ha	71.0	101.7	136.3	1.73	0.78
T_4- UPH-203 60 g/ha + Na-acifluorfen 123.7 g/ha	63.7	94.00	129.3	1.78	0.81
T_5- UPH-203 80 g/ha + Na-acifluorfen 165 g/ha	56.0	87.7	120.0	1.84	0.85
T_6- UPH-203 100 g/ha + Na-acifluorfen 206.2 g/ha	40.0	74.7	90.0	2.16	1.15
T_7- Na-acifluorfen 123.7 g/ha	91.3	129.3	159.3	1.52	0.56
T_8- Na-acifluorfen 165.0 g/ha	82.0	117.3	151.7	1.61	0.64
T_9- Na-acifluorfen 206.2 g/ha	77.7	110.3	139.3	1.65	0.67
T_{10}- Imazethapyr 1000.0 g/ha	49.3	91.0	101.7	2.04	0.99
T_{11}- Twice hand weeding at 15 and 30 DAS	27.3	56.7	80.0	2.35	1.10
T_{12}- Weedy check (untreated)	120.0	162.3	186.7	1.12	0.18
LSD (P=0.05)	16.7	24.2	30.4	0.14	

cantly among the treatments (Fig. 1). At 15 DAA, unweeded control plot exerted a significant increase in the population of aerobic non-symbiotic nitrogen fixing bacteria in soil over all the treatments. On the other hand, all the treatments except hand weeding twice showed a significant reduction in number of the micro flora at 15 DAA as compared to unweeded control. Unweeded control treatment recorded highest population which was followed by Na-acifluorfen 10% SL 123.7 g/ha. At harvest, population of aerobic non-symbiotic nitrogen fixing bacteria was remarkably increased in all the chemical treatments due to release of carbon from degraded chemicals. However, UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha recorded significantly higher value over the other treatments and statistically at par with imazethapyr 10% SL 1000 g/ha. These herbicides might nourish bacteria with nutrient and energy sources for higher proliferation.



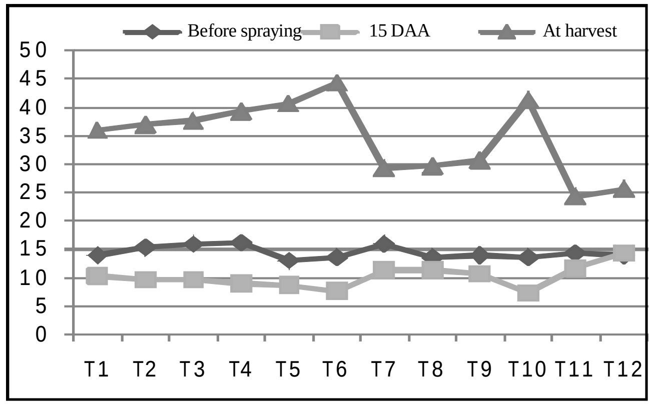
Treatment details are given in Table 1

Fig. 1. Influence of treatments on the population of aerobic non-symbiotic N_2- fixing bacteria (CFU x10^6/g of soil)

The population of aerobic non-symbiotic nitrogen fixing bacteria decreased on the 15 DAA as compared to before spraying and then increased at harvest. The decrease in the bacterial population at initial stage after application of herbicides was due to competitive influence and the toxic effect of chemicals in soil. On the contarary, the population was seen to increased by the commensalic or protocooperative influence of various micro-organisms on non-symbiotic nitrogen fixing bacteria in the rhizosphere soil of soybean crop after the degradation of the applied herbicides in soil within a considerable time.

Phosphate-solubilising bacteria

The population of phosphate solubilising bacteria did not differ significantly with the treatments before spraying of herbicides (Fig. 2). Similar findings were recorded in case of aerobic non-symbiotic nitrogen fixing bacteria at 15 DAA. At harvest, treatments recorded a significant increase in the population of phosphate solubilising bacteria except the treatment hand weeding twice. UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha was followed by imazethapyr 10% SL 1000 g/ha in this respect.



Treatment details are given in Table 1

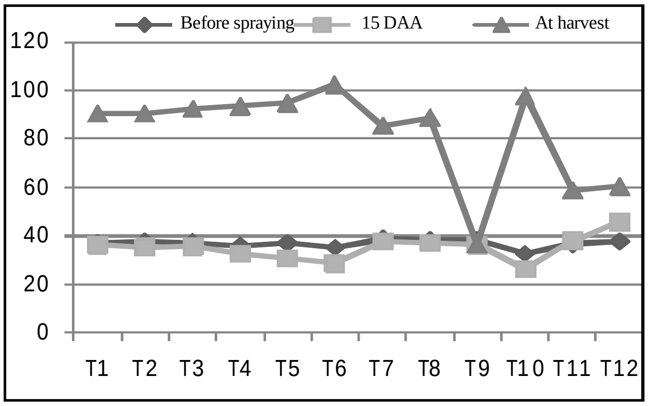
Fig. 2. Influence of treatments on the population of phosphate-solubilising bacteria (CFU x 10^6/g of soil)

The population of phosphate solubilising bacteria decreased at 15 DAA as compared to the observation before spraying and then again it increased at harvest. The increase may be due to the commensalic or protocooperative influence of various micro-organisms on phosphate solubilising bacteria in the rhizosphere soil of soybean crop after degradation of applied herbicides in soil.

Total bacteria

Similar trends in case of total bacteria population have been found (Fig. 3). Before spraying, population of total bacteria did not differ significantly among the treatments. At 15 DAA and at harvest similar trends were recorded regarding total bacterial population. UPH-203 100 g/ha Na-acifluorfen 10% SL 206.2 g/ha recorded highest population count followed by imazethapyr 10% SL1000 g/ha.

Here also, the population of total bacteria decreased on the 15^{th} day of application as compared to that of before spraying and then increased at harvest. The decrease in the bacterial population was due to competitive influence and the toxic effect of chemicals in soil. On the other hand, the increase might be due to the commensalic or protocooperative influence of various micro-organisms on total bacteria in the rhizosphere soil of soybean crop (Ghosh *et al.* 2012).



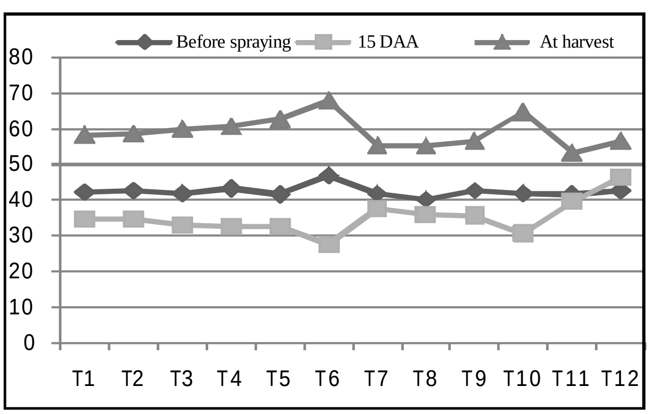
Treatment details are given in Table 1

Fig. 3. Influence of treatments on the population of total bacteria (CFU x 10^6/g of soil)

Actinomycetes

Before spraying, population of actinomycetes did not differ significantly among the treatments (Fig. 4). The actinomycetes population decreased at 15 DAA as compared to before spraying. This might be due to the competitive influence of various micro-organisms on the population of actinomycetes in the rhizosphere soil of soybean as well as toxic effect of the chemicals applied. Highest actinomycetes population was recorded in unweeded control plot which was statistically different than other treatments.

Before spraying, at 15 DAA and at harvest, similar trends were recorded regarding actinomycetes like other microorganisms. At harvest, UPH-203 80 g/ha + Na-acifluorfen 10% SL 165 g/ha also recorded promising result in population which was significant over all other treatments including control plot. In general, the population



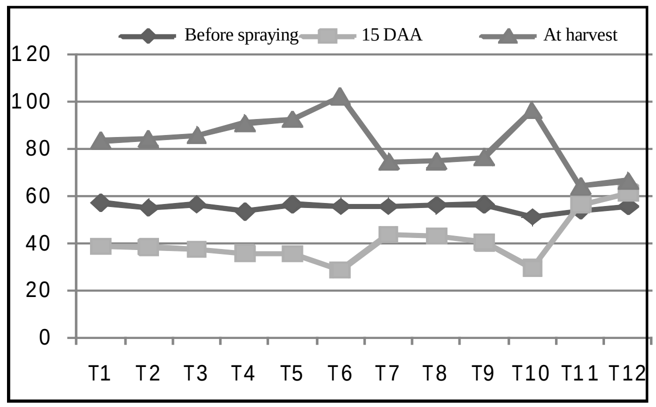
Treatment details are given in Table 1

Fig. 4. Influence of treatments on the population of tactinomycetes (CFU x 10^5/g of soil)

count for actinomycetes increased at harvest in all the treatments in comparison to 15 DAA because at that time chemicals were degraded and the availability of carbon was increased in the soil which ultimately helped in increasing the population in soil. Sapundjieva *et al.* (2008) reported similar findings.

Fungi

Before spraying, population of fungi did not differ significantly among the treatments. Hand weeding twice exerted a significant enhancement in the population of fungi in soil at different stages. At 15 DAA, population of fungi decreased in the chemical treated plots. However, at harvest, all the treatments in comparison to 15 DAA showed a significant increase in the population of fungi in soil (Fig. 5).



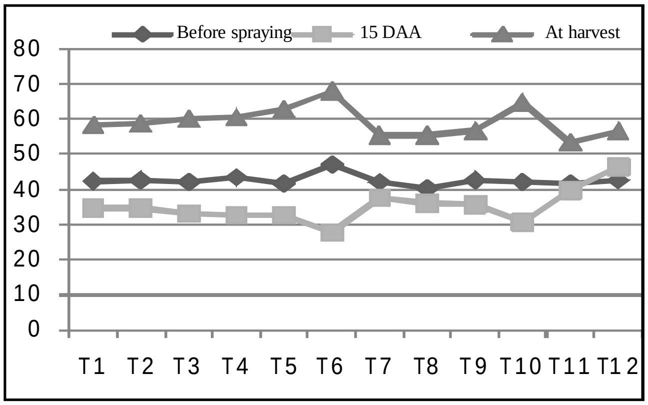
Treatment details are given in Table 1

Fig. 5. Influence of treatments on the population of fungi (CFU x 10^4/g of soil)

The decrease in fungal population at 15 DAA might be due to the toxic effect or ammensalic or competitive influence of various micro-organisms on the population of fungi in the rhizosphere soil of soybean. At harvest the population was again significantly increased in all treatments because chemicals were degraded at that time and no toxic effect in the soil remained afterward. Similar findings were recorded by Sokolova and Gulidova (2010).

Urease enzyme activity in rhizosphere

Among all herbicidal treatments, UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha showed best performance in urease enzyme activity in all the three observations. At 15 DAA, UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha treatment was statistically at par with UPH-203 80 g/ha + Na-acifluorfen 10% SL 165 g/ha in this respect (Fig. 6). At 30 DAA and 45 DAA, similar trends were recorded. Imazethapyr 10% SL 1000 g/ha recorded the lowest urease activity at 15 DAA and 30 DAA which was significantly lower than other treatments. At 45 DAA, similar trends were recorded. Application of UPH-203 as sole or in combination with Na-acifluorfen 10% SL recorded significantly better urease activity than that of imazethapyr 10% SL treatment and untreated control.



Treatment details are given in Table 1

Fig. 6. Influence of treatments on the population of urease enzyme activity (μg NH_4-N/g of soil 2/h at 37^0C)

It is very clear from the data presented regarding soil microflora populations and urease enzyme activity that all kinds of soil microflora (total bacteria, non-symbiotic nitrogen fixing bacteria, phosphate solubilising bacteria, actinomycetes and fungi) has a positive relationship with the activity of urease enzyme. Microflora and urease activity were highly positively correlated. But it was not enough to effect on yield negatively. Byrnes and Freney (1995) also reported that high biological activity at the soil surface promote soil enzyme urease which was similar to the present findings.

It may be concluded that considering the seed yield of soybean as well as soil health (soil beneficial microflora population and urease enzyme activity), combined chemical methods can replace hand weeding twice. Amongst the different methods used in this experiment, UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha gave higher economic yield over other methods (except hand weeding twice). It can further be concluded that in spite of 8.60% less yield in this treatment UPH-203 100 g/ha + Na-acifluorfen 10% SL 206.2 g/ha was also superior over the hand weeding twice as it gave higher benefit: cost ratio (1.15) whereas hand weeding twice is laborious, time consuming, costly (benefit: cost ratio 1.10) and problematic as labourers were not available at the critical period of crop weed competition.

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Yield and economics of soybean under integrated weed management practices

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ABSTRACT

A field experiment was conducted at Agricultural Research Station, Karad, Satara, Maharashtra to find out the suitable integrated weed management method to enhance the yield in soybean. Higher yield component and yield were recorded under weed free treatment. Weed biomass was reduced significantly by the integrated weed management methods comprising quizalofop ethyl 0.05 kg/ha + chloromuron-ethyl 0.009 kg/ha as post-emergence application at 15 DAS + hand weeding at 30 DAS.

Key words: Economics, Integrated weed management, Soybean, Yield

Soybean (*Glycine max*) is an important rainy season crop having national productivity of 1006 kg/ha (Anonymous 2010). The sowing time for soybean in rainy season is very short and farmers give first priority for sowing the crop rather than controlling the weeds. The weeds-emerges simultaneously with the crop and compete with soybean causing loss in yield upto 35-55% depending upon the weed flora and density (Chandel and Saxena 1998, Kewat *et al.* 2000, Singh 2007). Manual weeding at right stage is difficult, time consuming and expensive due to intermittent rainfall during rainy season and scanty labour, therefore, farmers rarely adopt manual weeding for weed control. Under such situation, herbicides use with suitable dose remains the pertinent choice for controlling the weeds.

Herbicides in isolation, however, are unable do complete weed control because of their selective kill. Their use can be made more effective if supplemented with hand weeding or hoeing *etc*. A judicious combination of chemical and cultural methods of weed control would not only reduce the expenditure on herbicides but would benefit the crop by providing proper aeration and conservation of moisture (Prakash *et al.* 1991, Velu and Shankaran 1996). Thus, an experiment was conducted with an objective to identify a judicious combination of chemical and cultural methods for controlling weeds in soybean.

MATERIALS AND METHODS

The experiment was conducted during *Kharif* season of 2010, 2011 and 2012 at Agricultural Research Station, Karad, Satara, Maharashtra, India to identify the suitable integrated weed management method for managing weeds in soybean. The experiment was laid out in randomized block design with 10 treatments replicated thrice. The soil of the experimental field was medium deep, with low in available nitrogen (260 kg/ha) medium in available phosphorus (45.2 kg/ha) and rich in available potash (350 kg/ha). The soil was slightly acidic in reaction with pH 6.7.

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Experimental treatments comprised hoeing at 15 days after seeding (DAS) and 30 DAS, hoeing at 15 DAS and hand weeding (HW) at 30 DAS, imazethapyr (Pursuit) 10 EC, 0.075 kg/ha as post-emergence (POE) at 15 DAS, imazethapyr 10 EC, 0.075 kg/ha as POE at 15 DAS and HW at 30 DAS, pendimethalin 1.0 kg/ha as pre-emergence, pendimethalin 1.0 kg/ha as pre-emergence and HW at 30 DAS, quizalofop-ethyl (Turga super) 5% EC 0.05 kg/ha + chlorimuron-ethyl (Cloben) 25% WP 0.009 kg/ha as post-emergence at 15 DAS, quizalofop-ethyl (Turga super) 5% EC 0.05 kg/ha + chlorimuron-ethyl (Cloben) 25% WP 0.009 kg/ha as post-emergence at 15 DAS + HW at 30 DAS and of weedy check, weed free check.

Weed biomass was recorded by weighing the dry weeds from the treatment plots. Weed control efficiency was estimated on the basis of reduction in weed weight in comparison with unweeded control and expressed as an index taking weed free as 100% efficiency. Weed index refers to reduction in yield due to presences of weeds in comparison to the weed free treatment plot yield. The economics of treatment was computed with prevailing market prices of products. The experimental plot size was 6.00 x 4.20 m. The soybean was sown by dibbling at 30 x 10 cm spacing.

RESULTS AND DISCUSSION

Effect on yield

Among the integrated weed management treatments, T_{10} *i.e.* quizalofop-ethyl 0.05 kg/ha + chlorimuron-ethyl 0.009 kg/ha as post-emergence at 15 DAS + hand weed-

Table 1. Soybean plant height, pods per plant and weed biomass as influenced by different weed management treatments

Treatment	Plant height (cm)	Pods/plant	Weed biomass (kg/ha)
T_1 - Hoeings (at 15 DAS and 30 DAS)	64	24	666
T_2- Hoeings (at 15 DAS and HW at 30 DAS)	69	24	448
T_3 - Imazethapyr 0.0750 kg/ha (POE at 15 DAS)	59	19	726
T_4 - T_5 + HW at 30 DAS	70	22	457
T_5 - Pendimethalin 1.0 kg/ha (PE)	60	22	727
T_6 - T_7 + HW at 30 DAS	52	25	613
T_7 - Quizalofop-ethyl 0.05 kg/ha + chlorimuron-ethyl 0.009 kg/ha (POE at 15 DAS)	65	26	655
T_8- T_7 + HW at 30 DAS	71	28	381
T_9- Weedy check	63	18	1047
T_{10} - Weed free check	75	29	0000
LSD (P=0.05)			

*DAS- Days after sowing, HW- Hand weeding, POE- Post-emergence, PE- Pre-emergence

Table 2. Effect of different weed management treatments on soybean yield and weed control measures

Treatment	Soybean yield (t/ha)		Weed control efficiency (%)	Weed index (%)
	Grain	Straw		
T_1	2.46	1.74	38	34
T_2	3.42	2.45	62	8
T_3	2.54	1.92	36	32
T_4	2.90	2.17	55	23
T_5	2.35	1.70	31	37
T_6	3.08	2.22	54	18
T_7	2.34	1.75	30	37
T_8	2.70	2.07	47	28
T_9	1.90	1.61	0	49
T_{10}	3.73	2.60	100	0
LSD (P=0.05)	0.32	0.18	5	8

Treatment details are given in Table 1

ing at 30 DAS, recorded significantly higher plant height, pods/plant, less weed biomass and higher seed and straw yield (3423 and 2448 kg/ha), respectively, and was at par with weed free check (Table 1 & 2). Similar trend was also noticed in case of growth and yield attributes, weed control efficiency and weed index. Pendimethalin 1.0 kg/ha as pre-emergence recorded the lowest seed yield among the chemical weed control treatments which was followed by imazethapyr 10 EC, 0.750 kg/ha as post-emergence at 15 DAS.

These results revealed that comparative inefficiency of the chemical methods of weed control in isolation in reducing the crop weed competition resulting in comparatively lower yields as compared to their use in combination. These results were in conformity with Dubey *et al.* (1996). The increase in soybean seed yield with integrated methods could be attributed to the fact that the crop was kept free of competition at the early critical stages of growth which resulted efficient use of land and climatic resources by the crop. These results were in confirmations with the earlier findings of Velu and Sankaran (1996) and Natrajan *et al.* (1997).

Economics

The monetary returns were found to be significantly influenced by different weed control treatments. Quizalofop-ethyl 0.05 kg/ha + chlorimuron-ethyl 0.009 kg/ha as post-emergence at 15 DAS + hand weeding at 30 DAS recorded the significantly higher gross and net monetary returns and B:C ratio than other treatments and were at par with weed free treatment (Table 3). These results are in close conformity with the findings of Chandel *et al.* (1995) and Jain *et al.* (2000).

Table 3. Economics of different weed management treatments used for managing weeds in soybean

Treatment	Gross monetary returns (x10^3 ₹/ha)	Net returns (x10^3 ₹/ha)	B:C ratio
T_1	46.43	27.12	2.40
T_2	52.94	31.90	2.52
T_3	42.98	22.87	2.14
T_4	56.25	34.28	2.56
T_5	42.85	23.29	2.19
T_6	49.36	27.94	2.30
T_7	44.91	25.21	2.28
T_8	62.62	41.06	2.90
T_9	34.74	18.34	2.12
T_{10}	68.26	45.85	3.05
LSD (P=0.05)	5.82	5.82	0.28

Treatment details are given in Table 1

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Effect of mulching, herbicides and hand hoeing on seedling growth and weed population in jujube nursery

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ABSTRACT

Experiment was conducted to evaluate the efficacy of pre- and post-emergence herbicides and organic and plastic mulches to control weeds in jujube (*Zizyphus mauritiana*) nursery. Nutsedge (*Cyperus rotundus*) was the major monocot weed (67.9%), followed by wiregrass *Eleusine indica* (18.2%), love grass, *Eragrostis tenella (*8.2%) and bermuda grass, C*ynadon dactylon* (5.8%). Among the dicot weeds, puncture vine (*Tribulus terrestris*) was the major weed (88.1%), followed by 10.3% in case of pigweed (*Amaranthus viridis)*. All the herbicidal treatments hampered jujube seed germination. Pendimethalin resulted in highest inhibition of jujube seed germination. Paraquat resulted in poor seed germination as compared to glyphosate treatments. Pyrazosulfuron-ethyl delayed germination, led to plants with lesser plant girth and reduced proportion of buddable plants. The highest proportion of buddable plants (85.9%) was obtained with straw mulch which did not differ significantly from proportion of buddable plants recorded with weed mulch, black polythene mulch and weed free check. Paraquat treatments resulted in lesser number of buddable plants as compared to glyphosate. At all the intervals, highest weed control efficiency was obtained with straw mulch which did not differ significantly from the weed control efficiency obtained with weed mulch. Among the herbicidal treatments, double application (10 and 60 DAS) of glyphosate resulted in the best control of monocot as well as dicot weeds.

Key words: *Ber*, Herbicides, Jujube, Mulching, Nursery, Weed control, Weed population

Indian jujube (*Zizyphus mauritiana* L.) commonly known as 'Ber' in India is a hardy fruit tree and cultivated all over the hot arid and semi-arid regions of North-West India. The jujube nursery is raised during summer season. The seeds of jujube rootstock (*Zizyphus rotundifolia* Lam.) are sown in the month of April and the rootstock is budded in July–August. High soil moisture due to frequent surface irrigations, abundant application of farmyard manure, and warm and humid environment favour the profuse growth of grassy and broad-leaved weeds in jujube nursery. *Cyperus rotundus* is the major weed in jujube nursery. The infestation of weeds in the jujube nursery results in the poor growth of the rootstock. Therefore, all the jujube seedlings do not attain buddable stem thickness even after four months of sowing and budding success is reduced due to delayed budding. The delay in the attainment of desirable stem thickness also results in staggering of budding process in two to three stages and even after this many rootstocks do not even become buddable during that budding season. In the next season, the leftover rootstocks become unbuddable as they attain very vigorous size, hence, the rootstocks are wasted. Some nursery men utilize these leftover rootstocks in next budding season. They cut the rootstock to ground level at the end of winter and a single sprout is maintained and budded in the budding season. The jujube plants such raised on the two year old rootstocks show poor transplanting success. Moreover, it is very tedious and laborious to maintain the rootstocks till next year.

In the jujube nursery, the weeds are generally being controlled by hand hoeing. Hand weeding is very labour intensive and in the arid regions of North-West India, there is an acute shortage of labour especially during the nursery production of jujube. Hand hoeing has been even realized not effective in controlling weeds as they grow again very rapidly after hand hoeing. The use of herbicides as suggested by Yadav *et al.* (2004) and locally available waste material such as crop straw, weeds, bark and composted municipal green waste can provide effective weed control (Radwan and Hussein 2001). Hence, the present study was conducted to evaluate the efficacy of different mulches and herbicides for the management of weeds in jujube nursery.

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MATERIALS AND METHODS

The present study was conducted at fruit nursery of Punjab Agricultural University, Regional Research Station at Bathinda (latitude 30^0 17" N, longitude 74^0 58" E and altitude 211 m). The soil was sandy loam and characterized with pH 8.5, organic carbon (0.55%), EC 0.21 dS/m^2, calcium carbonate, N (290 kg/ha), P (18.6 kg/ha) and K (219 kg/ha). The jujube seeds were collected from a single plant of jujube rootstock (*Zizyphus rotundifolia* Lam.) and sown in beds in April, 2007 and 2008 in paired rows. The paired rows were 45 cm apart and the inter row distance within a paired row was kept 15 cm. The weed control treatments were assigned to plots of 1.5 x 1.5 m having 6 rows.

There were 17 weed control treatments, *viz*. pendimithalin (0.25, 0.50, 0.75 and 1.0 kg/ha), pyrazosulfuron- ethyl (0.005, 0.01 and 0.02 kg/ha), glyphosate (1.64 kg/ha) at 10 DAS *i.e.* after emergence of weeds but, before germination of jujube seeds, paraquat (0.72 kg/ha) at 10 DAS, double application of glyphosate (1.64 kg/ha) at 10 and 60 DAS, double application of paraquat (0.72 kg/ha) at 10 and 60 DAS, wheat straw mulch 6 cm (14.0 t/ha), weed mulch 6 cm (9.0 t/ha) [*Kans* grass mulch (*Saccharum spontaneum* L.)], black plastic mulch 200 µm, weedy check, weed free check (hand hoeing done at weekly intervals to maintain weed free plots.), hand hoeing (3 weeks interval). The pre-emergence herbicides (pendimethalin 0.25, 0.5, 0.75 and 1.0 kg/ha and pyrazosulfuron- ethyl 0.005, 0.01 and 0.02 kg/ha) were sprayed on the beds after seed sowing. The herbicides were sprayed with a knapsack sprayer using 500 l/ha. The post-emergence application of herbicides (glyphosate 1.64 kg/ha and paraquat 0.72 kg/ha) was done 10 days after sowing (DAS). In another treatment, glyphosate and paraquat were applied twice *i.e*. 10 DAS and 60 DAS at the same doses mentioned above. The second spray of the herbicide at 60 DAS was directed in between the rows with the help of a hood fitted on the nozzle of sprayer. The organic mulches (wheat straw and *Saccharum* grass mulch) were spread all over the bed *i.e.* beneath the jujube seedlings and in between the rows of seedlings and the thickness of the mulch was maintained at 6 cm by giving topping mulch after 6 weeks, whereas black polyethylene mulch was spread only in between rows of jujube seedlings after 5 weeks of sowing. All the plots subjected to mulch treatments were manually weeded till 5 weeks. The weed control efficiency was calculated.

The experiment was carried out in randomized block design and replicated thrice. The data was pooled as an average of 2007 and 2008. The least significant difference (LSD) was calculated by multiplying standard error with't' value (P=0.05) at error degree of freedom to compare the means of the treatments.

RESULTS AND DISCUSSION

The monocot weeds which appeared in the jujube nursery were nutsedge (*Cyperus rotundus* L.), wire grass [*Eleusine indica* (L.) Gaertn.], bermuda grass [*Cynodon dactylon* (L.) Pers.] and love grass *Eragrostis tenella* (Linn.) P Beauv. Pigweed (*Amaranthus viridis* L.), puncture vine (*Tribulus terrestris* L.), spurge (*Euphorbia hirta* L.) and horsepurslane (*Trianthema portulacastrum* L.) were the prominent dicot weeds. Out of these, nutsedge was the major monocot weed (67.9%), followed by wiregrass (18.2 %), love grass (8.1%) and bermuda grass (5.8%). Among the dicot weeds, puncture vine (88.1%) was the major dicot weed followed by pigweed (10.3%).

All the weed control treatments significantly affected the germination of jujube seeds (Fig. 1). The highest germination (81.8 %) was found in weed free check and it was at par with the mulching treatments (polyethylene and organic mulches), hand hoeing, and manual weeding. In the mulching treatments, hand weeding was done till 5 weeks after sowing till the plants become big enough to put the mulches hence, the mulching treatments were at par with weed free check for seed germination. All the weedicide treatments hampered jujube seed germination. Pendimethalin at 1.0 kg/ha resulted in minimum seed germination (21.7%). Pendimethalin at 0.25, 0.50 and 0.75 kg/ha did not differ significantly for seed germination. Paraquat resulted in poor seed germination as compared to glyphosate treatments. The paraquat treatments were at par to pyrazosulfuron-ethyl at 0.02 kg/ha. Among the herbicidal treatments, the highest seed germination (76.6 %) was recorded with pyrazosulfuron-ethyl at 0.005 kg/ha and it was at par with pyrazosulfuron-ethyl at 0.01 kg/ha. Highest proportion of buddable plants (85.9%) was obtained with straw mulch and it was at par with weed mulch, black polyethylene mulch and weed free check (Fig. 1).

The lowest number of buddable plants was obtained with pyrazosulfuron-ethyl at 0.02 kg/ha and it did not differ significantly from pyrazosulfuron-ethyl at 0.01 kg/ha and pendimethalin treatments at 0.75 and 1.0 kg/ha. Paraquat treatments also resulted in lesser number of buddable plants as compared to glyphosate. Paraquat reduced germination and had some detrimental effects on plant growth which lead to lesser proportion of buddable plants as compared to glyphosate. The effect of different treatments on the proportion of buddable plants might be due to their effect on plant girth (Table 1). Mulching treatment which suppressed the weeds and checked moisture loss from the soil resulted in highest proportion of buddable plants. Pyrazosulfuron-ethyl delayed germination and lead to plants with lesser girth, produced lowest number of buddable plants.

Data on plant height (Table 1) revealed that after 40 and 80 days, the highest plant height was obtained with weed free check and after 120 days the highest plant height (64.5 cm) was observed with black polyethylene mulch which was at par with straw and weed mulch. The mulch treatments were able to check weed growth (Table 2) and mulches have been reported to conserve moisture which may be responsible for the good seedling growth as reported by Faber *et al.* (2001).

At all the intervals, the highest weed control efficiency (Fig. 2) was obtained with straw mulch which was at par with weed mulch. At 40 DAS, black polyethylene mulch was also on par with organic mulches. However, at 80 and 120 DAS, the weed control efficiency was reduced to 60.5 and 45.4%, respectively. The black polyethylene mulch was spread in-between the plant rows and it could not be applied beneath the plants within the rows, hence it controlled the weeds only in between the rows. Single application of glyphosate at 10 DAS also resulted in high weed control efficiency (88.3%) till 40 DAS which was at par with single glyphosate application at 10 DAS, single paraquat application at 10 DAS and double application of glyphosate at 10 and 60 DAS. At 80 DAS, glyphosate showed better WCE (70.3%) and it was at par with double application of paraquat. However, these treatments resulted in poor weed control efficiency (42.6 and 30.9%, respectively) after 120 DAS. This is because the second application of post-emergence herbicides, *viz.* glyphosate and paraquat was done only in-between the rows. The pre-emergence herbicdes pendimethalin and pyrazosulfuron-ethyl resulted in very poor weed control efficiency (Fig. 2).

Different weed control treatments affected number of monocot and dicot weeds at 40, 80 and 120 DAS (Table 2). There were no monocot and dicot weeds after 40 and 80 days of treatment in straw and weed mulch. In the mulching treatments, hand weeding was done till 5 weeks after sowing till the plants became big enough to put the mulches. The higher efficacy of the mulches may be because of reduction in light interception (Mohanty *et al.* 2002). The study corroborated with earlier findings that organic mulches are capable of providing effective weed control (Timothy 2007, Abouziena *et al.* 2008). However, after 120 days, some monocot and dicot weeds developed in wheat straw and weed mulches, respectively. In

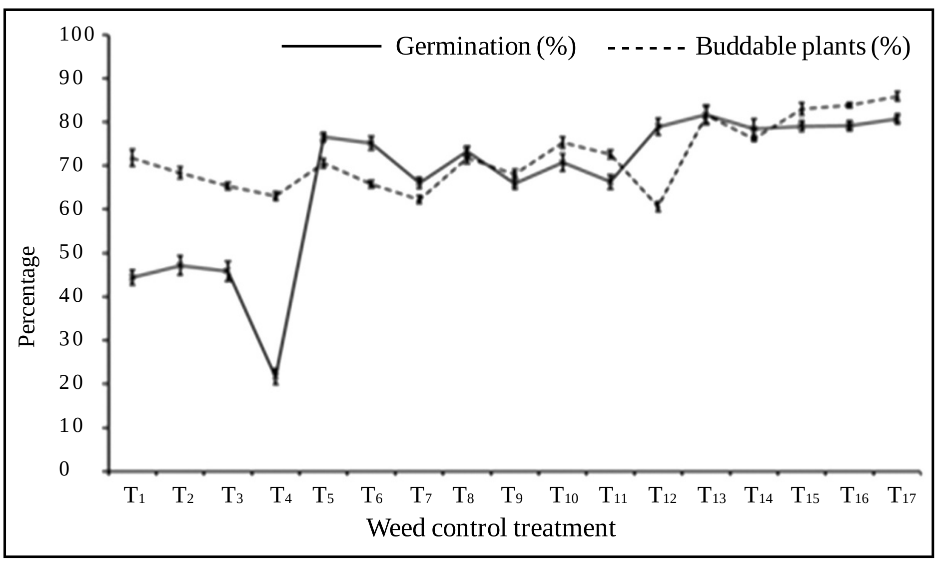
Table 1. Effect of organic and polyethylene mulches, herbicides and hand hoeing on plant girth and height

Treatment	Plant girth (cm)	Plant height (cm)		
		40 DAS	80 DAS	120 DAS
T_1- Pendimithalin 0.25 kg/ha	0.73	11.5	34.5	53.2
T_2- Pendimithalin 0.50 kg/ha	0.67	10.3	29.5	49.0
T_3- Pendimithalin 0.75 kg/ha	0.65	8.3	27.1	49.1
T_4- Pendimithalin 1.0 kg/ha	0.55	2.4	25.8	47.8
T_5- Pyrazosulfuron- ethyl 0.005 kg/ha	0.74	8.0	34.7	50.3
T_6- Pyrazosulfuron-ethyl 0.01 kg/ha	0.56	6.8	26.3	48.6
T_7- Pyrazosulfuron-ethyl 0.02 kg/ha	0.44	5.8	24.0	43.6
T_8- Glyphosate 1.64 kg/ha at10 DAS	0.77	8.4	34.4	50.5
T_9- Paraquat 0.72 kg/ha at 10 DAS	0.66	6.2	30.7	44.9
T_{10}- Glyphosate 1.64 kg/ha at 10 and 60 DAS	0.79	8.8	31.3	49.8
T_{11}- Paraquat 0.72 kg/ha at 10 and 60 DAS	0.70	6.3	29.5	45.5
T_{12}- Wheat straw mulch	0.89	10.9	33.1	64.0
T_{13}- Weed mulch	0.91	10.8	32.2	63.5
T_{14}- Black polyethylene mulch	0.91	11.3	30.4	64.5
T_{15}- Weedy check	0.67	10.2	26.0	45.4
T_{16}- Weed free check	0.84	13.6	38.7	58.4
T_{17}- Hand hoeing	0.81	11.8	33.8	54.0
LSD (P=0.05)	0.08	1.4	3.7	5.3

Table 2. Effect of organic and polyethylene mulches, herbicides and hand hoeing on weed density (no./m²) at different days after sowing

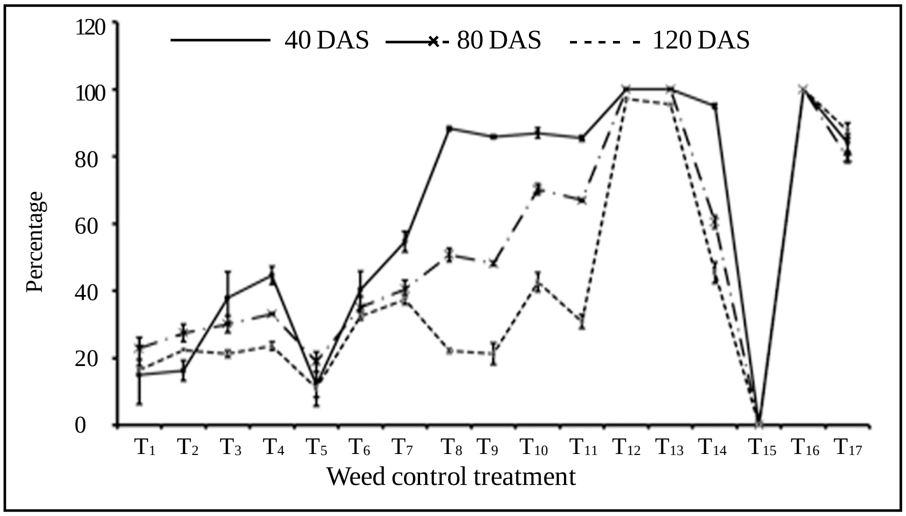
Treatment	Monocot weeds			Dicot weeds		
	40 DAS	80 DAS	120 DAS	40 DAS	80 DAS	120 DAS
T_1	26.5 (701.3)	28.9 (834.2)	30.5 (928.0)	1.0 (0.0)	11.7 (136.3)	12.4 (154.3)
T_2	25.4 (647.0)	27.9 (777.5)	28.5 (814.3)	1.0 (0.0)	10.0 (98.0)	12.7 (160.7)
T_3	22.5 (506.3)	26.0 (675.2)	26.8 (715.7)	1.0 (0.0)	8.8 (76.3)	11.1 (122.3)
T_4	18.8 (354.0)	24.3 (587.5)	24.9 (617.3)	1.0 (0.0)	7.9 (61.3)	9.3 (86.3)
T_5	24.5 (601.3)	26.1 (681.2)	27.9 (778.3)	17.3 (299.0)	19.4 (376.3)	20.3 (411.3)
T_6	22.1 (488.7)	23.2 (536.7)	23.7 (563.7)	18.2 (329.0)	19.7 (386.3)	21.1 (442.3)
T_7	19.6 (385.0)	21.2 (448.3)	22.2 (493.7)	17.7 (313.0)	20.4 (414.7)	21.3 (453.0)
T_8	11.8 (139.0)	17.9 (320.7)	20.2 (409.0)	6.0 (35.4)	8.2 (66.3)	11.1 (122.3)
T_9	12.1 (146.0)	20.1 (402.0)	18.9 (367.3)	4.6 (20.7)	8.7 (76.7)	99.1 (82.67)
T_{10}	12.6 (157.7)	9.4 (88.9)	10.6 (112.3)	5.6 (30.7)	4.1 (23.0)	1.0 (0.0)
T_{11}	11.7 (137.0)	9.9 (96.7)	11.8 (140.0)	5.2 (26.3)	4.2 (27.3)	1.0 (0.0)
T_{12}	1.0 (0.0)	1.0 (0.0)	8.5 (69.3)	1.0 (0.0)	1.0 (0.0)	14.7 (219.7)
T_{13}	1.0 (0.0)	1.0 (0.0)	9.5 (88.0)	1.0 (0.0)	1.0 (0.0)	3.7 (12.7)
T_{14}	8.0 (61.7)	13.6 (185.0)	18.7 (347.0)	4.8 (22.0)	7.7 (57.3)	4.2 (17.0)
T_{15}	32.6 (1035.3)	36.6 (1336.7)	39.3 (1539.7)	18.5 (343.9)	14.2 (225.0)	21.2 (469.3)
T_{16}	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
T_{17}	12.1 (145.0)	13.6 (184.0)	32.2 (1041.3)	3.9 (15.7)	5.6 (29.0)	13.8 (193.0)
LSD (P=0.05)	1.7	1.2	2.8	1.2	1.4	1.8

Figures in parenthese correspond to the original values of the data, which were transformed ($\sqrt{x+0.1}$) before analysis.
Treatment details are given in Table 1.



Treatment details are given in Table 1.

Fig. 1. Effect of organic and polyethylene mulches, herbicides and hand hoeing on seed germination and percentage of buddable plants. Vertical bars represent S.E.



Treatment details are given in Table 1.

Fig. 2. Effect of organic and polyethylene mulches, herbicides and hand hoeing on weed control efficiency after 40, 80 and 120 DAS in Indian jujube. Vertical bars represent S.E.

black polyethylene mulch, weeds were even after 40 days and the weed density increased by 120 days. The black polyethylene can only be applied in between the rows of the plants and weeds developed beneath the plants within the plant rows, hence, the monocot and dicot weeds developed in this treatment. Among the herbicidal treatments, double application (at 10 and 60 DAS) of glyphosate resulted in the best control of mono and dicot weeds. Yadav *et al.* (2004) also reported that glyphosate provided good control of prominent weeds of the jujube nursery. The straw mulch was also equally effective to double application (10 and 60 DAS) of glyphosate but, only up to 60 days after treatment. In the present experiment, the thickness of the straw mulch was maintained at 6 cm by giving some toppings after 6 weeks which made organic mulches very effective in controlling the weeds.

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Integrated management of weeds in raw jute

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ABSTRACT

Net profit from raw jute (jute and mesta together are called raw jute) cultivation is very poor owing to its high cost involvement (35-40% of the total cost of cultivation) in conventional manual weeding process. So far only post-emergence grass weed killing herbicides have been found to be successful in jute. After controlling grassy weeds, *Cyperus rotundus* and other broad-leaved weeds have become menace to these fibre crops which were effectively controlled adopting stale seedbed technique (herbicides applied on established weeds 10 days ahead of sowing jute and mesta) in Bararckpore, West Bengal. In stale seedbed method in jute,(cv '*JRO-524*'), glyphosate 2.46 kg SL/ha and 2,4-D 2 kg/ha in combination, and glyphosate 2.46 kg SL/ha and pyrazosulfuron-ethyl 60g/ha in combination followed by one hand weeding were found promising to control mixed weed flora in jute field. After two years' cycle, these herbicide combinations reduced the *Cyperus rotundus* population by more than 80% over control and produced a mean of fibre yield of 28 to 3.04 t/ha and a maximum of 4.3 t jute fibre/ha in 2006-08. In mesta (cv. '*HC-583*'), in **s**tale seedbed method, butacholor 0.75 kg/ha and 2, 4-D 2 kg/ha in combination followed by 2-HW produced a mean fibre yield of 2.65 t/ha with a maximum 3.2 t mesta fibre/ha in 2007-08 and kept the mesta field free from weed for a couple of weeks. Pretilachlor (0.5 kg/ha) and paraquat (0.48 kg SL/ha) in combination, when applied 10 days ahead of mesta sowing on established weeds, it controlled mixed weed flora and produced a mean mesta fibre yield of 2.68 t/ha. Quizalofop-ethyl 5% EC 60 g/ha and Dhanuvit 0.5 to 0.6 l/ha at 21 DAE and one hand weeding produced a mean mesta fibre yield of 2.76 t/ha with a maximum of 3.45 t fibre/ha in 2007-08. Except chlorimuron-ethyl, other herbicides did not affect the soil microbial flora in post harvest jute soil. All these methods produced mean fibre yields at par with two manual weedings.

Key words: Chemical control, Integrated weed managment, Herbicde, Jute, Mesta

Raw jute [jute: C*orchorus olitorius* and mesta: *Hibiscus cannabinus*] is the cheapest sources of natural fibre in the world. Small and marginal farmers of Indo-Bangladesh sub-continent and other countries like China, Thailand, Nepal, Myanmar, Brazil, Congo, *etc*. grow raw jute in humid tropical climate mainly as a rainfed crop. Conventional manual weeding in raw jute involves around 40% of the total cost of cultivation (Saraswat 1974) and fibre yield reduction is up to 70% under unweeded situation. The weeding operation becomes very difficult particularly when weed flora establishes prior to crop sowing due to rain. In this context, it is imperative to mention that, after controlling grassy weeds, *Cyperus rotundus* (sedges) and other broad-leaved weeds (*Trianthema portulacastrum* and, *Ludwigia parviflora* in particular) have become menace to these fibre crops. Moreover, lack of sufficient human labour at peak weeding hour is also a bottleneck to manual weeding in jute. Effective chemical weed management in jute and mesta have also been less studied. Some viable chemical weed management technology is thus imminent to sustain raw jute fibre production by the small and marginal farmers. Stale seedbed technique has been found to be worthy in controlling composite weed flora in different field crops. A stale seedbed is one where initial 1-2 flushes of weeds are destroyed before planting a crop (Gupta 2000). In chemical method**,** quizalofop-ethyl, a post-emergence herbicide successfully controls grassy weed in jute field (Ghorai *et al*. 2008). Experiments were thus conducted to screen out suitable chemical weed control methods to combat composite weed flora in raw jute.

MATERIALS AND METHODS

Experiments were conducted for two consecutive years from 2006-07 and 2007-08, at Central Research Institute for Jute and Allied Fibres, Barrackpore, Kolkata, West Bengal, India. The experimental soil was sandy clay loam in texture with 44% sand, 28% silt and 28% clay. Its available nitrogen, phosphorus and potassium content

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was 180, 34 and 133 kg/ha, respectively. Experiments were conducted in randomised block design with ten treatments replicated thrice. The jute cultivar cv. '*JRO-524*' and mesta cultivar cv. '*HC 583*' were grown in the experiments. The crop was sown on June 2006 (stale seedbed) in the first year and on May 2007 in the second years of experiments. For stale seedbed method the herbicidal combinations were sprayed on established weeds ten days ahead of raw jute sowing. After complete death of mixed weed flora, the soil was ploughed and jute and mesta were sown. The treatment setup was: i) unweeded control (M: mesta), ii) hand weeding twice (M), iii) quizalofop-ethyl 5% EC (60 g/ha) + dhanuvit 0.6 l/ha at 21 DAE + 1 HW (M), iv) quizalofop ethyl 5% EC, (60 g/ha) + chlorimuron-ethyl (CME 37.5 g/ha, at 21 DAE) + 1HW (M), v) quizalofop-ethyl 5% EC, 60 g/ha + chlorimuron ethyl (CME 37.5/ha) at 21 DAE + HW (J: jute), vi) 2,4-D (2 kg/ha) + butachlor 50% EC (0.75kg/ha) 10 days before sowing on established weeds (stale seedbed) + 1 HW (M) vii) Glyphosate (2.46 kg SL/ha) + 2,4-D (2 kg/ha, stale seed bed) + 1 HW (J), viii) glyphosate (2.46 kg SL/ha) + 2,4-D (2 kg/ha) + chlorimuron-ethyl (CME, 37.5 g/ha, stale seedbed) + 1HW (J), ix) pretilachlor (0.50 kg/ha) + paraquat (0.48 kg SL/ha, stale seedbed) + 1HW (M), x) glyphosate (2.46 kg SL kg SL/ha) + pyrazosulfuron-ethyl 10WP (PSE,60g/ha, stale seedbed) + 1 HW (J). Weed samples were collected at 15 Days after emergence of raw jute following standard procedure for count. Whole plot weeds were collected to find out the weed dry matter production/ha. Soil samples were collected for soil microbial analysis immediately after jute and mesta harvest. The crop was harvested near 110 to 120 days of crop age. Data were analysed using statistical package MSTAT-C.

RESULTS AND DISCUSSION

Weed flora

Weed flora consisted of i) Grasses: *Echinochloa colona*, *Digitaria* spp. ii) Sedges: *Cyperus difformis* and *Cyperus rotundus*. iii) Broad-leaved weeds: *Ludwigia purviflora*, *Trianthema* spp. Broad-leaved weeds and *Cyperus difformis* dominated the weed population in the experimental plots.

Fibre yield

In rainy season, stale seedbed technique was found to be very promising for composite weed control in raw jute field. Fibre yield during 2006 was relatively lower than that obtained in 2007 due to excess rainfall in 2006. In stale seedbed method, i) glyphosate 2.46 kg SL/ha + 2,4-D 2 kg/ha, and ii) glyphosate 2.46 kg SL/ha+ pyrazosulfuron-ethyl (PSE) 60 g/ha followed by 1 HW was found promising for controlling wide range of weeds at early stage. These two combinations reduced the *Cyperus rotundus*, broad-leaved, grassy and *Cyperus difformis* weed population. After two years' cycle, it reduced the *Cyperus rotundus* population by more than 80% over control (Table 1) and produced comparable mean fibre yield of 2.7 to 3.0 t/ha with a maximum of 3.9 to 4.3 t/ha in 2007-08. These combinations did not affect mustard crop in sequence and maintained significantly lower *Cyperus rotundus* population (14-38/m^2) than unweeded control and manual weeding twice (53-76/m^2).

In mesta, quizalofop-ethyl 60 g/ha + dhanuvit 0.5 to 0.6 l/ha applied at 21 DAE and one hand weeding produced comparable mean fibre yield (2.76 t/ha and 3.4 t fibre/ha in 2006 and 2007) compared to manual weeding twice (2.82 t/ha) (Table 1). This post-emergence herbicide quizalofop-ethyl 60 g/ha killed only grassy weeds at 7-10 days after its application and similar observations were recorded in jute also (Ghorai 2008). Under stale seedbed technique, butachlor 0.75 kg/ha + 2,4-D 2 kg/ha and pretilachlor 0.5 kg/ha + paraquat 0.48 kg SL/ha followed by one hand weeding produced comparable mesta fibre yield (2.6 to 2.8 t/ha) compared with manual weeding twice (2.8 t/ha). At 15 days after emergence of mesta, mixture of butachlor 0.75 kg/ha + 2,4-D 2 kg/ha reduced the sedge (*Cyperus rotundus*), broad-leaved, grassy and *Cyperus difformis* weed population by 89, 89, 15 and 99%, respectively over unweeded control. The combination of pretilachlor (0.5 kg/ha) and paraquat (0.48 kg SL/ha) reduced the broad-leaved and *Cyperus difformis* weed population by 99 and 76%, respectively. This method kept the mesta field free from weed for 15 to 21 days. It requires one wheel hoe at 15 days after emergence (DAE) and one manual weeding between 21 to 25 DAE for proper growth and development of mesta. These combinations did not affect mustard crop in sequence and maintained significantly lower *C. rotundus* population (35-54/m^2) than unweeded control and manual weeding twice (53-76/m^2, Table 1).

These herbicides when applied 10 days before sowing did not affect the germination and growth of jute and mesta. Post-emergent sedge killer, chlorimuron-ethyl killed sedges and broad-leaved weeds in jute and mesta field but showed phytotoxicity. However, after rain and application of nitrogen these plants recovered. These two herbicidal combinations did not affect the yield of mustard crop (1.57 to 1.71 t/ha) significantly over manual weeding twice (1.54 t/ha), while grown in sequences (Table 1).

Table 1. Composite weed control in jute and mesta using different herbicides and effect on fibre productivity

Treatment	Weed Cont at 15 DAE (no./m^2)			Fibre yield (t/ha)		*Cyperus rotundus* in mustard/m^2 (21 DAE)	Mustard yield (t/ha)
	Grasses	Sedge	Broad-leaved	2006-07	2007-08		
Quizalofop-ethyl (60g/ha) + 1 HW (M)	65	112	1059	2.08	3.45	76.7	1.61
Quizalofop-ethyl (60 g/ha) + CME (37.5g/ha) + 1HW (M)	39	164	1059	1.69	2.75	76.7	1.61
Quizalofop-ethyl (60 g/ha) + CME (37.5 g/ha) +1 HW (J)	39	122	1033	1.12	2.29	183.3	1.68
2,4-D (2 kg) + butachlor (0.75 kg/ha) + 1 HW (M) + 1 WH	17	36	19	2.08	3.22	54.3	1.75
Glyphosate (2.46 kg SL/ha) +2,4-D (2 kg/ha) +1 HW (J)	16	13	73	1.34	4.29	37.7	1.57
Glyphosate (2.46 kg SL/ha) + 2,4-D (2 kg/ha) + CME (37.5 g/ha) + 1 HW (J)	16	13	73	1.54	3.91	37.7	1.57
Pretilachlor (0.5 kg/ha) + paraquat (0.48 kg SL/ha) +1 HW (M)	35	330	89	2.57	2.80	34.7	1.75
Glyphosate (2.46 kg SL/ha) + PSE (60 g/ha) + 1 HW (J)	19	2	113	1.77	4.31	14.3	1.71
Unweeded control (M)	20	328	872	1.27	3.17	79.0	1.79
Hand weeding twice(M)	46	176	1120	2.16	3.49	53.0	1.54
LSD (P=0.05)	NS	337	576	0.32	0.61	33.1	NS

J = Jute , M = Mesta, CME= Chlorimuron-ethyl, PSE= Pyrazosulfuron-ethyl, HW = Hand weeding, WH= Wheel hoe

Table 2. Microbial population as affected by different weed control treatments in post-harvest jute and mesta soil

Treatment	Bacterial population (cfu x10^5/g soil	Actinomycetes population (cfu x10^5/g soil	Fungi population (cfu x10^5/g soil
Quizalofop-ethyl (60 g/ha) + 1 HW (M)	6.83	44.38	18.12
Quizalofop-ethyl (60 g/ha) +CME (37.5 g/ha) + 1HW (M)	3.50	44.38	18.12
Quizalofop-ethyl (60 g/ha) +CME (37.5 g/ha) +1 HW (J)	9.38	65.37	19.28
2,4-D (2 kg) + butachlor (0.7g kg/ha) + 1 HW (M)	14.37	119.37	18.75
Glyphosate (2.46 kg SL/ha) +2,4-D (2 kg/ha) +1 HW (J)	8.00	40.62	11.87
Glyphosate (2.46 kg SL/ha) + 2,4-D (2 kg/ha)+ CME (37.5 g/ha) + 1 HW (J)	3.10	40.62	11.87
Pretilachlor (0.5 kg/ha) + paraquat (0.48 kg SL/ha) +1 HW (M)	5.00	34.27	9.58
Glyphosate (2.46 kg SL/ha) + PSE (60 g/ha) + 1 HW (J)	8.75	48.78	19.37
Unweeded control (M)	7.50	29.37	11.25
Hand weeding twice (M)	7.08	44.37	12.50
LSD (P=0.05)	3.90	36.41	NS

J = Jute , M = Mesta, CME= Chlorimuron ethyl, PSE= Pyrazosulfuron ethyl

Microbial population

After crop harvest, when fungal and bacterial population of treated and control soils were compared, it was recorded that, the fungi and bacterial population of jute and mesta fields were not affected due to different herbicides, except in chlorimuron-ethyl in combinations with other herbicides and pretilachlor with paraquat (Table 2). The actinomycetes population were not affected due to different herbicides applied in jute and mesta soil. Post emergence herbicide quizalofop-ethyl 60 g/ha, butachlor 0.75 kg/ha in combinations with 2,4-D (2 kg/ha) and glyphosate (2.46 kg SL/ha) in combinations with 2,4-D (2 kg/ha) and pyrazosulfuron-ethyl (60 g/ha) did not affect the microbial population in jute and mesta soil (Table 2). Application of pretilachlor (0.5 kg/ha) and paraquat (0.48 kg Sl/ha) reduced the fungi (9.58 x cfu x10^5/g oven dry soil) and bacterial (5.0 cfu x10^5/g oven dry soil) population over untreated plots like in unweeded control (11.25 cfu x10^5/g and 7.5 cfu x10^5/g oven dry soil, respectively) and manual weeding twice (12.5 cfu x10^5/g and 7.08 cfux10^5/g oven dry soil), respectively.

From the study it appears that in jute, glyphosate 2.46 kg SL and 2,4-D 2 kg/ha in combination and glyphosate 2.46 kg SL/ha and pyrazosulfuron-ethyl 60g/ha in combination followed by one hand weeding were found promising to control mixed weed flora. Repetitive applications of these combinations year after year can effectively reduce *C. rotundus* population by 80% without incurring any yield loss and it did not affect the yields of succeeding crop at all.

In mesta, butachlor (0.75 kg/ha) and 2,4-D (2 kg/ha) in combination and pretilachlor (0.5 kg/ha) and paraquat (0.48 kg SL/ha) in combination using stale seedbed method followed by one hand weeding can be used effectively without any loss in fibre yield compared to that achieved in manual weeding twice. Where grassy weeds dominated, quizalofop-ethyl 60 g/ha followed by one manual weeding can effectively control weeds instead of manual weeding twice. Except, chlorimuron-ethyl, other herbicides were safe to the soil and succeeding crops in sequence. Above herbicidal combinations can be effectively utilized for composite weed control in raw jute field where weed flora establishes prior crop sowing particularly in rainy season.

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Control of purple nutsedge in okra through integrated management

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ABSTRACT

Field experiments were conducted to study the effect of integrated weed management practices on growth, regeneration and tuber viability of purple nutsedge in okra for two years during summer seasons at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India. Eleven treatments tested in RBD with three replications were combinations of stale seedbed with glyphosate application and black polythene mulching, eucalyptus leaf mulching and cowpea smother cropping in relation to weed free and weedy check. Among the treatments, stale seedbed combined with pre-plant application of glyphosate 1.5 kg/ha (before sowing okra) followed either by polythene mulching or directed application of glyphosate 1.5 kg/ha between rows of okra was the most effective treatment in controlling nutsedge tuber production. Tuber viability and regeneration were lowest under stale seedbed in combination with pre-plant followed by post-emergence directed application of glyphosate or black polythene mulching. A combination of stale seedbed with glyphosate application followed by black polythene mulching was the best treatment for nutsedge management in okra.

Key words: Nutsedge, Regeneration, Solarisation, Stale seedbed, Tuber viability

Okra is one of the important vegetable crops grown throughout Kerala during summer. The problem of weeds is severe in okra as it is initially slow growing and incapable of offering competition to the aggressive weeds. During warm-season, perennial sedges especially purple nutsedge (*Cyperus rotundus* L.), is a serious problem as light and frequent irrigations cause their underground propagules to germinate in flushes. Research workers from time to time have suggested various cultural, mechanical, chemical and biological control measures, yet this weed continue to infest vast productive land and still remain as the tropical scourge in cultivated crop. The longevity of tubers, the ability of tubers to sprout several times, and lack of herbicides that can kill dormant tubers have made purple nutsedge control difficult. Glyphosate is promising in effective control of purple nutsedge since it translocate rapidly to the tubers (Bhatia *et al.* 2000). However, herbicide application alone can not completely manage the weed because of its failure to control or desiccate the dormant tubers. Hence, the present investigation was undertaken to study the effect of integrated weed management practices on regeneration and tuber viability of purple nutsedge in okra.

MATERIALS AND METHODS

Field experiments were undertaken at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India during summer season for two consecutive years in a nutsedge infested area to study the effect of cultural practices along with herbicides on nutsedge growth, regeneration and tuber viability in okra field. Soil of the experimental site belonged to the taxonomical class, loamy kaolinitic isoheperthermic, rhodic haplustox, low in available nitrogen, medium in available phosphorus and potassium with a pH 5.2. The experimental site was lying fallow and was completely infested with nutsedge. The experimental site was ploughed, clods broken, stubbles removed and the field was laid out in randomised block design with three replications. Recommended package of practices was adopted to raise the experimental crop. Treatments consisted of combinations of stale seedbed with glyphosate application and polythene mulching, eucalyptus leaf mulching, cowpea smother cropping along with weed free and weedy check (Table 1).

Stale seedbeds were prepared by digging the field during the month of February to expose and break the nutsedge tuber chains. This was followed by irrigation to stimulate sprouting of dormant tubers. Glyphosate 1.5 kg/ha was sprayed after one month of growth as pre-plant spraying *i.e.* before sowing okra and as post-planting direct spraying after one month of sowing between rows along with hand weeding between plants. Black polythene sheets of 300 gauge thickness were used as the mulching material. For imposing the treatment, the land was thoroughly levelled and holes of 12 cm diameter were made

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Table 1. Effect of weed management practices on reduction in nutsedge population, shoot dry weight and tuber dry weight

Treatment	Percentage reduction in nutsedge population			Percentage reduction in nutsedge shoot dry weight			Percentage reduction in nutsedge tuber dry weight		
	I year	II year	Pooled	I year	II year	Pooled	I year	II year	Pooled
T_1- Stale seedbed + glyphosate + HW	32.6	31.5	32.1	49.0	33.7	41.4	50.7	37.5	44.1
T_2- Stale seedbed + glyphosate + polythene	67.5	82.6	75.1	50.6	67.7	59.2	74.1	72.5	73.3
T_3- Stale seedbed + glyphosate + eucalyptus	52.2	29.4	40.8	41.6	38.3	39.9	45.8	45.4	45.6
T_4- Stale seedbed + glyphosate + cowpea	26.9	26.5	26.7	35.5	20.5	28.0	18.6	15.9	17.3
T_5- Stale seedbed + glyphosate + glyphosate (pre and post)	65.9	64.8	65.3	51.7	59.3	55.5	67.6	62.3	64.9
T_6- Soil exposure + HW	30.2	40.2	35.2	30.5	39.5	35.0	53.1	40.9	47.0
T_7- Soil exposure + polythene	71.2	72.7	71.9	54.7	70.7	62.7	49.3	64.9	57.1
T_8- Soil exposure + eucalyptus	15.3	36.8	26.0	34.3	23.4	28.8	23.2	42.8	33.0
T_9- Soil exposure + cowpea	41.7	22.1	31.9	57.6	23.3	40.5	46.7	21.1	33.9
T_{10}-Weedy check	-13.9	-27.2	-20.5	-59.8	-57.2	-58.5	-151.7	-92.6	-122.2
T_{11}-Weed free	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LSD (P=0.05)	22.4	21.1	8.8	-	13.0	-	23.8	10.8	NS

HW - Hand weeding; NS - Non significant

on polythene sheet at 60 and 30 cm distance and the sheet was spread on the whole plot. Dry leaves of eucalyptus were used as the mulch material at 10 t/ha. Three rows of cowpea cv. '*C-152*' were raised in between two rows of okra at a spacing of 15 cm and were mulched at 25 days after sowing. In soil exposure plots (T_6 to T_9), the land was dug well and exposed to sun for three days for desiccation of the underground tubers.

The okra cv. '*Varsha Uphar*' was sown on ridges at a spacing of 60 x 30 cm. In each plot, 0.1m^2 area was marked and kept undisturbed after imposing the treatments and new sprouts appeared were recorded at weekly interval to assess the regeneration rate. After the application of treatments, ten tubers were collected at random from each plot, detached and the individual tubers were kept in Petridishes for testing the tuber viability. Number of tubers germinated were counted at two and three weeks after sowing and expressed as percentage. Weed data were subjected to log ($\sqrt{x+1}$) transformation.

RESULTS AND DISCUSSION

Effect on nutsedge growth

Among the treatments, black polythene mulching in combination with stale seedbed recorded maximum reduction in all growth parameters of nutsedge. During first year, the lowest nutsedge population was recorded by stale seedbed with pre- and post-emergent herbicide application with a reduction percentage of 65.9%. However, solarisation with polythene mulching was the most successful in bringing down the nutsedge population in both the years (71.2 and 72.7%). The pooled analysis data indicated the superiority of polythene mulched plots in combination with stale seedbed. Regarding shoot dry weight, polythene mulching was the most effective in bringing down the nutsedge shoot production (Table 1). However, stale seedbed combined with polythene mulching was the most effective in controlling nutsedge tuber production in both the years.

By stale seedbed technique, the dormant underground tubers were stimulated to sprout and the sprouted shoots were killed by glyphosate spraying which reduced the weed seed bank or dormant tuber reserve in soil. The cost effectiveness of stale seedbed to achieve nutsedge control in rice–vegetable cropping system was reported by Islam *et al.* (2009) and John and Mathew (2001). Post-emergence glyphosate application after stale seedbed was found to show spectacular inhibitory effect on nutsedge multiplication and spread and this treatment recorded the highest percentage reduction of nutsedge population, shoot and tuber. The effectiveness of glyphosate 1.5 kg/ha in controlling nutsedge was in conformity with Ameena (1999) who reported nutsedge without regeneration for a

Table 2. Effect of weed management practices on regeneration count (no./ 0.1 m^2) and tuber viability of nutsedge (%)

Treatment	Number of tuber sprouts/0.1 m^2				Tuber viability (%)	
	Regeneration – I year		Regeneration – II year			
	I WAH	3 WAH	I WAH	3 WAH	I year	II year
T_1	11.3	15.7	9.3	12.7	33.3	43.3
T_2	8.7	9.0	3.3	7.0	30.0	26.7
T_3	13.7	20.0	16.0	16.0	36.7	63.3
T_4	19.0	23.3	16.0	20.3	40.0	46.7
T_5	4.7	8.0	4.3	6.0	23.3	20.0
T_6	17.0	20.0	14.0	16.7	43.3	46.7
T_7	8.7	12.3	6.3	9.3	33.3	26.7
T_8	20.7	24.0	20.0	20.3	33.3	46.7
T_9	25.9	23.7	16.3	20.7	36.7	53.3
T_{10}	-	-	-	-	63.3	83.3
T_{11}	10.7	13.7	9.3	10.3	66.7	80.0
LSD (P=0.05)	1.2	3.9	3.0	2.9	8.9	9.8

WAH-Weeks after harvest; Treatment details are given in Table 1

period of six weeks. Wangchengyuh (2001) also reported that glyphosate caused inhibition of bud elongation, increased total free amino acids concentrations and caused rapid accumulation of shikimic acid in sprouted tubers. These studies suggested that spraying of glyphosate at 1.5 kg/ha prevented regeneration of nutsedge tuber.

Effect on nutsedge regeneration and tuber viability

During the entire period of study, stale seedbed with pre and post-planting glyphosate application was the best treatment in controlling regeneration of nutsedge with the lowest tuber viability (23.2%). Glyphosate is a translocated herbicide which moves to underground organs and appears to inhibit the aromatic amino acid biosynthetic pathway (Jawarski 1972). In purple nutsedge, glyphosate moves basipetally into the shoots and tubers with its translocation increased from 5% at 1 day to 19% at 4 days after application and accumulation is greater in tubers than in leaves (Reddy and Bendixen 1988).

Black polythene mulching integrated with stale seedbed was also found superior in later stages in reducing the regeneration of nutsedge in terms of tuber viability as the viability of tubers collected from these plots recorded the lowest values. This could be due to the higher temperature developed under black polythene sheets which made them non-viable. The effectiveness of black polythene mulch in reducing nutsedge growth has been reported by Yadav *et al.* (1996) stating that black polythene mulching after one hand weeding could provide more than 98% control of *Cyperus rotundus*.

Purple nutsedge stored more food in tubers and exposure to higher temperature desiccated the tubers in the shallow soil more than in the deeper depths. Tubers that survived desiccation due to their placement in deeper depths of soil have a better chance of producing new plants when they contain more stored food. Similar findings have been made by Patterson (1998) who observed that shoots that develop under the mulch produce no tubers. Highest regrowth and viability percentages recorded in weedy check plots with no herbicides revealed that newly formed tubers of purple nutsedge sprouted readily showing no seasonal dormancy which is important in integrating approaches that may direct weed management priorities on depleting or inhibiting the tuber reserve.

Thus for management of nutsedge in okra, adoption of stale seedbed followed by application of glyphosate 1.5 kg/ha *fb* black polythene mulching or directed application of glyphosate 1.5 kg/ha between rows of okra was the effective method to cause reduction in shoot weight, tuber weight and number of tubers with lower tuber viability.

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Suitability of tough Asiatic grass for vermicomposting

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ABSTRACT

A study was conducted at Vermiculture and Vermicomposting Centre of the University in 2009-10 on *Saccharum munja* as a feed material for the compost worm, *Eisenia foetida,* using three combinations with cattle dung. Impact of weed-dung combinations on the biomass of worms and their rate of reproduction was evaluated. Physico-chemical parameters of weed-dung combinations and vermicompost produced from these combinations were tested on the growth parameters of *Vigna radiata*. Fresh weed was chopped into 2 cm size, mixed with fresh cattle dung in 1:3, 1:1 and 3:1 combinations separately in rectangular plastic tub sized 43 x 32 x 14 cm in replicates of five. After pre-decomposition period of 15 days, 10 g matured *E. foetida* were introduced in each tub. It was found that worms fed upon 1: 3 (weed : dung) combination faster than other two combinations and transformed it earlier into vermicompost. Rate of reproduction of worms was recorded 2.47 times faster and total biomass of worms was 2.15 times more in 1 : 3 combinations than that of 3: 1. Application of vermicompost, transformed from 1:3 combination of weed: dung medium, with soil of known parameters in 1:1 combination showed an increase in the shoot length of *V. radiata* by 1.68 times compared to 3:1 combination.

Key words: Earthworm, *Eisenia foetida, Saccharum munja,* Vermicompost, Weed utilization

Tough Asiatic grass, *(Saccharum munja)* commonly known a 'munj' is a monocot perennial grass weed with a strong deep root system. It is fast spreading, weed found mostly in field bunds, roadsides, uncropped fields, river side and in low lying grounds. It reproduces rapidly, tillers profusely and develops barren conditions in the soil (Mandal and Pal 1997). In Rohilkhand region of Uttar Pradesh, India, it infests cropped and non-cropped areas both. The present paper synthesizes the use of *Saccharum munja* as a feed material for the worm, *Eisenia. fetida,* along with the cattle dung in three different combinations. Effect of these combinations on the growth and reproduction of worms was evaluated besides the effect of vermicompost on the growth of *Vigna radiata*.

MATERIALS AND METHODS

Weed was collected from the University campus area, chopped into small pieces of 2 cm. Pieces were mixed with cattle dung in three combinations of 1:3, 1:1 and 3:1, separately. Five rectangular plastic tubs (size 43 x 32 x 14 cm) were taken for each combination. In first five tubs, 4 kg mixed combination of 1:3 was filled in each; while in 2nd and 3rd sets, mixed combination of 1:1 and 3:1 were filled, respectively. All tubs were kept for pre-decomposition process for a fortnight. Moisture was maintained by sprinkling 250 ml tap water/tub regularly. Ten g matured (clitellates) earthworms, *Eisenia foetida* were introduced into each tub. After vermicomposting, the worms were sorted out from vermicompost and their biomass was taken by electronic balance (Afcoset ER-182A) and rate of reproduction was calculated as per Chaudhuri *et al*. (2001).

Physico-chemical parameters of different combinations and transformed vermicompost were analyzed. Moisture content (MC), water holding capacity (WHC) and bulk density (BD) as per Saxena (1994) and pH by Systronics pH meter (MK VI), organic matter and carbon by Walkley and Black method (1947), nitrogen by Kjeldhal method, phosphorus and potassium by Dass and Jadhav (2004). Estimation of micronutrients was carried out by atomic absorption spectrophotometer (Spectra A 220 model, VARIAN, Australia) (Srinivasa Murthy *et. al.* 1999). Experiment was conducted during winter months at room temperature 20-22^{0}C.

Effect of vermicompost was evaluated by mixing them separately with the soil of known parameters in the ratios of 1:3, 1:1 and 3:1 on the shoot length of *V. radiata*. Earthen pots having surface diameter of 11 cm were used in replicates of eight along with control. Three healthy seeds were sown in each pot at the depth of 1 cm. Moisture of each pot was maintained by sprinkling 100 ml of

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tap water every day. The shoot length of grown plants was measured after 40 days and the data was compared with the plants grown in the plane soil.

RESULTS AND DISCUSSION

It was found that feeding ability of earthworms was different in different combinations of weed and dung. It was more in 1:3 weed-dung combinations and least in 3:1. Increase in total biomass of worms was 4.75 and 2.25 times in 1:3 and 3:1 combinations, respectively with their initial values indicating worm's preferential feeding pattern. However, initial biomass of clitellate worms was slightly decreased in 1:3 and 3:1 combinations during and after the process of vermicomposting, while non-clitellates were developed 4 times more in 1:3 combination and 1.5 times only in 3:1 from the initial weight of clitellates. The total biomass of worms and rate of reproduction were also recorded maximum in 1:3 and minimum in 3:1 combinations. This difference was 2.17 times. It may also be noted that total gain in worm's biomass was 2.16 times in 1:3 than that of 3:1 weed-dung combination from the initial and the rate of reproduction was 2.47 times faster in 1:3 than that of 3:1 combinations (Table-1).

The transformed vermicompost was found to have reduced level of moisture, pH, organic matter, carbon and C/N ratio and increased level of N, P, K, Zn, Fe, Cu and Mn than the initial weed-dung combinations. Decreasing and increasing pattern of different parameters was recorded more in 1:3 combinations than that of other two combinations (Table 2). Such decrease in moisture content was in the range of 1.07 -1.17 times in different experimental combinations than that of their respective controls. Higher values of per cent moisture content in the experimental control media might be due to absence of worms.

It was also noted that worm's reduced the pH of weed-dung combination. Singh *et al.* (2010) reported that the level of such reduction in pH was less when plant waste was used. In weed-dung combinations, the maximum reduction in pH was from 1.08-1.17 in the experimental media with respect to experimental controls. The weed-dung combinations always had higher level of pH

Table 1. Biomass of worms, *Eisenia foetida* after vermicomposting of *Saccharum munja*

Weed-dung combinations	Clitellates (g) (A)	Non-clitellates (g) (B)	Total biomass of worms (g) (A+B)	Rate of reproduction (young/worm/week)
1:3	7.85 ± 0.40	39.69 ± 0.42	47.54 ± 1.3	2.3 ± 0.02
1:1	10.1 ± 0.37	25.53 ± 0.48	35.63 ± 1.3	1.3 ± 0.11
3:1	7.20 ± 0.53	15.34 ± 0.35	22.54 ± 1.4	0.93 ± 0.21

Table 2. Physico-chemical parameters of *Saccharum munja* before and after vermicomposting

Initial parameters of weed-dung combinations			Parameter	Experimental media (with worms)			Experimental control media (without worms)		
1:3	1:1	3:1		1:3	1:1	3:1	1:3	1:1	3:1
79.3±0.14	89.2±0.11	83.3±0.13	% MC	44.9±0.14	58.0±0.27	61.5±0.42	50.0±0.16	53.9±0.33	56.8±0.23
8.67±0.23	8.90±0.67	9.19±0.34	pH	7.01±0.77	7.54±0.52	7.64±0.26	8.25±0.55	8.72±0.61	8.78±0.29
27.91±0.33	19.47±0.66	11.87±0.87	% OM	9.75±0.15	8.33±0.22	6.08±0.28	25.9±0.42	17.1±0.61	11.4±0.08
16.22±0.23	11.29±0.84	6.90±0.60	% C	5.65±0.87	4.83±0.71	3.52±0.16	15.06±0.26	9.96±0.66	6.65±0.00
2.0±0.14	1.8±0.00	1.4±0.66	% N	3.3±0.17	3.0±0.77	2.0±0.77	2.2±0.60	2.1±0.15	2.0±0.77
8.11±0.72	6.27±0.53	4.92±0.19	C/N	2.95±0.61	2.77±0.16	3.04±0.13	6.84±0.14	4.75±0.62	3.33±0.28
0.14±0.02	0.10±0.05	0.09±0.01	% P	0.31±0.02	0.20±0.01	0.20±0.07	0.20±0.02	0.16±0.01	0.12±0.02
1.31±0.61	1.14±0.02	1.03±0.71	% K	2.03±0.13	1.71±0.27	1.29±0.18	1.68±0.41	1.49±0.15	1.21±0.60
1.02±0.77	1.16±0.77	0.92±0.77	Zn (ppm)	2.02±0.11	1.81±0.10	0.98±0.01	1.10±0.41	1.33±0.15	1.17±0.13
26.91±0.44	25.93±0.11	21.12±0.31	Fe (ppm)	28.92±0.22	28.08±0.34	28.18±0.44	24.87±0.67	27.04±0.77	21.53±0.73
0.25±0.01	0.09±0.01	0.14±0.01	Cu (ppm)	0.38±0.03	0.33±0.02	0.30±0.01	0.26±0.04	0.24±0.06	0.18±0.01
4.03±0.11	3.23±0.35	1.02±0.02	Mn (ppm)	4.26±0.75	3.23±0.22	3.18±0.21	3.88±0.25	4.09±0.57	2.92±0.25

than that of the plant waste media. Zhenjun (1995) has also reported higher level of such reduction in pH in weed media than the plant wastes.

The level of macro and micro nutrients was found increased in vermicompost then the control. The maximum increase in the level of nitrogen was 1.50 times when weed was taken with cattle dung in 1:3 combinations. More difference in nitrogen level in 1:3 combinations with respect to their experimental controls might be due to lignified foliage of weed, that would not be decomposed easily in experimental controls-devoid of worms, than that of those with worms. In contrast, the C/N ratio of feeding material gets reduced more in 3:1 weed-dung combinations than that of other two. Increase in phosphorus level was 2.14 times higher in 3:1 experimental media than control. This value was 1.66 times in 3:1 media and 1.55 times in 1:3 media. Increase in the amount of potassium was more in 1:3 combinations. The level of increase of potassium in the vermicompost prepared from different weed-dung combinations had different values. Sannigrahi and Chakravarthi (2002) have reported that vermicompost transformed from crop residues had nearly 0.6-1.5% potassium; while it was slightly more (0.7-1.9%) in the vermicompost prepared from this weed. The level of Cu was recorded more in all the vermicompost than that of their respective controls.

It was recorded that the growing medium having vermicompost, which was transformed from 1:3 combination, and soil in the ratio of 1:1 was best suited medium for the shoot length of the experimental plants than that of other media and least when vermicompost transformed from 3:1 weed-dung combination (Table 3). Although further studies are required to know the influence pattern of vermicompost and variations in shoot elongation of experimental plants. Tomati *et al*. (1995) have mentioned that the earthworm casts and vermicompost influenced the development of the plants and promoted stem elongation, root initiation and root biomass which suggest the linkage between biological effects of vermicompost and microbial metabolites that influence the plant growth and development. Das *et al*. (2002) have mentioned the effect of integrated application of vermicompost and chemical fertilizer on growth and yield of paddy crop in red soil of south eastern Ghat zone of Orissa. They have noticed that vermicompost integrated treatment have better influence than FYM integrated treatment at all the level of chemical fertilizer dose. These studies showed that transformation of such weed into vermicompost could certainly help in preventing barren conditions of the soil on one side and improving its health on the other.

Table 3. Effect of transformed vermicompost from *Saccharum munja* on the shoot length (cm) of *V. radiata* after 40 DAS

VC: soil media	Vermicompost transformed from weed-dung combination		
	1:3	1:1	3:1
1:3	24.2 ± 0.33	18.6 ± 0.32	21.9 ± 0.68
1:1	26.0 ± 0.95	23.8 ± 0.08	21.3 ± 0.01
3:1	22.1 ± 0.40	22.3 ± 0.23	15.5 ± 0.05
Plane soil		19.4 ± 0.25	

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Evaluation of imazethapyr leaching in soil under natural rainfall conditions

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ABSTRACT

Though herbicides are designed as biologically active but often their residues are found in crop produce and water. Herbicides may reach to ground water through runoff, drift, untargeted spray and heavy rain. Therefore, leaching beahiviour of imazethapyr, was evaluated in soil columns under natural rainfall conditions. Imazethapyr was applied at 100 and 200 g/ha on the soil columns. Columns were arranged randomly and allowed to receive approximately 850 mm rain for three months. Soil and leachates were analyzed for imazethapyr residues. Maximum concentration of imazethapyr was recovered from 0-10 cm depth. Results indicated that imazethapyr could leach in clay loam soil up to the depth of 70 cm.

Key words: Clay soil, Column, Imazethapyr, Leaching, Movement, Rainfall

Use of herbicides for weed control has increased with the introduction of modern intensive crop management practices. Increasing use of herbicides may pose serious environmental problems through off site movement and leaching, which must be controlled to minimize harmful effects on non-targeted organism. Ultimately, leaching and transport of herbicides may not only result in low efficacy, but also in groundwater contamination (Ritter *et al.* 1996, Sondhia 2008a).

Imazethapyr belongs to imidazolines group having a toxicity class of III and used as a selective herbicide. It is applied as pre-plant incorporated, pre-emergence, and post-emergence to control grasses and broad-leaf weeds. Imazethapyr persist longer in acid than in alkaline soils. Organic matter and pH significantly affect the imazethapyr behaviour in soil. However, imazethapyr does not readily leach under field condition but few authors reported leaching of imazethapyr below 25 cm in four months in acidic soil under laboratory studies (Basham *et al.* 1987). Residues of imazethapyr are detected in stream and river water in Midwestern US at concentrations above the maximum residue limits in 71% of samples (Battaglin *et al.* 2000).

Imidazolinone herbicides are generally weakly adsorbed to soil (Basham *et al.* 1987, McDowell *et al* 1997, Sondhia 2008b). Few studies have shown that imidazolinone adsorption is not affected by clay or organic matter content (Bresnahan *et al.* 2000). However, few other studies have indicated that adsorption increases with increasing clay and organic matter content (Loux *et al.* 1989, Battaglin *et al.* 2000).

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In India, despite of the extensive use of herbicides, information on leaching potential of herbicides under high rainfall conditions is meager. Therefore, the present study was undertaken with the objective to study the mobility and leaching potential of imazethapyr under natural rainfall conditions.

MATERIALS AND METHODS

Leaching experiment was conducted at Residue Laboratory of Directorate of Weed Science Research, Jabalpur at ambient temperature (27 to 32^{0}C) as described by Sondhia and Yaduraju (2005) in polyvinyl chloride (PVC) columns (10 cm internal diameter and 90 cm long).

Herbicide free surface soil samples (0-20 cm) from the surrounding area of the Directorate of Weed Science Research were collected, air-dried and passed through a 3 mm sieve. Soil characteristic was clay, 31.27; silt, 11.15; sand, 56.39% with 7.2 pH and 0.82% organic carbon. Approximately 9 kg soil was placed in each PVC column. The bottoms of the columns were closed with a double layer of cheese cloth. Columns were sequentially filled with soil from the bottom with 3 cm of sand and 86 cm of dry soil. The surface of each column was then covered with sand (3 cm) and filter paper disks were placed on top of the each column to assist uniform dispersion of the water across the column surface. A perforated PVC cap connected to a funnel with polyethylene tubing was attached to the bottom of the each column to collect the leachates into 500 ml flasks. Commercial grade of imazethapyr (10% SL) were used in leaching experiment.

Imazethapyr was dissolved in distilled water and simultaneously applied to the surface of the column with a pipette at dose of 100 and 200 g/ha. Physico-chemical property of imazethapyr is given in Table 1. The columns were arranged randomly under field condition to receive the water through natural rainfall. Treatments were replicated three times. A set of soil columns receiving respective amount of rain only served as control. Columns were arranged in a completely randomized design and each treatment combination was replicated three times. Water eluting from the column were collected in flask and stored at 5^0C for herbicide analysis. After 13 weeks, soil columns were cut into two equal halves and the soil was sampled in 10 cm segments. The segments from same column were pooled for use in analyzing residues.

Table 1. Physico-chemical properties of imazethapyr

Molecular weigh	289.33
Molecular formula	$C_{15}H_{19}N_3O_3$
Formulation	Sl 10%
Solubility	0 0.14 g/ml at mg/L (25 ^{0}C)
Vapour pressure	1.33 X 10^{-02} mPa at 25 ^{0}C
Hennery constant	1.30 X 10^{-02} Pa $m^{3/}$mol
Partition coefficient LogP$_{ow}$	1.49

Imazethapyr residues were determined as described by Sondhia (2008b). Twenty five g representative soil samples were taken in 250 ml Erlenmeyer flask, and extracted with 50 ml of 0.5 N NaOH for 1 hour in a horizontal shaker (repeated twice). Flask were washed with 50 mL of methanol, shacked vigorously and adjusted the pH to 2 with 6 N hydrochloric acid. The content was transferred to a 250 ml separatory funnel and partitioned with methylene chloride (50 ml twice). The lower methylene chloride layer was collected and combined. The organic layer was dried on anhydrous Na_2SO_4 and passed through activated charcoal. The solvent evaporated to dryness on rotary evaporator at 40^0C. Finally residues were dissolved in 5 mL of methanol.

25 ml water samples were passed through filter paper No 2 and pH was adjusted to 2 with 6 N hydrochloric acid and separated with methylene chloride (50 ml twice) in a 250 ml separatory funnel. The lower methylene chloride layer was collected and combined, processed and concentrated as discussed above for the soil samples.

Imazethapyr reference analytical standard was obtained from Ehrenstorfer GmbH, Germany. All the other chemicals and solvents used in the study were of analytical grade obtained from Merck, Germany. Imazethapyr content in soil and leachates at various depths were determined by Shimadzu HPLC, coupled to diode array detector using Phenomenex C-18 (ODS) column (250 x 4.6 mm) and methanol: water (70:30 v/v) as mobile phase at a flow rate of 0.8 ml/min Detection of imazethapyr in soil and leachates was carried out at 250 nm. 20 µl of the aliquot of samples and standard was injected into the column through fixed loop Rheodyne injector using micro syringe. The retention time of imazethapyr was found approximately 3.45 minutes. At the limit of detection 0.001µg/ml the signal to noise ratio was 3:1. Imazethapyr content in the soil and leachates was determined by comparing peak area of samples with standards.

RESULTS AND DISCUSSION

Columns placed in field received approximately 850 mm natural rain during the experimental period, *viz*. Jun 2007 to September 2008 (Fig. 1).

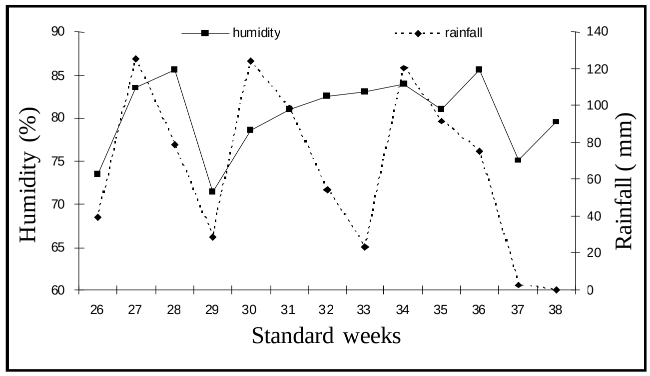

Fig. 1. Variation in humidity and rainfall during experimental period from July to September 2007

Significant difference of imazethapyr content was observed at 0-10, 10-20 and 20-30 cm depth at P=0.05 level (Table 2) in both the application rates. However, at 30-40, 40-50, 50-60, 60-70, and 70-80 cm soil depths difference of imazethapyr content were non significant. Results showed that 0.119 µg/g of imazethapyr was found in 0-10 cm depth, however 0.039, 0.0210, 0.160, 0.013, 0.011, and 0.010 µg/g imazethapyr content was detected in 10-20, 20-30, 30-40 40-50, 50-60 and 60-70 cm soil depth in 100 g/ha treated soil columns (Table 2).

Approximately 48% imazethapyr was found distributed in 0-10 cm depth and 4.49 and 4.08% imazethapyr could leach to the 50-60 and 60-70 cm soil depths which showed high adsorption of imazethapyr at the surface soil (0-10 cm) as compared to sub-surface soil (50-70 cm). However, 15.92, 8.57, 6.53 and 4.49% of imazethapyr was recovered from 20-30, 30-40, 40-50 and 50-60 cm depths in 100 g/ha treated soil columns (Fig. 2).

Table 2. Herbicides content at different depths in soil column that received 850 mm rainfall

Soil depth (cm)	Imazethapyr content (µg/g)*	
	100 g/ha	200 g/ha
0-10	0.119 a** (+0.03***)	1.411 a (+0.01)
10-20	0.039 b (±0.01)	0.654 b (±0.02)
20-30	0.021 a (±0.01)	0.182 a (±0.01)
30-40	0.016 a (±0.03)	0.151 a (±0.04)
40-50	0.013 a (±0.01)	0.059 a (±0.02)
50-60	0.011 a (+0.01)	0.067 a (+0.01)
60-70	0.010 a (±0.01)	0.032 a (±0.01)
70-80	<0.010	<0.010

* Average of four replications, ** Within each column and for each depth mean followed by similar letter are not significant according to LSD (P=0.05), *** Standard deviation

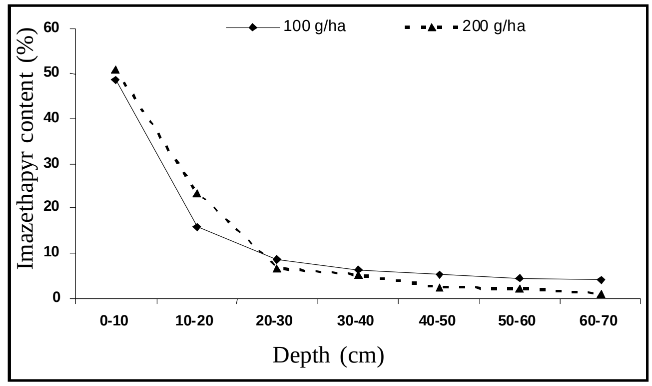

Fig. 2. Distribution of imazethapyr at different depths in soil column

Whereas, approximately 50% imazethapyr was found distributed in 0-10 cm depth in soil column where imazethapyr was applied at 200 g/harate, however 23.58% imazethapyr could leach to the 10-20 cm soil depths. At 20-30, 30-40, 40-50, 50-60 and 60-70 cm depths, 6.56, 5.44, 2.41, 2.13 and 1.15% of imazethapyr was recovered from 200 g/ha treated soil columns (Fig. 2) that showed high adsorption of imazethapyr at surface soil (0-10 cm) as compared to subsurface soil (20-70 cm) at higher application rate. These findings were in conformity of Battaglin *et al.* (2000) and indicated that imazethapyr may leach in clay soil up to the depth of 80 cm if soil received rainfall of 850 mm. Organic matter and pH significantly affect the imazethapyr behaviour in soil (Mangles 1991). Some authors reported leaching of imazethapyr below 25 cm in four months in acid soil in lab studies and detected imazethapyr residues in stream and river water in Midwestern US at concentrations above the maximum residue limits in 71% of samples (Basham *et al.* 1986, Battaglin *et al.* 2000).

Results obtained by this study revealed that imazethapyr was mobile in soil columns and can leach by irrigation water. The highest concentration of imazethapyr was found at 0-10 cm depth in both the application rates and it was higher in 100 g/ha application rate than 200 g/ha rate. The presence of organic matter constitutes an impediment for imazethapyr movement because of its high adsorption capacity. Thus maximum amount of applied imazethapyr was retained from 0-10 cm depth followed by 0-20 cm depth in both application rates (Fig. 2).

Recovery of imazethapyr from the leachates was low and only 1.75 and 1.13% of imazethapyr was recovered from leachates where imazethapyr was applied at 100 and 200 g/ha doses, respectively. Soil moisture, temperature, organic matter, pH, texture and rains are the main factors that determine mobility of herbicide (Vanwyk and Reinhardt 2001, Sondhia 2008). The data generated here indicated mobility of imazethapyr up to 70 cm soil depth under continuous rainfall, which is significant in terms of ground water contamination. Leaching of some other classes of herbicides through soil is also reported by other worker. James *et al.* (1999) also reported detectable and significant amounts of metsulfuron-methyl into the 50–100 mm soil layer. Sondhia (2008b) reported that metsulfuron is more mobile in a sandy soil than in clay soil and found that metsulfuron mobility in soil was increased with increasing application rate.

Combination of chemical, biological, physical and environmental factors may operate at different level in influencing the degradation of herbicides. Some researchers recommend re-cropping periods of up to 6-34 months for imazethapyr due to leaching and persistence and reported that imazethapyr has a rapid initial phase of degradation, followed by a slower second phase leading to long term persistence especially in clay soil Bresnahan *et al.* (2000).

Imidazolinone herbicides are generally weakly adsorbed to soil. Few studies have shown that imidazolinone adsorption is not affected by clay or organic matter content (Goetz *et al.* 1986, Mangles 1991, Gan *et al.* 1994, McDowell *et al.* 1997. However, few other studies have indicated that adsorption increases with increasing clay and organic matter content (Stougaard *et al.* 1990). Solubility of imazethapyr is high in water (140 mg/ml), hence able to leach from the top-soil to deeper in the soil profile and thus may not be available in the surface soil (0-20 cm). In general, depth wise mean concentration of all herbicides followed the decreasing pattern. The top soil acts as the inoculum for the system and is likely to vary in terms of its physical, chemical, and microbiological characteristics from one form to another. The presence of organic matter constitutes an impediment for herbicides movement because of its high adsorption capacity.

Downward herbicide movement is influenced by characteristics of the soil. In addition, certain soil microorganisms and living weeds can sometimes metabolize absorbed herbicides, rapidly or gradually altering those to non-phytotoxic forms that may have different leaching characteristics. Downward movement is most likely with chemicals that do not degrade quickly and do not adsorb strongly to clay or organic matter. The potential for groundwater contamination is greatest with such chemicals when heavy rain comes soon after application, or where spills occur. Increasing the time interval between herbicide application and the incidence of rainfall reduced the amounts of herbicides found in the leachates. Pesticide leaching from zone of the soil application is also dependent on amount of rainfall or irrigation received. Low recovery of imazethapyr from soil and water may be due to formation of bound residues, secondary metabolites and dissipation of imazethapyr from soil.

Although, soil moisture generally has an effect on the adsorption of herbicides to soil, it is unlikely to dominate herbicide transport unless this transport is very rapid. Thus, in leaching study in soil column, leaching could have been slow initially and gradually increased as water penetrated deeper. The data generated indicated that imazethapyr can move up to 70 cm in soil profile under continuous and high rainfall conditions.

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Parthenium infestation and evaluation of botanicals and bioagents for its management

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ABSTRACT

Systematic surveys of *Parthenium hysterophorus* L. infested regions on 12 selected national highways of North-Eastern India were conducted during 2009-2011. In all the surveyed sites, *Parthenium hysterophorus* was present but its abundance was more during the month of June to August. Complete inhibition of *Parthenium* seed germination was recorded at 20% of leaf and stem extracts of *Cassia sericea*, *Mimosa pudica* and *Cassia tora*. Different stages of *Zygograma bicolorata* (grubs to adult) showed reduction in plant height, shoot length, root length and biomass *of Parthenium* when exposed in mosquito net cages.

Key words: Allelopathic effect, Biological control, *Parthenium hysterophorus*, Survey, *Zygogramma bicolorata*

Parthenium hysterophorus L. commonly known as Congress grass, gajar ghas or white top is an annual herbaceous weed which has spread like a wild fire in almost every state of India. It is known as a noxious weed because of its allelopathic effect (Wakjira *et al*. 2005, Kohli *et al*. 2006, Wakjira 2009), strong competitiveness with both crops and pasture for soil moisture and nutrients (Singh *et al.* 2003, 2005) and the hazard it poses to humans and animals (Wiesner *et al*. 2007, Sushilkumar and Varsheny 2007) and biodiversity (Tefera 2002). Due to its prolific cover, known hazardous properties and lack of previous report from North–Estern region, proper management of *Parthenium* using adequate measure are needed in this region. The present study was undertaken with the objective to asses intensity of infestation of *Parthenium hysterophorus* on selected national highways of North-East India, quantify allelopathic effects of certain plant extracts on *Parthenium* germination and seedling growth and to test the damage potential of *Zygogramma bicolorata* on seedling growth of *Parthenium*.

MATERIALS AND METHODS

The study site had three main seasons in a year, *viz.* summer (April to May), rainy (June to October) and winter (November to March). Sporadic winter rains were common during November to January. The annual mean temperature was 27–30^{0}C with mean maximum temperature of 32^{0}C in April–May and the mean minimum temperature of 6^{0}C in December–January.

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Systematic field surveys were conducted during 2009-2011, on 12 selected national highways (NH-31 - Bongaigoan, NH-37 - Nagaon, NH-37 - Jorhat, NH-39 - Manipur, NH-39 - Nagaland, NH-40 - Shillong, NH-44 - Agartala, NH-52 - Tezpur, NH-52A - Itanagar, NH-53 - Manipur, NH-54 – Aizawl and NH-150 Manipur) from the nearest city of each highway in North-East India. Road surveys were done by vehicle along the highways by driving at moderate speed and observing the infestation of *Parthenium.* The distances of the infested region along both sides of the highways were noted in field notebook and photographs were taken. If the distance between two infested site was within 100 m, it was taken as one group. The longitude and latitutdes of each high ways was recorded with the help of GPS.

Bioassays were conducted with aqueous leaf and stem extract of *Cajanus cajan, Sida spinosa, Mimosa pudica, Rumex maritimus, Ipomoea carnea, Gynura cusimba, Cassia tora* and *Cassia sericea* on germination and seedling growth of *Parthenium*. 100 g each of the different parts of the selected botanical agents were chopped and homogenized in 100 ml of the sterilized distilled water in a fine grinder. The extract was filtered through Whatman No.1 filter paper and the filtrates were taken as 100% aqueous extract. Then 5, 10, 20, 30, 50 and 75% aqueous extract of each of the different parts of selected botanical agents were prepared by diluting 100% aqueous extract with distilled water.

Seeds of *Parthenium* were thoroughly washed with tap water and surface was sterilized with 0.1% $HgCl_2$ for 2 to 3 minues and further washed with distilled water for

4 to 5 times. Then, the seeds were soaked for 2 h in 10 ml of 5, 10, 20, 30, 50 and 75% extracts of different parts of selected botanical agents and in distilled water for control. Ten seeds each were allowed to germinate in a Petridish lining by filter paper moisture with different concentrations of extracts and distilled water as control. For each concentration, three replicates were made. The Petridishes were kept undisturbed for 15 days in a plant growth chamber at 26±2^{0}C. The germination of seeds, root and shoot length of *Parthenium* seedlings were recorded on 15th day and dry weight per plant (biomass) was recorded after drying in an oven at 55-60^0 C for 24 h. The vigour index of *Parthenium* seedling was calculated following Abdul-Baki and Anderson (1973).

An experiment was carried during 2011-2012 by using Mexican beetle (*Zygogramma bicolorata*) procured from Directorate of Weed Science Research (DWSR), Jabalpur (India) by maintaining the temperature at 25^{0}C and relative humidity at 55%. Healthy and mature seeds of *P. hysterophorus* were collected and sown in pots filled with steam sterilized soil with farm yard manure (FYM). The emerging seedlings with 4-5 leaves stage were transplanted to 12 earthen pots, each with 20 plants filled with garden soil. The potted plants were transferred to the 12 insect proof nylon net cages (87 x 43 cm). Grubs (2nd instar) and freshly emerged adult (fourdays) of *Z. bicolorata* were released to the potted plants of 6 to 8 cm in height. Out of 12 cages, 6 cages were selected for 15 days observation and another 6 cages for 30 days observation. In both the cases, out of 6, three (50%) were kept as control and another three (50%) were exposed to insects.

Plant height, shoot length, root length, stem diameter and plant biomass were recorded. Plants biomass obtained by drying in an oven at 55^{0}C for 72 h and dry weight were recorded. For taking observations, 10 plants from each pot were randomly selected.

The percentage reduction of *Parthenium* plant growth was calculated following the formula of Pant and Mukhopadhyay (2001)

Q = (a-b/a) x 100; where Q = % reduction in growth; a = average growth in healthy plant: b = average growth in treated plant.

Tests of significance ('t' value) were determined between healthy and treated plants under parameters like plant height, shoot length, stem diameter, root length and plant biomass. Data were subjected to ANOVA (analysis of variance) and mean was compared using LSD (least significant difference) test at P=0.05.

RESULTS AND DISCUSSION

Survey of *Parthenium* infestation

Severe infestation of *Parthenium* was recorded in NH-31 (Bongaigoan), high in NH-37 (Nagoan) and NH-39 (Imphal), medium in NH-37 (Jorhat), NH-44 (Agartala, Tripura), NH-52 (Tezpur) and NH-53 (Imphal-Jiri), mild in NH-39 (Nagland), NH-40 (Shillong, Meghalaya), NH-54 (Aizawl, Mizoram) and NH-150 (Imphal) while negligible infestation was observed in NH-52A (Itanagar, Arunachal Pradesh) (Table 1). Infestation of *Parthenium* was more prominent near the city and generally on the road commenced from the city. It might be due to disturbed natural habitat of native vegetation because of human disturbance like construction work, vehicular movements *etc*. This condition might have harboured and influenced the speedy succession of *Parthenium* in such habitat. Vehicular movements also facilitated the spread of *Parthenium*. The wide spread of *Parthenium* throughout India was reported by Sushilkumar (2012). Spread and infestation level was medium in Assam and low in Arunachal Pradesh, Manipur, Mizoram, Meghalaya and Nagaland in North-East India as compared to other states of India. However, in reference to North-East India, infestation level was found high in Assam, medium in Manipur and low in Arunachal Pradesh, Meghalaya, Mizoram Nagaland and Tripura.

Till 1980, *Parthenium* spread was restricted mostly to uncultivated land, on road side and raiwlway track side and that time it was not considered a problem in North-East India (Sushilkumar and Varshney 2007) but in a span of 30 years, the arid and hilly areas in North–East India have been infested with *Parthenium* and may become a serious problem to health of human beings, animals and agricultural fields. In the present study, the growth of *P. hysterophorus* was observed throughout the year in all the surveyed sites with greater abundance during the month of June to August. This might be due to congenial climatic conditions like high rainfall, optimum temperature and high relative humidity which favoured the growth of *Parthenium*. Till now, it was found to be growing only along the road side, waste land and non-cropped area but if timely control measure are not taken, it may cause a serious threat to crop land and biodiversity.

Allelopathic effect of botanicls

Application of 20% concentration of leaf extract of *Mimosa pudica*, *Cassia sericea* and *Cassia tora* resulted in 100% inhibition of *Parthenium* germination (Table 2). Allelochemicals present in *Cassia tora*, *Cassia sericea* and

Mimosa pudica might have inhibited the process of seed germination. The reduction in germination was higher under leaf extract than stem extract. The effect of all the selected plant's extract on *Parthenium* seed germination increased with the increase in concentration. Nearly 89.7 and 96.7% reduction in *Parthenium* germination were observed in stem extract of *Sida spinosa* and *Ipomoea carnea* and stem extracts of *Cajanus cajan* and leaf extract of *Ipomoea carnea* at 30% concentration, respectively. No *Parthenium* seed germination was observed in 30% con-

Table 1. Survey sites of selected National highways of North–East India

No.	Highway	Longitude and latitude of survey area	Place/state	Remark
1	NH-31	N26^{0}9.513$'$, E91^{0}40.370$'$ N 26^{0}30.169$'$, E90^{0}33.240$'$	Adabari to Bongaigoan, Assam	Severe
2	NH-37	N 26^{0}9.311$'$, E 91^{0}40.581$'$ N 26^{0}32.266$'$, E 92^{0}55.677$'$	Jalukbari to Kaliabor through Nagoan, Assam	High
3	NH-37	N27^{0}10.994$'$, E94^{0}54.897$'$ N26^{0}38.341$'$, E93^{0} 45.650$'$	Moranhat Town to Kamargoan through Jorhat , Assam	Medium
4	NH-39	N 24^{0}57.892$'$, E93^{0}53.162$'$ N 24^{0}29.801$'$, E 94^{0}0.707$'$	Imphal, Manipur	High
5	NH-44	N 23^{0}40.440$'$, E 91^{0}16.915$'$ N 24^{0} 9.749$'$, E 92^{0}2.270$'$	Bishalgarh to Pabiachhara part through Agartala, Tripura	Medium
6	NH-52	N26^{0} 53.271$'$, E93^{0}37.920$'$ N26^{0}33.357$'$, E92^{0}11.994$'$	Gohpur to Dalgoan through Tezpur, Assam	Medium
7	NH-53	N24^{0}33.357$'$, E92^{0}11.994$'$ N24^{0}44.750$'$, E93^{0}25.540$'$	Sagolband Silchar parking, Imphal to Nungba, Manipur	Medium
8	NH-54	N 23^{0}44.193$'$, E 92^{0}47.820$'$ N 24^{0} 48.708$'$, E 92^{0}47.841$'$	Tuirial jail to Rangirkhari bus stand through Aizawl, Mizoram	Mild
9	NH-39	N25^{0}40.095$'$, E94^{0}6.285$'$ N25^{0}54.811, E93^{0}43.709$'$	Kohima – Dimapur Road, Nagaland	Mild
10	NH-40	N25^{0} 26.826$'$, E 91^{0}50. 394$'$ N26^{0}5.959$'$,E91^{0}52.576$'$	Laitlyngkot to Jorabat through Shillong, Meghalaya	Mild
11	NH-150	N 24^{0}52.188$'$, E 94^{0}3.866$'$ N 24^{0}29.827$'$, E 93^{0}45.919$'$	Lamlai to Moirang Lamkhai, Manipur	Mild
12	NH-52A	N27^{0}6.524$'$, E93^{0}49.447$'$ N26^{0}56.790$'$, E93^{0}35.725$'$	Banderdewa police outpost to Itanagar, Arunachal Pradesh	Negligible

Table 2. Allelopathic effect of selected plant extract on *Parthenium* seed germination

Plants	Germination (%)											
	5% conc.		10% conc.		20% conc.		30% conc.		50% conc.		75% conc.	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Cajanus cajan	26.7	30.0	16.7	26.7	10	16.7	0.0	6.7	0.0	0.0	0.0	0.0
Sida spinosa	26.7	40.0	20.0	23.3	16.7	20.0	0.0	10.0	0.0	0.0	0.0	0.0
Mimosa pudica	23.3	26.7	13.3	20.0	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0
Rumex maritimus	53.3	56.7	30.0	43.3	16.7	23.3	13.3	16.7	0.0	0.0	0.0	0.0
Gynura cusimba	60.0	63.4	46.7	50.0	33.3	43.3	23.3	16.7	0.0	0.0	0.0	0.0
Ipomoea carnea	36.6	43.3	23.3	26.7	16.7	23.3	6.7	10.0	0.0	0.0	0.0	0.0
Cassia tora	16.7	26.7	10.0	20.0	0.0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
Cassia sericea	23.3	30.0	16.7	26.7	0.0	16.7	0.0	0.0	0.0	0.0	0.0	0.0
Control	96.7*											

*Mean value of all the control; conc. - concentration

centration of leaf and stem extract of *C. tora, C. sericea* and *M. pudica* and leaf extract of *C. cajan* and *S. spinosa.* The high reduction in the former and total failure of seed germination in the latter species as compared to control was an indication that allelochemicals were released by all these plant species. The quantum of allelochemicals leached varied with the variation of the selected plant species and the part used (Evenari 1945).

The stem extracts (5%) of *Rumex maritimus* and *Gynura cusimba* did not have much effect on the seedling growth of *Parthenium* as compared to control. However, high reduction of 82 and 83.5% in *Parthenium* root growth was observed over control by 20% stem extract of *C. tora* and *C. cajan* and leaf extract of *M. pudica*, respectively (Table 3). Leaf and stem extract of *Cassia tora* and *Mimosa pudica* at lower concentration of 5% could arrest the aerial growth of *Parthenium* but at the higher concentration. Almost all the selected plant species had a drastic effect to reduce aerieal grwoth as compared to control (Table 3). The reduction root and shoot length in seedlings may be attributed to the reduced rate of cell division and cell elongation due to the presence of allelochemicals in the aqueous extracts.

The dry matter accumulation of *Parthenium* seedlings was reduced by 8.3-71.3% when treated with 5% aqueous extract of different part of selected plants. Dry matter accumulation decreased with increase in concentration of aqueous extract. At higher concentrations (10% and 20%), significant reductions of 72.7-79.2% were observed in leaf and stem extracts of *C. tora* and *M. pudica*, respectively (Table 4). This might be due to the inhibition of CO_2 efficiency as allelochemicals could inhibited the carbon fixation pathway either directly or indirectly in barley (Overland 1996).

At higher concentration, all plant extracts could reduce the vigour index of *Parthenium* seedling as compared to control (Table 4). The maximum vigour indexes of *Parthenium* seedling were obtained at 5% concentration of stem extract of *Rumex meritimus* and *Gynura cusimba*. Dhawan *et al.* (1997) found that extract of *Delonix regia, Trifolium alexandrinum, Moringa indica, Tephrosia purpurea Bauhinia varigata, Albizzia procera*

Table 3. Allelopathic effect of different parts of plant aqueous extracts at different concentration on *Parthenium* root and shoot length

Plants	Concentration											
	5%		10%		20%		30%		50%		75%	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Root length (cm)												
Cajanus cajans	0.70	0.73	0.63	0.60	0.53	0.36	-	0.47	-	-	-	-
Sida spinosa	1.23	1.23	1.16	1.10	1.00	0.83	-	0.63	-	-	-	-
Mimosa pudica	0.63	0.74	0.53	0.67	-	0.33	-	-	-	-	-	-
Rumex maritimus	1.26	1.60	1.13	1.30	1.03	1.13	0.63	0.76	-	-	-	-
Gynura cusimba	1.33	1.53	0.76	0.90	0.50	0.50	0.46	0.53	-	-	-	-
Ipomoea carnea	1.10	1.20	0.86	1.00	0.70	0.70	0.64	0.63	-	-	-	-
Cassia tora	0.76	0.66	0.56	0.59	-	0.36	-	-	-	-	-	-
Cassia sericea	0.76	0.73	0.60	0.56	-	0.53	-	-	-	-	-	-
Control						2.00*						
LSD (P=0.05)	0.19	0.19	0.22	0.21	0.20	0.20	0.07	0.15				
Shoot length (cm)												
Cajanus cajans	0.96	1.10	0.70	0.87	0.70	0.83	-	0.53	-	-	-	-
Sida spinosa	1.13	1.30	0.90	1.27	0.83	0.93	-	0.80	-	-	-	-
Mimosa pudica	0.80	0.93	0.70	0.85	-	0.60	-	-	-	-	-	-
Rumex maritimus	1.33	1.70	1.17	1.47	0.93	1.23	0.63	0.73	-	-	-	-
Gynura cusimba	1.53	1.60	1.36	1.33	0.90	1.10	0.83	0.90	-	-	-	-
Ipomoea carnea	1.00	1.20	1.00	1.10	0.86	0.98	0.65	0.73	-	-	-	-
Cassia tora	0.63	0.77	0.53	0.63	-	0.43	-	-	-	-	-	-
Cassia sericea	0.83	0.97	0.63	0.77	-	0.63	-	-	-	-	-	-
Control						1.80*						
LSD (P=0.05)	0.20	0.15	0.19	0.14	0.12	0.19	0.09	0.14				

*Mean value of all the control

and *Prosopis spicigera* had a allelopathic effect on *Parthenium* and reduced the vigour index considerably as compared to control.. Among all plant extracts, leaf and stem extract of *C. tora*, *M. pudica*, *C sericea* and *Cajanus cajan* had more inhibitory effect on vigour of *Parthenium*.

Damage potential of *Zygogramma bicolorata*

Adults and grubs of *Z. bicolorata* damaged *Parthenium* and reduced plant height, shoot length, root length, stem diameter and plant biomass than control. The damage was more pronounced after 30 days of initial introduction compared to 15 days (Table 5). The grubs fed more vigorously on leaves of *Parthenium* than the adults. However, the reduction in root length was not significant. 30 days of continuous feeding reduced 66.3% of plant height and caused 100% reduction in flower production. *Zygogramma bicolorata* was considered effective biocontrol agent for *Parthenium* suppression (Sangamitra and Monica Basu 2008). Sushilkumar (2010) discussed and reviewed the impact of bioagent *Z. bicolorata* in detail.

Table 4. Allelopathic effect of plants leaf and stem extracts at different concentration on *Parthenium* biomass and vigour index

Plants	Concentration											
	5%		10%		20%		30%		50%		75%	
	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem
Biomass (mg/plant)												
Cajanus cajan	2.0	2.1	1.1	1.2	1.2	1.1	-	1.1	-	-	-	-
Sida spinosa	2.7	2.8	2.4	2.5	2.0	2.1	-	1.0	-	-	-	-
Mimosa pudica	1.0	1.5	0.9	1.4	-	0.8	-	-	-	-	-	-
Rumex maritimus	3.0	3.2	2.3	2.9	2.1	2.2	1.13	1.1	-	-	-	-
Gynura cusimba	3.2	3.3	2.4	2.7	2.1	1.5	1.53	1.3	-	-	-	-
Ipomoea carnea	2.4	2.5	2.0	2.3	1.4	1.7	1.33	1.2	-	-	-	-
Cassia tora	1.2	1.1	1.0	1.0	-	0.7	-	-	-	-	-	-
Cassia sericea	1.4	1.6	1.2	1.3	-	1.2	-	-	-	-	-	-
Control						3.6*						
LSD (P= 0.05)	0.3	0.1	0.2	0.1	0.1	0.1	0.2	0.1				
Vigour index												
Cajanus cajans	443.2	549.0	222.1	392.5	123.0	198.7	-	67.0	-	-	-	-
Sida spinosa	630.1	1012	246.0	552.2	305.6	352.0	-	143.0	-	-	-	-
Mimosa pudica	333.2	445.9	163.6	304	-	123.7	-	-	-	-	-	-
Rumex maritimus	1380.5	1871.1	690.0	1199.4	327.3	549.9	167.6	248.8	-	-	-	-
Gynura cusimba	1716	1984.4	990.0	1045.0	466.2	692.8	300.6	238.8	-	-	-	-
Ipomoea carnea	768.6	1039.2	433.4	560.7	260.5	391.4	86.4	136.0	-	-	-	-
Cassia tora	232.1	381.8	109.0	244.0	-	79.0	-	-	-	-	-	-
Cassia sericea	370.5	510.0	205.4	355.1	-	193.7	-	-	-	-	-	-
Control						3674.6*						

*Mean value of all the control

Table 5. Impact of *Zygogramma bicolorata* on growth of *Parthenium* after 15 and 30 days of release

Criteria	After 15 Days				After 30 days			
	Control	Treated	% reduction	Calculated ‘t’ value	Control	Treated	% reduction	Calculated ‘t’ value
Plant height (cm)	10.8	6.5	39.8	13.2	18.4	6.2	66.3	15.6
Shoot length (cm)	8.1	5.3	34.2	15.3	14.3	5.6	60.8	12.6
Stem diameter (mm)	2.6	1.9	26.9	7.3	2.6	2.1	22.2	2.2
Root length (cm)	7.4	6.3	14.9	1.6	8.1	7.1	12.1	2.0
Plant biomass (mg/plant)	465.0	278.9	40.0	42.3	584.0	132.0	77.4	136.7

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Short communication

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Dissipation and harvest time residue of 2,4-D in soil and wheat crop

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Key words: 2,4-D, Dissipation, Herbicde, Persistence, Residues, Wheat

Wheat, a member of family *Poaceae* is one of the major food crops in the world. Globally, it occupies about 17% of the cropped land and contributes 35% of the staple food (Pingali 1999).Wheat constitutes one of the most abundant sources of energy and protein for the world population and its increased production is essential for food security (Chhokar *et al.* 2006). Severe competition from weeds is one of the most important factors determining productivity and sustainability of any crop. Weeds compete with crop plants for space, solar radiation, nutrients, water and carbon dioxide. Usually, the intensity of weeds in wheat remains higher. In the absence of efficient control measurers, weed plants cause 15-50% or more yield reduction depending upon the weed density and type of weed flora (Chhokar *et al.* 2006, Kumar *et al*. 2007). In weed management practices, chemical weed control contributes gainful increment in crop production. The use of 2,4-D has contributed greatly to increase the production of wheat.

2,4-D (2,4-dichlorophenoxy acetic acid) is a systemic auxin type selective herbicide and is commonly used in cereal crops (Jat *et al*. 2003). However, the usage of pesticides in agriculture is a matter of both food and environmental safety concern because these chemicals are recognized as a source of potential adverse impact (Alexandre and Claudio 2002). So, their environmental behavior is required to be studied to ensure their use safely. Therefore, the present work was undertaken to study the dissipation and residues of 2, 4-D in wheat and soil under field conditions.

Field investigations pertaining to dissipation studies of 2,4-D in wheat grown soil were conducted at the Research Farm of Department of Agronomy, CSK HPKV, Palampur (HP). Wheat variety '*HPW-155*' was used in study and 2,4-D doses were applied at the rate of 0.5, 1.0 and 2.0 kg/ha in wheat crop at 35 days after sowing. Soil samples were collected at 0, 1, 3, 5, 7, 15, 30, 45 60, 75 and 90 days after herbicide application and were processed. Wheat straw and grain samples were collected at harvest of crop. 2,4-D standard used was procured from Accu Standard, USA. 2,4-D residues from different substrates (soil, wheat straw and grain) were extracted as described by Marquadt *et al*. (1955), and Devi *et al*. (2001).

The validation of spectrophotometeric method for 2,4-D was carried out. The standard curve for reference material was prepared by plotting graph of concentration versus absorbance for 2,4-D . Beer's law plot was linear with good correlation coefficient (R^2=0.998). LOD and LOQ values were 0.01 µg/ml and 0.02 µg/ml, respectively calculated using following equations.

LOD: X*bi* + 3S*bi*

LOQ: X*bi* + 10S*bi*

where X*bi* is the mean concentration of the blank and S*bi* is the standard deviation of the blank.

The validated procedure was used for quantitative measurement of 2,4-D in further study. The recoveries of 2,4-D of soil, wheat plant and grain ranged from 82 to 83.2% for fortification of 1 and 2 µg/g, respectively.

Initial residues of 2,4-D applied at 0.5, 1.0 and 2.0 kg/ha were 0.023, 0.041 and 0.066 µg/g which after 3 days of herbicide application reached to 0.015, 0.025 and 0.041 µg/g, respectively (Table 1). The corresponding per cent losses of applied 2,4-D was 34.8%, 39.0% and 37.9%, respectively at three days after application. Dissipation of 2,4-D revealed that approximately 21.7, 34.1 and 45.5% of applied 2,4-D remained in soil at 7 days after herbicide application at three levels of 2, 4-D *i.e.* 0.5 , 1.0 and 2.0 kg/ha. After 15 days of herbicide application, dissipation of 2, 4-D (35 DAS) was highest (91.3%) in 2, 4-D 0.5 kg/ha (35 DAS) followed by 2,4-D 1.0 kg/ha (35 DAS) (78%) and for least in highest dose *i.e.* 2.0 kg/ha (62.1%). This clearly indicated that 2,4-D (35 DAS) at higher dose persisted in the soil for longer periods than at lower doses. The residues (Table 1) were below detectable levels for 2,4-D 0.5 kg/ha at 30 days after herbicide application. The concentration of 2, 4-D 1.0 kg/ha was 0.004 µg/g and for 2,4-D 2.0 kg/ha was 0.019 µg/g. The corresponding dissipation was 100, 90.2 and 71.2%, respectively indicating

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Table 1. Residues of 2,4-D in soil treated at different doses

Application	Residues (µg/g)		
	Rates of 2,4-D application		
	0.5 kg/ha	1.0 kg/ha	2.0 kg/ha
0	0.023 (-)	0.041 (-)	0.066 (-)
1	0.020 (13.04)	0.030 (26.82)	0.046 (30.30)
3	0.015 (34.78)	0.025 (39.02)	0.041 (37.87)
5	0.007 (69.56)	0.020 (51.21)	0.036 (45.45)
7	0.005 (78.26)	0.014 (65.85)	0.030 (54.54)
15	0.002 (91.30)	0.009 (78.04)	0.025 (62.14)
30	ND	0.004 (90.24)	0.019 (71.21)
45	-	0.002 (95.19)	0.008 (87.87)
60	-	ND	0.005 (92.42)
75	-	-	0.002 (96.96)
90	-	-	ND

Values in parenthesis are % dissipation, ND-Not detectable

Table 2. Slope of curve, correlation coefficient, half life and regression equation of 2,4-D residues in soil

Treatment	Slope of curve	Half life (days)	Correlation coefficient	Regression equation
2,4-D 0.5 kg/ha	0.073	4.12	0.95	y=0.073x + 1.325
2,4-D 1.0 kg/ha	0.027	11.1	0.96	y=0.027x + 1.463
2,4-D 2.0 kg/ha	0.017	17.70	0.98	y=0.017x + 1.694

that only 0, 9.8 and 28.8% of applied 2,4-D 0.5 kg/ha, 2,4-D 1.0 kg/ha and 2,4-D 2.0 kg/ha was left in soil.

The residues of 2,4-D exhibited a declining pattern as a function of time. Rate of dissipation was very rapid during initial 30 days when dissipation was of order 100, 90.24 and 71.21% at three levels of 2,4-D that is 0.5, 1.0 and 2.0 kg/ha, respectively. As the period of 30 days experienced rainfall, it is quite likely that 2,4-D (Na) (aqueous solubility = 45g/l) might have leached down or washed off due to rains. Similar conducive environmental conditions prevailing during the tenure of 30 days might have resulted in rapid loss of herbicide from field. Combined effect on dissipation has also been reported previously by Devi *et al.* (2001). Similar observations have been reported by Randhawa and Sandhu (2004), and Fengfu *et al.* (2009).

The plots indicated that the dissipation of 2, 4-D at 0.5 to 2.0 kg/ha fitted first order kinetics decay curve

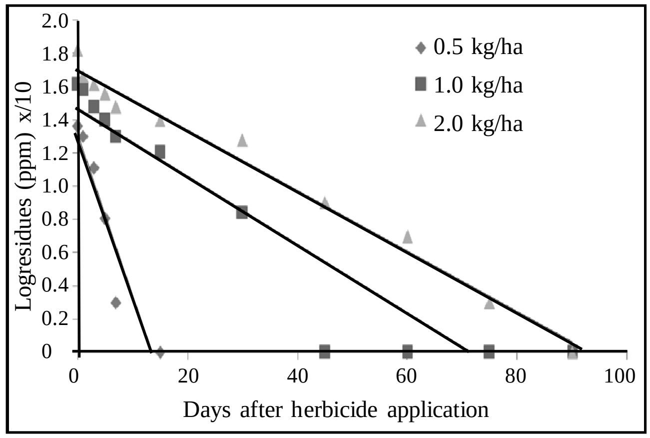

Fig. 1. First order dissipation curve of 2,4-D at 35 DAS in soil

(Fig. 1). The slope of curve, correlation coefficient, half life of herbicide along with regression equation are summarized in Table 2. The correlation coefficient for 2,4 D 0.5 kg/ha, 1.0 kg/ha and 2.0 kg/ha were 0.95, 0.96 and 0.98, respectively indicating perfect fit. As time versus log residue plot is linear, dissipation followed first order kinetic reaction. These findings were in conformity with Cheah *et al.* (1998) and Jiang *et al.* (2010).

Terminal residues of 2,4-D in wheat plant and wheat grain were determined by estimating 2,4-D concentration at the maturity of the crop. It was found that residues of 2,4-D were below detectable level in both plant and grain samples at harvest. The above findings were in conformity with results given by Kumari *et al.* (2004) and Jiang *et al.* (2010).

SUMMARY

Application 2,4-D at three levels in 0.5, 1.0 and 2.0 kg/ha in wheat crop at 35 days after sowing persisted in soil up to 15, 45 and 75 days, respectively. The logarithmic plots of herbicide residues versus time obtained by fitting the regression equation indicated that disappearance of 2,4-D in soil followed a first order kinetics decay curve at all the levels of application with the half life period varying from 4.21-17.70 days. Residues of 2,4-D were found below detectable level (0.02 ppm) in wheat grain and wheat straw.

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Allelopathic potential of *Coleus* on water hyacinth

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Key words: Allelopathic potential, Botanical extract, *Coleus* spp. *Eichhornia crassipes*, Water hyacinth

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms - Laubach: Pontederiaceae) is one of the most troublesome aquatic weeds in India. This affects water quality, water traffic, fishing potential, hydro electricity generation, water use *etc*. The Veeranum lake and its distributaries in Tamilnadu in India, forms the major irrigation source that covers large rice tract of the state with a command area of 18,000 ha. The weed severely invaded Veeranum distributaries (Kannan and Kathiresan 1999). The physical removal is not cost effetive and sustainable which may be realized that Tamil Nadu state Government spent Rs.1.74 crores for cleaning water hyacinth from Ooty lake during single season (The Hindu 2003).The lake was again infested with the weed. The use of herbicides is associated with risk such as water quality deterioration, residual effect *etc*. Biological control using insects offers satisfactory control but takes long time usually 2 to 4 years. An Indian medicinal herb *Coleus amboinicus*/ *aromaticus*, (*Coleus* spp.) showed remarkable allelopathic inhibition of *E. crassipes* (Kathiresan 2000). Based on this observation, the present study was undertaken to compare the allelopathic potential of different parts of *Coleus* spp. on *E. crassipes.*

The experiment was conducted at Annamalai University, Tamil Nadu, India during 2004 to compare allelopathic potential of different part of *Coleus* spp. on water hyacinth. Different parts of *Coleus* spp., *viz.* leaf, stem, whole plant along with leaf and stem were collected separately; shade dried and ground to fine powder in Willey mill. Leaf, stem and whole plant powders were applied alone and in combination (Table 1) on medium growth stage of water hyacinth (weight 100-120 g). The plastic pots were used in the study and on an average each pot accommodated five plants of *E. crassipes*. The experiment was conducted in completely randomized design with five replications. Percentage reduction in fresh weight and chlorophyll content of water hyacinth was recorded at 3 days intervals (in comparison with initial fresh weight of plants in the same treatment). Chlorophyll content of *E. crassipes* was estimated at 3 days interval by extracting the leaf tissue using dimethyl sulphoxide (DMSO) (Hiscox and Israeltam 1979). The experimental data were statistically analyzed.

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The magnitude of inhibition varied with varying combination of different parts of *Coleus* spp. as well as with varying duration of exposure (Table 1). Among the different parts of *Coleus* spp., leaves showed higher maximum inhibition with 100% reduction in chlorophyll content and fresh weight on 6 and 9 DAT (days after treatment), respectively compared to the stem and whole plant powders. This could be due to higher content of active allelopathic principles such as carvacrol, thymol and others as demonstrated by Vasquez *et al*. (1999). This was followed by the combination of 3/4th of dried leaf powder (18.75 g/l) + 1/4th of dried whole plant powder (6.25 g/l). Dried stem powder (25 g/l), imparted only 19.61 and 16.98% reduction in fresh weight and chlorophyll content, respectively on 9 DAT. However, 100% reduction in fresh weight and chlorophyll content of the weed was observed with other treatments comprising 3/4th of dried leaf powder (18.75 g/l) + 1/4th of dried stem powder (6.25 g/l), 3/4th of dried leaf powder (18.75 g/l) + 1/4th of dried whole plant powder (6.25 g/l), 1/2 of dried leaf powder (12.5 g/l) + 1/2 of dried whole plant powder (12.5 g/l) on 12 and 6 DAT, respectively.).

With increase in period of exposure, *viz*. 12, 15, 18 and 24 DAT, all the treatments except full dose of stem powder registered 100% reduction in fresh weight and chlorophyll content of the weed. The stem powder exhibited least allelopathic potential with a chlorophyll content and fresh weight reduction of 29.87 and 38.49% on 15 and 24 DAT, respectively. Accordingly, the whole plant powder also showed a lesser magnitude of inhibitory response, compared to leaf powder. Result showed that all plant parts possessed allelopathic principles capable of controlling *E. crassipes*, however, leaves possesed high allelopathic activity. If adequate quantities of leaf are not available, even whole plant of *Coleus* spp. may be used as this also offered reduction in chlorophyll content and fresh weight of the weed within 21 DAT. However, care need to be taken that either three fourth or at least half of the quantity of plant product is constituted by the leaf powder.

Table 1. Allelopathic potential of different parts of *Coelus* spp. on *Eichhornia crassipes*

Treatment	Percentage reduction in fresh weight					Percentage reduction in chlorophyll content					
	1 DAT	6 DAT	12 DAT	18 DAT	24 DAT	1 DAT	3 DAT	6 DAT	9 DAT	12 DAT	15 DAT
Leaf powder (25 g/l)	38.5	72.7	100.0	100.0	100.0	53.7	78.8	100.0	100.0	100.0	100.
Stem powder (25 g/l)	4.8	15.1	23.4	31.2	38.5	5.0	11.2	17.0	20.9	26.7	29.9
Whole plant (25 g/l)	16.0	32.9	58.4	84.4	100.0	14.7	51.1	81.1	100.0	100.0	100.0
¾th of leaf powder + ¼th of stem powder	27.8	58.8	100.0	100.0	100.0	49.0	70.6	100.0	100.0	100.0	100.0
¾th of leaf powder + ¼th of whole plant powder	28.9	63.8	100.0	100.0	100.0	49.9	69.0	100.0	100.0	100.0	100.0
½ of leaf powder + ½ of stem powder	15.0	38.2	77.1	100.0	100.0	18.0	54.5	69.0	81.7	100.0	100.0
½ of leaf powder + ½ of whole plant powder	27.0	56.9	100.0	100.0	100.0	47.1	68.2	100.0	100.0	100.0	100.0
¼th of leaf powder + ¾th of stem powder	14.0	30.0	55.5	77.9	100.0	13.6	28.1	49.9	68.2	81.0	100.0
¼th of leaf powder + ¾th of whole plant powder	14.7	38.6	74.4	100.0	100.0	16.4	53.0	68.4	80.0	100.0	100.0
Untreated control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD (P=0.05)	2.12	3.18	3.11	5.08	3.28	2.51	3.24	3.80	4.28	2.71	2.03

DAT- Days after treatment

SUMMARY

Among different parts of *Coleus* spp., dried leaf powder (25 g/l of water) was found most effective in reducing the fresh weight and chlorophyll content of *E. crassipes* and showed 100 reduction on 9 and 6 days after treatment, respectively. Combination of 3/4th of dried leaf powder (18.75 g/l) + 1/4th of dried whole plant powder (6.25 g/l) was also found effective next to 25 g/l dried leaf power. Dried stem powder (25 g/l) showed minimum reduction in fresh weight and chlorophyll content.

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Short communication

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Efficacy of early post-emergence herbicides against associated weeds in soybean

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Soybean has emerged as a potential crop for changing the economical position of the farmers in India particularly in Madhya Pradesh. Although ecological condition of the state are congenial for soybean production but the yield is substantially low, despite of best management practices. The poor weed management practices deprive the crop of its major requirement of nutrients, soil moisture, sunlight and space which results poor crop growth and yield. Being a rainy season crop, it has high yielding capacity but weed infestation is one of the major constraints in soybean cultivation (Bhan *et al.* 1974). The weed, if not controlled during critical period of weed crop competition, there may be reduction in the yield of soybean from 58-85% depending upon type and weed intensity (Singh and Singh 1987, Kolhe *et al.* 1998). Looking to the present need of post-emergence herbicides for higher soybean yield, this study was undertaken.

A field experiment was conducted during *Kharif* of 2009-10 at Research Farm, Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur. The soil of the experimental field was sandy loam in texture, neutral in reaction (pH 7.35) with normal electrical conductivity (0.48 ds/m). The organic content of the soil was 0.68% and low in available nitrogen (215 kg/ha), phosphorus (9.2 kg/ha) and medium in available potassium (318 kg/ha). Eleven treatments, *viz.* T_1- Odyssey 75 g/ha (mixture of imazethapyr + imazamox), T_2- Odyssey 87.5 g/ha, T_3- Odyssey 100 g/ha, T_4- Odyssey + adjuvant (75 g + 1000 ml/ha,) T_5- Odyssey + adjuvant (87.5 g + 1000 ml/ha),T_6- Odyssey + adjuvant (100 g + 1000 ml/ha), T_7- Imazethapyr + adjuvant (1000 ml + 1000 ml/ha), T_8- Imazamox + adjuvant (350 ml + 1000 ml/ha), T_9- chlorimuron-ethyl 37.5 g/ha, T_{10}- Fenoxoprop-ethyl 750 ml/ha and T_{11}- Weedy check. These eleven treatments were tested under randomized block design with three replication.

Pre-treated seeds (70 kg/ha) of soybean cv. '*JS 97-52*' was sown on July 8, 2009 in furrow opened manually at 30 cm apart rows and fertilized with 20:60:20 kg N, P_2O_5 and in K_2O/ha with urea, single super phosphate and muriate of potash, respectively. Odyssey (mixture of imazethapyr + imazamox) is a herbicides used as post-emergence in soybean. The total rainfall received during the field experimentation was 1339.3 mm and was received in well distributed pattern in 35 rainy days. The quadrate of 0.25 square meter was used to count the weeds in each plot species wise. The data thus obtained, were transformed and expressed in per square meter. The percentage of weed flora was estimated from weedy check plot. Weed control efficiency (WCE) was estimated by the formula given by Mani *et al.* (1973).

The major weed flora in the experimental field comprised of monocot weeds, *viz. Echinochloa colona*, *Dinebra retroflexa* and *Cyperus iria*; and dicot weeds, *viz. Eclipta alba* and *Alternanthera philoxeroides*.

All the weed control treatments significantly reduced the dry weight of weeds when compared with weedy check (Table 1 and 2). Among the herbicides, application of Odyssey + adjuvant (87.5 g + 1000 ml/ha) significantly reduced the weed dry weight than the weedy check and other herbicides at 40 DAS and harvest. The weed control efficiency was highest at 40 DAS and harvest (69.82 and 81.82%) with the application of Odyssey + adjuvant (87.5 g + 1000 ml/ha). The lower and the higher doses of Odyssey without adjuvant was not effective for controlling the weeds but found superior over other tested herbicides for controlling the weeds (Shete *et al.* 2008).

All the yield attributing traits (Table 3) namely branches/plant, leaf area index (LAI), dry matter production and pods/plant were significantly superior under application of Odyssey + adjuvant (87.5 g + 1000 ml/ha) than other treatments. Application of Odyssey 75, 87.5 g/ha, fenoxoprop-p-ethyl (750 ml/ha) and imazamox (350 ml/ha) as early post-emergence produced better yield attributing characters compared to weedy check an account of maximum reduction in weed growth coupled with no inhibitory effects on soybean plants (Kothawade *et al.* 2007). The lowest seed yield (0.080 t/ha) was observed

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Table 1. Weed density of the experiment field in weedy plot at 40 DAS and harvest

Treatment	Density (no./m^2)		Relative density (%)	
	40 DAS	At harvest	40 DAS	At harvest
Moncot weeds				
Echinochloa colona	8.00	10.67	4.41	8.60
Dinebra retroflexa	96.00	50.67	52.94	40.86
Cyperus iria	45.33	22.67	25.00	18.28
Dicot weeds				
Eclipta alba	14.67	9.33	8.09	07.53
Alternanthera philoxeroides	17.33	30.67	9.56	24.73
Total	181.33	124.01	100.00	100.00

Table 2. Influence of herbicides the dry weight and weed control efficiency at 40 DAS and harvest in soybean

Treatment	Dose (g/ha)	Weed biomass (g/m^2)		Weed control efficiency (%)	
		40 DAS	At harvest	40 DAS	At harvest
T_1 - Odyssey 75 g/ha	52.50	8.44	15.51	53.9	58.0
T_2 - Odyssey 87.5 g/ha	61.25	6.78	8.14	62.9	78.0
T_3 - Odyssey 100 g/ha	70.00	11.25	22.81	38.5	37.4
T_4 - Odyssey 75 g/ha + adjuvant	52.50+1000	7.72	13.89	57.8	62.4
T_5 - Odyssey 87.5 g/ha + adjuvant	61.25+1000	5.52	6.71	69.8	81.8
T_6 - Odyssey 100 g/ha + adjuvant	70.00+1000	10.03	19.31	45.2	48.2
T_7 - Imazethapyr 1000 g/ha + adjuvant	100.00+1000	12.57	23.95	31.3	35.1
T_8 - Imazethapyr 350 g/ha + adjuvant	42.00+1000	10.77	21.39	41.1	50.2
T_9 - Chlorimuron-ethyl 37.5 g/ha	9.37	13.72	25.86	25.0	29.0
T_{10} - Fenoxoprop-ethyl 750 g/ha	67.50	8.77	16.25	52.1	56.0
T_{11} - Weedy check	-	18.29	36.92	-	-
LSD (P=0.05)		4.60	NS		

Table 3. Influence of herbicides on growth and seed yield of soybean

Treatment	Dose (g/ha)	Branches/ plant (90 DAS)	Dry matter production (g/m^2)	LAI (60 DAS)	Pods/ plant	Seed yield (t/ha)	Harvest index
T_1 - Odyssey 75 g/ha	52.5	4.60	941.3	7.51	89.5	2.44	37.5
T_2 - Odyssey 87.5 g/ha	61.25	5.20	974.3	7.58	93.7	2.53	36.3
T_3 - Odyssey 100 g/ha	70.00	4.40	899.1	7.45	85.3	2.11	36.5
T_4 - Odyssey 75 g/ha + adjuvant	52.50+1000	4.73	943.6	7.55	90.5	2.49	37.1
T_5 - Odyssey 87.5 g/ha + adjuvant	61.25+1000	5.40	1020.9	7.78	95.8	2.86	38.9
T_6 - Odyssey 100 g/ha + adjuvant	70.00+1000	4.73	911.8	7.48	88.0	2.19	35.7
T_7 - Imazethapyr 1000 g/ha + adjuvant	100.00+1000	4.37	878.9	7.43	83.5	1.94	35.6
T_8 - Imazethapyr 350 g/ha + adjuvant	42.00+1000	4.47	904.0	7.47	87.8	2.18	36.2
T_9 - Chlorimuron-ethyl 37.5 g/ha	9.37	4.33	860.4	7.38	72.6	1.40	36.9
T_{10} - Fenoxoprop-ethyl 750 g/ha	67.50	4.53	916.2	7.49	89.1	2.43	38.1
T_{11} - Weedy check	-	3.67	804.0	7.30	59.7	0.78	35.4
LSD (P=0.05)	0.87	75.0	0.30	13.7	286.3		

in weedy check treatment and it was due to severe competitional stress right from crop establishment upto the end of critical period of crop growth, leading to poor growth, yield attributing traits and finally the yield. The grain yield of soybean was significantly higher (2.9 t/ha) under Odyssey + adjuvant (87.5 + 1000 ml/ha) and found

Table 4. Economics of soybean as influenced by different herbicides

Treatment	Dose (g/ha)	Cost of cultivation ($x10^3$ ₹ /ha)	Gross monetary returns ($x10^3$ ₹ /ha)	Net monetary returns ($x10^3$ ₹ /ha)	B:C ratio
T_1 - Odyssey 75 g/ha	52.5	15.65	50.85	35.20	3.25
T_2 - Odyssey 87.5 g/ha	61.25	15.83	52.78	36.94	3.33
T_3 - Odyssey 100 g/ha	70.00	16.01	43.94	27.93	2.74
T_4 - Odyssey 75 g/ha + adjuvant	52.50+1000	16.05	51.87	35.81	3.23
T_5 - Odyssey 87.5 g/ha + adjuvant	61.25+1000	16.23	59.46	43.23	3.67
T_6 - Odyssey 100 g/ha + adjuvant	70.00+1000	16.41	45.72	29.31	2.79
T_7 - Imazethapyr 1000 g/ha + adjuvant	100.00+1000	16.21	40.64	24.42	2.50
T_8 - Imazethapyr x 350 g/ha + adjuvant	42.00+1000	16.13	45.48	29.35	2.81
T_9 - Chlorimuron-ethyl 37.5 g/ha	9.37	15.11	29.13	14.01	1.92
T_{10} - Fenoxoprop-ethyl 750 g/ha	67.50	16.06	50.63	34.57	3.15
T_{11} - Weedy check	-	14.56	16.22	16.56	1.11

superior over other treatment, because of relatively low competitional stress and better yield attributes. These results were in conformity to the findings of Vyas and Jain (2003), Kothawade *et al.* (2007) and Shete *et al.* (2008).

Benefit: cost ratio as influenced by various treatments (Table 4) revealed that highest net returns and B:C ratio was observed in plots treated with Odyssey + adjuvant (87.5 g + 1000 ml/ha) followed by Odyssey + adjuvant (75 g + 1000 ml/ha). The minimum net returns and B:C ratio were recorded under weedy check treatments.

SUMMARY

A field experiment was conducted during *Kharif* season of 2009-10 at Research Farm, Adhartal, JNKVV, Jabalpur to study the effect of early post-emergence herbicides against weeds in soybean (*Glycine max* L.). The density and dry weight of weeds were higher under weedy check treatment. However, identical reduction in density and dry weight of weeds were observed when weeds were controlled chemically. Significantly higher weed control efficiency (81.82%) and seed yield (2.9 t/ha) was observed under Odyssey (mixture of imazethapyr + imazamox) + adjuvant (87.5 g + 1000 ml/ha). The maximum net profit (₹ 43233/ha) and B: C ratio (3.67) were also recorded under the same treatment.

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