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Crop establishment methods and weed management on growth and yield of dry direct-seeded rice

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ABSTRACT

A field study was undertaken to evaluate the crop establishment and weed management options for direct-seeded rice (DSR) in the Institute for Agricultural Sciences, BHU, Varanasi, India during rainy season in 2008 and 2009. The weed flora were grasses as *Echinochloa colona, Echinochloa crusgalli, Cynodon dactylon, Paspalum* spp., sedges as *Cyperus rotundus*, *Cyperus iria* and broad-leaved weeds like *Caesulia axillaris*. Data were recorded on weed dynamics, crop growth and yield of the direct-seeded rice crop. Rice established by zero-till DSR with 40 cm anchored residue had minimum density of grasses, sedges and broad-leaved weeds and dry weight at 60 DAS. Among weed management methods, use of pendimethalin 1000 g/ha (pre-em) *fb* azimsulfuron 35 g/ha at 15-20 DAS + one HW at 40 DAS proved to be most effective in minimizing the weed density, dry weight and weed persistence index (0.08 and 0.04) and in enhancing the weed control efficiency (72.04% and 76.77%). The maximum grain yield, straw yield and biological yield was found with application of pendimethalin 1000 g/ha (pre-em) *fb* azimsulfuron 35 g/ha at 15-20 DAS + one HW at 40 DAS, which was significantly superior to rest of the treatments during both the years of experimentation.

Key words: Crop establishment, Direct-seeded rice, Weed management, Weed persistence index, Zero-tillage

Dry direct-seeding is probably the oldest method of crop establishment. Historical accounts of rice cultivation in Asia indicate that, during its early period of domestication, rice used to be dry sown in a mixture with other crops that were established under the shifting cultivation system (Grigg 1974). In the 21st century, rising scarcity of agricultural land and water and continuing shortage of labour would maintain pressure for a shift towards direct seeding method in rice production system (Mortimer *et al.* 2005). The main driving forces of these changes are the rising wage rate, non-availability of labour and scarcity of water. Direct seeding offers certain advantage *i.e.* save labour, faster and easier planting helps in timely sowing, less drudgery, less water requirements, high tolerance to water deficit, often higher yield, low production cost and more profit, energy saving, better soil physical conditions for following crop (Balasubramanian and Hill 2002). Despite several advantages, various production obstacles are also encountered in direct-seeded rice in which heavy weed infestation is the major one.

Weeds cause heavy damage to direct-seeded rice (DSR) crop which can be to the tune of 5-100% (Kohle 1989). Manual removal of weeds is labour intensive, tedious, back breaking and does not ensure weed removal at critical stage of crop-weed competition due to non-availability of labours and sometimes bad weather condition which does not allow labours to move in the field. Thus, herbicides are considered to be an alternative/supplement to hand weeding (Singh *et al.* 2007). Herbicides are more effective in controlling the weeds besides reducing the total energy requirement for rice cultivation. Besides chemicals and manual weeding agronomic practices like, crop establishment by zero tillage or reduced tillage with residue retention play an important role in weed suppression and improving the yield. Hence, considering the importance the present investigation was undertaken to study the effect of different crop establishment and weed management methods on weed flora, crop growth and yield in direct dry seeded rice.

MATERIALS AND METHODS

The study was undertaken during 2008 and 2009 at Institute of Agricultural Sciences, BHU, Varanasi, U.P., India. The soil of the experimental site was Gangetic alluvial having sandy loam in texture with pH 7.2. It was moderately fertile, being low in organic carbon (0.43%), available N (198 kg/ha) and medium in available P (24.6 kg/ha) and K (210 kg/ha). The experiment was laid out in split plot design with three crop establishment methods and nine weed management treatments in three replication. The treatments were, zero-till DSR, zero-till DSR with anchored resi-

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due and reduced tillage DSR with zero till-drill. The weed management treatment included weedy check, weed free, hand weeding (20 and 40 DAS), glyphosate 1000 g/ha (pre-seeding) *fb* pendimethalin 1000 g/ha (pre-em), *fb* 2,4-D EE 500 g/ha at 25 DAS, pendimethalin 1000 g/ha (pre-em) *fb* 2,4-D EE 500 g/ha at 25 DAS + one hand weeding (HW) at 40 DAS, pendimethalin 1000 g/ha (pre-em) *fb* metsulfuron + cholorimuron 4 g/ha at 20 DAS + one HW at 40 DAS, pendimethalin 1000 g/ha (pre-em) *fb* azimsulfuron 35 g/ha at 15-20 DAS + one HW at 40 DAS, fenoxaprop with safener 56 g/ha + ethoxysulfuron 18 g/ha at 20-25 DAS + one HW at 40 DAS and bispyribac 25 g/ha at 20-25 one HW at 40 DAS in sub-plots. The crop establishment methods were kept in main plot whereas; weed management treatments adjust in sub-plots. Seeding was done with pre-sowing irrigation by zero-till drill machines in all the crop establishment methods. An uniform dose of 120 kg N + 60 kg P + 60 kg K + 5 kg Zn/ha was applied in all the treatments in the form of urea, DAP, MOP and $ZnSO_4$, respectively. Half of total N and full dose of P_2O_5, K_2O and Zn was applied as basal and remaining half dose of N was top dressed in two equal splits at active tillering and panicle initiation stage. Rice cv '*Sarjoo-52*' of 120-130 days duration was used as test variety. Dry seed of rice at 30 kg/ha was used for seeding by zero-till drill fitted with flatted roller. The total rainfall received during crop season was 1042.8 and 528.4 mm during 2008 and 2009, respectively. Distribution of rainfall was more uniform during first year as compared to second year in crop period. The crop received 2 and 4 irrigations during 2008 and 2009, respectively. Pre-emergence (just after sowing) and post-emergence (as per treatments) herbicides were applied with the help of a hand-operated knapsack sprayer fitted with flat-fan nozzle and water as a carrier at 600 litres/ha. Data on weed density were subjected to square root transformation ($\sqrt{x+0.5}$) before statistical analysis to normalize their distribution. The data were analyzed statistically as per standard method (Panse and Sukhatme 1978). Data on dry weight of weeds were recorded by cutting weeds at ground level, washed with tap water, sun dried first followed oven drying at 70 °C ± 2 for 48 hours and then weighed. To determine the effect of crop growth, data on initial plant population (m/row at 20 DAS), plant height (cm), tillers (m/row), plant dry matter (g/m row) recorded at harvest and leaf area index was recorded at 60 days after sowing. Weed control efficiency and weed persistence index was calculated using following formula.

$$\text{Weed control efficiency (WCE)} = \frac{(WD_C - WD_T)}{WD_C} \times 100$$

Where, WD_C is the weed density (number/m^2) in control plot; WD_T is the weed density (number/m^2) in treated plot; in both WD_C and WD_T; the unit should be same or uniform.

$$\text{Weed Persistence Index (WPI)} = \frac{\text{Weed population in treated plot}}{\text{Weed population in control plot}} \times \frac{\text{Weed dry weight in treated plot}}{\text{Weed dry weight in control plot}}$$

RESULTS AND DISCUSSION

Effects on weeds

Experimental field was infested with grassy (*Echinochloa colona*, *E. crusgalli*, *Paspalum* spp., *Cynodon dactylon*), sedges (*Cyperus rotundus* and *Cyperus iria*), and broad-leaved weed (*Caexulia auxillaries*). Among the weed flora, averaged over two years, the maximum relative percentage was of *Echinochloa colona* (23.8, 24.5 and 23.4%), *Echinochloa crusgalli* (23.4, 24.0 and 22.9%), *Cyperus rotundus* (16.1, 15.7 and 16.2%) and *Caesulia axillaries* (7.8, 6.8 and 8.2%) in zero-till DSR, zero-till DSR with anchored residue and reduced till, respectively.

Weed density

The rice established with zero-till DSR with anchored residue had minimum density among crop establishment methods at 60 DAS. Maximum weed density was recorded under reduced till DSR followed by zero-till DSR (Table 1). All weed management treatments resulted in significant reduction in total weed density as compared to weedy check. The significant effect of establishment methods with anchored residue and herbicides in combination with hand weeding can be ascribed to the broad spectrum of weed control (Singh *et al.* 2006, Singh *et al*. 2007). Application of pendimethalin *fb* azimsulfuron + one HW 40 DAS showed maximum efficacy in minimizing all kinds of weed flora and proved significantly superior over all the weed management treatments. The next best treatment in this respect was pendimethalin 1000 g/ha (pre-em) *fb* 2,4-D EE 500 g/ha at 25 DAS + one HW at 40 DAS. The integration of post-emergence herbicide and hand weeding (HW) as fenoxaprop with safener 56 g/ha + ethoxysulfuron 18 g/ha at 20-25 DAS + one HW at 40 DAS and bispyribac 25 g/ha at 20-25 one HW at 40 DAS were less effective as compared to other weed control treatments in minimizing the density of weeds. This is due to the fact that field was infested with complex weed flora and these herbicides cannot control

Table 1. Effect of crop establishment methods and weed management on density of weeds (no./m^2), weed dry weight, WCE and WPI at 60 DAS

Treatment	Grasses		Sedges		Broad-leaved weeds		Weed dry weight (g)		Weed control efficiency (%)		Weed persistence index	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Establishment method												
Zero-till DSR	18.2 (380)	17.3 (344)	9.07 (99.0)	8.19 (82.3)	4.26 (20.6)	3.64 (15.6)	7.85 (70.2)	7.13 (57.5)	52.4	58.9	0.27	0.21
Zero-till DSR with residue	17.4 (347)	16.4 (310)	8.28 (83.4)	7.23 (66.6)	3.64 (15.0)	3.03 (10.6)	7.27 (59.8)	6.94 (54.4)	53.0	65.6	0.21	0.17
Reduced tillage DSR	18.6 (396)	17.7 (359)	9.51 (107)	8.70 (90.5)	4.53 (23.3)	4.05 (19.0)	7.92 (72.3)	7.33 (61.7)	50.8	57.9	0.30	0.24
LSD (P=0.05)	0.53	0.50	0.25	0.23	0.31	0.10	0.23	0.21	-	-	-	-
Weed management												
Glyphosate *fb* pendimethalin *fb* 2,4-D EE	18.4 (340)	17.2 (297)	8.58 (73.6)	7.24 (52.6)	4.17 (17.1)	3.45 (11.6)	7.51 (56.0)	7.03 (49.0)	57.8	68.2	0.19	0.14
Pendimethalin *fb* 2,4-D + one HW at 40 DAS	16.9 (286)	15.6 (243)	6.86 (47.2)	5.04 (26.1)	3.67 (13.1)	2.83 (7.71)	6.93 (47.5)	6.61 (43.3)	66.3	74.2	0.13	0.09
Pendimethalin *fb* metsulfuron + chlorimuron + one HW at 40 DAS	20.9 (435)	19.8 (393)	10.95 (119)	9.94 (98.6)	4.26 (17.7)	3.58 (12.3)	8.37 (69.5)	7.96 (62.9)	50.3	58.6	0.31	0.21
Pendimethalin *fb* azimsulfuron + one HW at 40 DAS	14.8 (218)	13.2 (176)	4.36 (18.7)	3.92 (15.4)	2.79 (7.73)	1.91 (3.69)	6.38 (40.3)	6.17 (37.5)	72.0	76.8	0.08	0.04
Fenoxaprop with safener + ethoxysulfuron + one HW	23.1 (534)	22.2 (491)	12.96 (168)	12.1 (147)	5.17 (26.8)	4.63 (21.4)	10.0 (100)	8.40 (70.1)	24.9	40.2	0.56	0.48
Bispyribac + one HW	22.3 (499)	21.4 (456)	12.28 (150)	11.4 (130)	4.71 (22.0)	4.10 (16.6)	9.49 (90.5)	8.16 (66.2)	34.7	46.1	0.47	0.39
Hand weeding (20 and 40 DAS)	19.9 (398)	18.9 (356)	10.20 (104)	9.11 (83.2)	5.04 (26.2)	4.52 (21.7)	7.83 (60.9)	7.48 (55.5)	62.6	63.9	0.25	0.16
Weedy check	25.7 (661)	25.0 (624)	13.68 (186)	12.9 (166)	6.80 (46.0)	6.40 (40.7)	11.9 (142)	11.7 (135)	0.00	0.00	1.00	1.00
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	100	100	0	0
LSD (P=0.05)	0.41	0.39	0.21	0.19	0.27	0.08	0.18	0.16	-	-	-	-

Data are subjected to square root transformation ($\sqrt{x+0.5}$); Data given in parentheses are original values; DAS - Days after sowing

initial flush of weeds and all three types of weeds like, grasses, sedges and broad-leaved weeds. Singh *et al.* (1999) and Yaduraju and Mishra (2004) also reported that control of initial weed emergence facilitates better environment for direct seeded rice crop.

Weed dry weight

Significant variation in total weed dry weight under different weed management and crop establishment methods was observed. Zero-till DSR with anchored residue had minimum weed dry weight and the maximum weed dry weight was recorded by reduced till DSR (Table 1). This might be due to the fact that zero-till DSR with anchored residue of wheat crop facilitates in minimizing the weed infestation through soil. Singh *et al.* (2007) also mentioned that previous crop residue provide soil cover helps to minimize the weed dry weight. Among weed management treatments, pendimethalin *fb* azimsulfuron + one hand weeding recorded the minimum weed dry matter followed by pendimethalin *fb* 2,4-D EE + one HW. The reason behind this integration of pre- and post-emergence herbicides along with manual weeding minimized the weed dry weight. Wallia *et al.* (2008) reported that integration of pre-emergence application of pendimethalin followed by post-emergence of azimsulfuron resulted in effective weed control. The maximum weed dry weight recorded in weedy plots in respect to other treatment. Among herbicidal treatments, fenoxaprop + ethoxysulfuron + one hand recorded maximum weed dry weight.

Weed control efficiency and weed persistence index

Weed control efficiency (WCE) varied significantly at 60 days after sowing under different weed control treatments (Table 1). Weed control efficiency recorded minimum in reduced tillage DSR while maximum in zero-till DSR with anchored residue plots. The data clearly showed the effect of keeping anchored residue in weeds management. Maximum weed control efficiency (100%) was found with weed free at 60 days after sowing. Whereas, in weed management treatments weedy plots contain minimum WCE. The maximum WCE is found in pendimethalin + *fb* azimsulfuron + one hand weeding. The reason of good control of weeds was because of pre-emergence application of herbicide which controled first flush of grassy weeds and post application controled the sedges and broad-leaved weeds and one hand weeding helped to minimize the problem of remaining weeds in experiment. The integrated weed control appeared essential for raising direct-seeded rice (Gill 2008). This may be attributed to least competition as a result of effective suppression of sedges and dicot weeds thereby enabling plant to exhibit full potential in a competition free environment as evident by higher WCE in the said treatments. Similar results have been reported by Bahar and Singh (2004). Fenoxaprop + ethoxysulfuron + one hand weeding was not as effective as combined application of pre- and post-emergence herbicides. Weed persistence index showed the relevance of weed management on comparative basis (Table 1). Minimum weed persistence index recorded under zero-till DSR with anchored residue treatment (0.21 and 0.17) among crop establishment methods while, maximum in reduced tillage DSR (0.30 and 0.24). In weed management methods, minimum weed persistence index recorded under pendimethalin *fb* azimsulfuron + one hand weeding (0.08 and 0.04). The next treatment in this respect was pendimethalin *fb* 2,4-D EE + one HW at 40 DAS (0.13 and 0.09).

Effect on crop growth

Application of pre- and post-emergence herbicides did not show any phytotoxic symptoms on rice plant. Crop growth was variably recorded in the experiment on the basis of crop establishment and different weed management methods. Initial plant population recorded maximum in zero-till DSR with anchored residue (28.11 and 30.52 m/row) which is significantly superior over rest of the crop establishment methods. Zero-till DSR with anchored residue contains (6.7% and 7.6%) and (10.3 and 12.2%) more initial plant population over zero-till DSR and reduced tillage DSR during both the year (Table 2). This result occurred due to presence of residue (anchored or loose) conserve the moisture and inhibits the weed growth. Among the weed management methods pendimethalin *fb* azimsulfuron + one hand weeding recorded maximum initial plant population. Plant height was recorded at harvest is maximum under zero-till DSR with anchored residue but at par with zero-till DSR and reduced tillage DSR, respectively. Among the weed management methods, pendimethalin *fb* azimsulfuron + one hand weeding recorded maximum plant height. It is significantly superior over the rest of the treatment in first year (2008) while, at par with other treatments in second year (2009). Effective tillers recorded in per meter row length in the experiment varied with the stage to stage and treatment wise. During first year, effective tillers was maximum in zero-till DSR with anchored residue but at par with rest of the crop establishment methods while, in second year, zero-till DSR with anchored residue was significantly superior over rest of the treatments. Plant dry matter at harvest was observed significantly among the crop establishment methods. Zero-till DSR with anchored residue had recorded maximum plant dry matter production (g/m row) which is significantly superior over zero-till DSR and reduced tillage DSR treatments. Zero-till DSR with anchored residue produced (9.31% and 11.66%) and (9.32% and 11.28) more plant dry matter rather than zero-till DSR and reduced tillage DSR, respectively. These similar results are corroborated by Yadav and Singh (2006). In weed management methods, weed free showed the maximum crop height, tillers and crop dry matter production which is significantly superior over rest of the treatments.

Leaf area index of direct seeded rice increased with crop age and recorded at 60 days after sowing (Table 2). Among the crop establishment methods, zero-till DSR with anchored residue (3.87 and 3.97) attained maximum leaf area index rather than zero-till DSR and reduced till DSR during both the year. In weed management methods, maximum LAI were recorded under weed free (4.71 and 4.80) treatment and at par with the application of pendimethalin *fb* azimsulfuron + one hand weeding (4.53 and 4.70) during both the years and significantly superior over rest of the treatments. Similar results were also in agreement with Gill *et al*. (2006).

Effect on crop yield and harvest index

Rice established by zero-till DSR with anchored residue produced significantly higher grain yield than other two methods of establishment (Table 3). The maximum grain yield was recorded during both the years (4.56 and 4.78 t/ha) in zero-till DSR with anchored residue method which was 25.6% more than reduced till DSR and 16.2% more than zero-till DSR. Similar findings were also mentioned by Gill (2008) and Mishra *et al*. (2012). All the herbicidal treatments either applied in sequential combination with herbicides or with hand weeding significantly increased yield of rice as compared to weedy check during both the years of investigation. Among weed management methods, pendimethalin *fb* azimsulfuron + one hand weeding (5.45 and 5.54 t/ha) produced significantly maximum grain yield over rest of the treatments during the experimentation of both the years. Singh *et al*. (2010) reported that combination of azimsulfuron with pre-emergence herbicide produce significantly higher grain yield and straw yield. This is due to the fact that application of herbicides and manual weeding reduced the weed competition which enabled the direct seeded

Table 2. Effect of crop establishment methods and weed management on growth attributes in direct seeded rice

Treatment	Initial plant population (m/row at 20 DAS)		Plant height (cm)		Tillers (m/row)		Plant dry matter production (g/m row)		Leaf area index (at 60 DAS)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Establishment method										
Zero-till DSR	26.2	28.2	96.3	99.8	44.3	45.5	961	987	3.72	3.73
Zero-till DSR with residue	28.1	30.5	98.0	102	46.2	48.9	1050	1080	3.78	3.97
Reduced tillage DSR	25.2	26.8	95.8	98.9	43.9	44.6	941	970	3.87	3.72
LSD (P=0.05)	1.82	2.02	NS	NS	NS	3.23	67	69	0.27	0.26
Weed management										
Glyphosate *fb* pendimethalin *fb* 2,4-D EE	28.0	28.4	92.0	100	46.4	48.3	1013	1043	4.13	3.99
Pendimethalin *fb* 2,4-D + one HW at 40 DAS	29.1	28.7	98.2	103	48.7	50.2	1054	1089	4.36	4.43
Pendimethalin *fb* metsulfuron + chlorimuron + one HW at 40 DAS	25.0	27.2	98.1	98.2	42.2	44.9	964	980	3.72	3.62
Pendimethalin *fb* azimsulfuron + one HW at 40 DAS	30.1	34.1	103	106	55.2	55.3	1111	1163	4.53	4.70
Fenoxaprop with safener + ethoxysulfuron + one HW	23.7	26.1	91.7	94.4	38.4	37.6	913	921	3.04	3.24
Bispyribac + one HW	25.1	26.9	95.3	98.0	39.0	41.2	944	957	3.54	3.42
Hand weeding (20 and 40 DAS)	26.6	28.9	96.0	99.7	44.2	44.8	978	1001	3.88	3.79
Weedy check	19.7	19.8	91.8	91.2	29.3	35.0	739	772	2.19	2.28
Weed free	31.3	36.4	104	110	59.9	59.5	1140	1186	4.71	4.80
LSD (P=0.05)	1.10	1.16	3.90	4.11	1.88	1.93	40.36	41.47	0.16	0.16

DAS, Days after sowing

Table 3. Effect of crop establishment methods and weed management on grain yield straw yield, biological yield and harvest index

Treatment	Grain yield (t/ha)		Straw yield (t/ha)		Biological yield (t/ha)		Harvest Index (%)	
	2008	2009	2008	2009	2008	2009	2008	2009
Establishment methods								
Zero-till DSR	3.90	4.10	5.49	5.68	9.42	9.78	41.1	41.4
Zero-till DSR with residue	4.60	4.78	6.33	6.55	10.89	11.34	41.4	42.0
Reduced tillage DSR	3.60	3.76	5.11	5.23	8.75	8.99	41.0	41.2
LSD (P=0.05)	0.29	0.30	0.40	0.41	0.69	0.71	2.80	2.81
Weed management								
Glyphosate *fb* pendimethalin *fb* 2,4-D EE	4.40	4.58	5.96	6.18	10.36	10.76	42.5	42.5
Pendimethalin *fb* 2,4-D + one HW at 40 DAS	4.72	4.93	6.32	6.50	11.05	11.43	42.8	42.8
Pendimethalin *fb* metsulfuron + chlorimuron + one HW at 40 DAS	3.74	3.92	5.35	5.52	9.09	9.44	41.1	41.5
Pendimethalin *fb* azimsulfuron + one HW at 40 DAS	5.45	5.54	7.16	7.22	12.61	12.76	43.2	43.3
Fenoxaprop with safener + ethoxysulfuron + one HW	3.03	3.23	4.58	4.75	7.61	7.98	39.9	40.4
Bispyribac + one HW	3.29	3.52	4.89	5.07	8.18	8.59	40.2	40.9
Hand weeding (20 and 40 DAS)	4.00	4.17	5.59	5.88	9.59	10.06	41.7	42.0
Weedy check	2.03	2.19	3.65	3.76	5.68	5.95	35.7	36.8
Weed free	5.68	5.85	7.32	7.54	13.01	13.39	43.7	43.7
LSD (P=0.05)	0.17	0.18	0.24	0.24	0.41	0.42	1.69	1.70

rice plant for better utilization of nutrient and growth factors which ultimately resulted in higher grain yield. Same pattern was observed in respect of straw yield and biological yield. Maximum harvest index was noticed in zero-till DSR with anchored residue (41.38 and 42.05) among crop establishment methods while in weed management methods pendimethalin *fb* azimsulfuron + one hand weeding had the maximum harvest index.

It can be concluded that zero-till DSR with anchored residue with pendimethalin 1000 g/ha (pre-emergence) *fb* azimsulfuron 35 g/ha at 15 - 20 DAS + one HW at 40 DAS was found to be most effective for minimizing weed growth and maximizing crop growth and yield of direct-seeded rice.

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Weed management in rice grown under System of Rice Intensification

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ABSTRACT

An experiment was conducted to assess the efficacy of different weed management practices in rice grown under the System of Rice Intensification (SRI) in comparison with the conventional system. The study was carried out during 2007 and 2008 in the lateritic sandy clay loam soils at Pattambi, Kerala. Density and dry weight of weeds were higher in SRI especially when weed control was done through repeated cono weeding, while they were lower in the conventional system. Conventional system with cono weeding at 10 DAT followed by hand weeding at 30 DAT, and post-emergence herbicides alone reduced the weed dry weight significantly. Net returns and B:C ratio were also the highest in the conventional system with post-emergence application of cyhalofop-butyl 0.1 kg/ha followed by metsulfuron-methyl + chlorimuron-ethyl. In SRI, the weed density and dry weight were the lowest with pre-emergence herbicide followed by hand weeding at 30 DAT, and cono weeding at 10 DAT followed by post-emergence herbicides. However, weed control with post-emergence application of cyhalofop-butyl, followed by metsulfuron-methyl + chlorimuron-ethyl gave higher B:C ratio in both systems.

Key words: Cono weeding, Conventional system, Herbicides, System of Rice Intensification, Weed management

System of Rice Intensification (SRI) is reported as a sustainable low-cost alternative to the conventional rice farming. This system ensures high yields with less input, especially with respect to irrigation water and seed. Heavy weed growth is a major problem in SRI mainly because of the wider spacing and lack of flooding in the field. Therefore, SRI warrants repeated weeding either by hand or by machine weeders such as the cono weeder. Cono weeding is a tiresome job under non-flooding situation requiring more labour investment, and hence is not being adopted successfully leading to occasional crop loss. Latif *et al.* (2005) reported the effectiveness of using herbicides in SRI, which could reduce labour for weeding and thereby minimize economic loss in SRI. The present study aims at identifying the weed problems under SRI in comparison with the conventional system (CS) of rice cultivation and developing an economic weed management strategy in SRI.

MATERIALS AND METHODS

An experiment using the rice cultivar '*Jyothi*' (110 to 120 days) was conducted during the *Rabi* seasons of 2007 and 2008 in the lateritic sandy clay loam soils of Regional Agricultural Research Station, Pattambi in Palakkad district in Kerala. The soil was with pH 5.0 and medium fertility. The area enjoys tropical monsoon climate with >80% rainfall distributed through South-West and North-East monsoon showers. The experiment was laid out in randomized block design with 16 treatments, replicated thrice in plots of 20 m^2 gross area. Details of the treatments are given below:

- T_1- SRI with four cono weedings at 10, 20, 30 and 40 days after transplanting (DAT)
- T_2- SRI with pre-emergence herbicide followed by one hand weeding at 30 DAT
- T_3- SRI with pre-emergence herbicide followed by one cono weeding at 30 DAT
- T_4- SRI with two cono weedings at 10 and 30 DAT
- T_5- SRI with one cono weeding at 10 DAT followed by one hand weeding at 30 DAT
- T_6- SRI with one cono weeding at 10 DAT followed by post emergence herbicides
- T_7- SRI with post emergence herbicides alone
- T_8- SRI with four cono weeding at 10, 20, 30 and 40 DAT + organic manure alone (the typical SRI)
- T_9- Conventional system (CS) with four cono weedings at 10, 20, 30 and 40 DAT
- T_{10}- CS with pre-emergence herbicide followed by one hand weeding at 30 DAT

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T_{11}- CS with pre-emergence herbicide followed by one cono weeding at 30 DAT

T_{12}- CS with two cono weedings at 10 and 30 DAT

T_{13}- CS with one cono weeding at 10 DAT followed by one hand weeding at 30 DAT

T_{14}- CS with one cono weeding at 10 DAT followed by post emergence herbicides

T_{15}- CS with post emergence herbicides alone

T_{16}- CS with two hand weedings at 20 and 40 DAT (Normal POP)

Pre-emergence herbicide butachlor 1.25 kg/ha was used. Post-emergence treatment included cyhalofop-butyl 0.1 kg/ha at 18 DAT followed by metsulfuron-methyl 10% + chlorimuron-ethyl 10% at 20 DAT.

In SRI, 10 days old single seedlings were transplanted at 30 x 30 cm spacing, while in the conventional system (CS), 20 days old seedlings (two each) were transplanted at 20 x 10 cm spacing. In the conventional system, water management was done as per the package of practices, whereas in SRI, irrigation was done just enough to get the soil saturated and subsequent irrigation was given as and when the soil developed fine cracks. This irrigation schedule was followed till the crop completed its tillering phase, and thereafter standing water of 2.5 cm depth was maintained in the field. Vermicompost (1.5% N, 0.4% P_2O_5, 1.8% K_2O) was used as the organic manure and chemical fertilizers, urea (46% N), phosphorus (20% P_2O_5) and muriate of potash (60% K_2O) were used to supply N, P and K, respectively.

The quantity of spray fluid used for both pre-emergence as well as post-emergence herbicides was 300 liter/ha. Cono weeding was done perpendicularly in two directions in the SRI, while in the conventional system, it was done between the rows only. Observations on growth parameters, yield attributes, and yield were recorded. Observations on weed density and weed dry weight were recorded from the sampling strip in each plot at 45 and 60 DAT, using a quadrat of size 0.5 m x 0.5 m.

The N, P and K contents of weeds at panicle initiation stage of the crop were estimated as per the standard procedures and calculated the nutrient uptake (kg/ha) by the weeds. Cost of cultivation was worked out taking into account the prevailing labour charge in the locality, cost of inputs and the extra treatment costs and expressed in `/ha. The gross return was calculated based on the local market prices of paddy and straw and expressed on per hectare basis.

RESULTS AND DISCUSSION

Major weeds in the experimental fields were: *Isachne miliacea* (grass), *Cyperus iria*, *Cyperus difformis*, *Fimbristylis miliacea*, and *Schoenoplectus lateriflorus* (sedges) and *Sphenoclea zeylanica*, *Ludwigia perennis* and *Dopatrium junce*um (broad-leaf weeds). Compared to sedges and broad-leaf weeds, grasses were less in SRI at 60 days after planting (Table 1). *Isachne miliacea*, *Cyperus iria*, *Fimbristylis miliacea* and *Sphenochlea zeylanica* grew taller than rice in the early growth phase of rice. Highest total weed density and weed dry weight at 45 days after planting were observed in SRI with two cono weedings at 10 and 30 days after transplanting (DAT) (T_4). At 60 days after planting also, the treatment T4 recorded the highest weed density, while the highest weed dry weight was recorded in SRI with four cono weedings at 10, 20, 30 and 40 DAT.

The results indicated higher occurrence of weeds in the System of Rice Intensification compared to the conventional system. In SRI, the practice of alternate wetting and drying created a congenial environment for proliferation of weeds and hence early and frequent weeding is essential (Singh *et al.* 2010). Increased spacing between or within rows increased light penetration to the soil surface which enhanced weed growth (Mertens and Jansen 2002). Higher weed competition under SRI compared to conventional system can be attributed to the congenial environment enjoyed by the weeds through wider plant spacing and aerobic soil condition.

Cono-weeding, either twice or four times could not check the growth of weeds even in the initial phases of crop growth in SRI as well as conventional system. The weed density at 60 days after transplanting was the highest in SRI with two cono-weeding at 10 and 30 DAT. Similarly, SRI with cono-weeding at 10, 20, 30 and 40 DAT recorded the highest weed dry weight at 60 DAT (Table 1). Further, the yield advantage in SRI through mechanical weeding as reported by Stoop *et. al.* (2002) was not observed in this study. Even though, SRI increased the number of productive tillers per hill, length of panicle as well as percentage of filled grains per panicle, the low yield in SRI, especially with twice or four times cono-weeding, was due to higher weed density and weed dry weight accompanied with lesser number of productive tillers per unit area.

Conventional system with cono weeding at 10 DAT followed by hand weeding at 30 DAT (T_{13}) recorded the lowest weed density and weed dry weight at 45 days after planting. At 60 days after planting, weed density was the lowest in the conventional system with pre-emergence herbicide followed by cono

Table 1. Density and dry weight of weeds at 60 days after planting in rice

Treatment	Weed density (no./m^2)				Weed dry weight (g/m^2)
	Grasses	Sedges	Broad-leaf weeds	Total weeds	
T_1	1.47^{cde} (2.00)	8.87^{ab} (78.33)	5.63^{b} (31.33)	10.57^{b} (111.7)	11.12^{a} (123.5)
T_2	2.53^{a} (6.00)	8.56^{bc} (73.00)	6.94^{a} (48.00)	11.27^{b} (127.0)	5.13^{d} (26.38)
T_3	1.94^{abcd} (3.33)	8.85^{ab} (78.67)	5.21^{bcd} (26.67)	10.43^{b} (108.67)	6.70^{c} (44.43)
T_4	1.29^{def} (1.33)	9.67^{a} (93.33)	7.81^{a} (60.67)	12.47^{a} (155.3)	9.44^{b} (89.84)
T_5	2.23^{ab} (4.67)	6.48^{d} (41.67)	4.90^{bcd} (23.67)	8.40^{cd} (70.00)	4.33^{de} (18.29)
T_6	2.08^{abc} (4.00)	4.52^{ef} (20.00)	3.42^{ef} (11.33)	5.97^{ef} (35.33)	3.75^{ef} (13.59)
T_7	1.94^{abcd} (3.33)	7.73^{c} (59.33)	3.38^{ef} (11.00)	8.61^{c} (73.67)	6.55^{c} (43.15)
T_8	1.29^{de} (1.33)	6.82^{d} (46.00)	3.06^{f} (9.33)	7.56^{d} (56.67)	7.16^{c} (50.75)
T_9	2.23^{ab} (4.67)	3.69^{fg} (13.33)	3.42^{ef} (11.33)	5.44^{ef} 29.33)	3.89^{e} (14.69)
T_{10}	2.08^{abc} (4.00)	3.23^{gh} (10.00)	3.80^{ef} (20.67)	5.34^{f} (28.00)	2.34^{gh} (5.05)
T_{11}	1.94^{bcde} (2.00)	2.44^{h} (5.647)	3.12^{f} (9.33)	4.16^{g} (17.00)	3.88^{e} (14.67)
T_{12}	1.29^{def} (1.33)	5.27^{e} (27.33)	5.19^{bcd} (27.33)	7.48^{d} (56.00)	4.99^{d} (24.43)
T_{13}	0.71^{f} (0.00)	3.62^{g} (12.67)	4.25^{cde} (17.67)	5.55^{ef} (30.33)	1.79^{h} (2.71)
T_{14}	1.76^{bcd} 2.67)	2.79^{gh} (7.33)	4.21^{de} (17.33)	5.27^{f} (27.33)	2.02^{gh} (3.630
T_{15}	1.00^{ef} (0.67)	3.32^{gh} (6.67)	5.24^{bc} (27.00)	6.23^{ef} (38.33)	1.54^{h} (1.88)
T_{16}	1.76^{bcd} (2.67)	4.96^{e} (24.33)	3.89^{ef} (14.67)	6.47^{e} (41.67)	2.81^{fg} (7.43)

Values are $\sqrt{x + 0.5}$ transformed, original values are in parentheses

The values followed by the same letters do not differ significantly in DMRT at 5% level

weeding at 30 DAT (T_{11}). Treatment (T_{13}) as well as conventional system with post-emergence herbicides (T_{15}) reduced the weed dry weight and nutrient removal by the weeds at 60 days after planting (Table 2). Treatment T_{15} increased the number of productive tillers per unit area, panicle length, number of filled grains/ panicle and 1000-grain weight, and produced the highest grain yield of 2.87 t/ha (Table 3). This was 32.7% higher than the grain yield in the typical SRI treatment. Conventional system with cono weeding at 10 DAT followed by hand weeding at 30 DAT (T_{13}) also produced yield at par with this, but the former recorded higher net returns and B:C ratio, which was significantly higher than the recommended practice of two hand weeding at 20 and 40 DAT.

Among the different weed control methods tried under SRI, pre-emergence herbicide combined with cono weeding at 30 DAT (T_3) recorded the lowest weed density at 45 days after planting. This was on par with pre-emergence herbicide combined with hand weeding at 30 DAT (T_2). The latter recorded the lowest weed dry weight at 45 days after planting. Pre-emergence herbicide combined with hand weeding at 30 DAT reduced densities of sedges and total weeds and the weed dry weight at 45 days after planting in SRI. At 60 DAT, cono weeding at 10 DAT combined with post-emergence herbicides (T_6) recorded the lowest densities of sedges, broad-leaf weeds and total weeds in SRI, and thereby reduced the dry weight and nutrient removal by the weeds (Table 1 and 2). SRI with pre-emergence herbicide followed by hand weeding at 30

Table 2. Nutrient removal by weeds at 60 days after planting in rice (kg/ha)

Treatment	N	P	K
T_1	24.05^{a}	3.88^{a}	1.52^{ab}
T_2	6.05^{de}	0.87^{d}	1.66^{a}
T_3	10.20^{c}	1.44^{c}	1.60^{ab}
T_4	16.59^{b}	2.78^{b}	1.48^{ab}
T_5	3.72^{efg}	0.56^{de}	1.64^{a}
T_6	2.94^{efg}	0.46^{def}	1.54^{ab}
T_7	7.65^{cd}	1.53^{c}	1.47^{abc}
T_8	10.12^{c}	1.51^{c}	1.39^{abc}
T_9	2.40^{fg}	0.41^{def}	1.29^{bc}
T_{10}	0.89^{g}	0.16^{ef}	0.57^{f}
T_{11}	3.12^{efg}	0.51^{def}	1.16^{cd}
T_{12}	5.00^{def}	0.74^{de}	0.66^{ef}
T_{13}	0.51^{g}	0.08^{f}	1.48^{abc}
T_{14}	0.71^{g}	0.11^{ef}	0.72^{abc}
T_{15}	0.36^{g}	0.06^{f}	0.94^{de}
T_{16}	1.19^{g}	0.25^{def}	0.71^{ef}

The values followed by the same letters do not differ significantly in DMRT at 5% level

DAT (T_2) increased the number of productive tillers/ hill, length of panicle and number of filled grains/ panicle and produced significantly higher grain yield which was 14.2% higher than the yield in the typical SRI treatment (Table 3).

Table 3. Effect of treatments on yield and economics of rice cultivation

Treatment	Productive tillers (no./hill)	Panicle length (cm)	Filled grains (%)	Grain yield (t/ha)	Straw yield (t/ha)	Net returns (x10^3 `/ha)	B:C ratio
T_1	21.9^{ab}	20.1^{ab}	87.3^{a}	1.88^{fg}	1.90^{cdef}	-11.01^{h}	0.72^{g}
T_2	23.5^{a}	20.4^{a}	82.0^{b}	2.47^{bcde}	2.29^{ab}	-3.84^{efg}	0.91^{def}
T_3	23.6^{a}	20.5^{a}	82.5^{ab}	1.60^{g}	1.94^{bcdef}	-11.76^{h}	0.68^{g}
T_4	18.5^{b}	20.0^{abc}	80.8^{b}	1.86^{fg}	2.26^{abc}	-8.04^{gh}	0.78^{fg}
T_5	22.1^{a}	20.5^{a}	82.1^{b}	2.51^{abcde}	2.23^{ab}	-4.34^{fg}	0.90^{ef}
T_6	23.2^{a}	20.3^{ab}	83.1^{ab}	2.33^{de}	2.51^{a}	-2.42^{cdef}	0.94^{de}
T_7	21.7^{ab}	20.3^{ab}	80.1^{b}	2.28^{de}	2.17^{abcde}	-1.05^{bcdef}	0.97^{cde}
T_8	21.3^{ab}	20.5^{a}	83.0^{ab}	2.16^{ef}	2.47^{a}	-3.26^{defg}	0.91^{def}
T_9	8.6^{c}	18.6^{de}	80.3^{b}	2.41^{cde}	2.00^{bcde}	1.86^{bcd}	1.05^{bcd}
T_{10}	10.3^{c}	18.7^{de}	81.9^{b}	2.81^{ab}	2.04^{bcdef}	4.43^{ab}	1.12^{b}
T_{11}	9.7^{c}	18.7^{de}	82.8^{ab}	2.35^{de}	1.97^{bcdef}	1.74^{bcde}	1.05^{bcd}
T_{12}	9.1^{c}	18.7^{de}	82.4^{ab}	2.85^{ab}	1.93^{bcdef}	9.35^{a}	1.29^{a}
T_{13}	8.9^{c}	19.8^{abc}	82.2^{b}	2.78^{abc}	1.87^{def}	4.19^{ab}	1.11^{bc}
T_{14}	9.5^{c}	19.0^{cde}	83.2^{ab}	2.56^{abcd}	1.82^{ef}	3.12^{bc}	1.09^{bc}
T_{15}	10.6^{c}	19.3^{bcd}	83.6^{ab}	2.87^{a}	2.04^{bcdef}	8.90^{a}	1.27^{a}
T_{16}	9.0^{c}	18.2^{e}	81.5^{b}	2.60^{abcd}	1.75^{f}	0.67^{bcdef}	1.02^{bcde}

The values followed by the same letters do not differ significantly in DMRT at 5% level

Economic analysis of the treatments showed that the net return and B:C ratio were the highest in the treatments where the weeds were controlled by post-emergence herbicides in the conventional (T_{15}) and SRI (T_7) systems of growing rice (Table 3). Cono weeding at 10 and 30 DAT (T_{12}) was at par with post-emergence herbicide treatment (T_{15}) in the conventional system but it could not repeat its performance in SRI.

It was concluded that weed control by post-emergence herbicides was superior in SRI as well as conventional system of rice cultivation. Even though hand weeding or cono weeding performed at par with post-emergence herbicides in reducing the weed dry weight, weed control with post-emergence application of cyhalofop-butyl followed by metsulfuron-methyl + chlorimuron-ethyl resulted in higher net returns and B:C ratio.

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Influence of crop density on weeds, growth and yield of direct-seeded rice

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ABSTRACT

Field experiment was conducted during *Kharif* 2009 and 2010 to study the effect of rice seed rate (20, 30, 40 and 50 kg/ha) and inter row spacing (15, 20, 25 and 30 cm) on weeds, crop growth and grain yield of direct-seeded rice. Population of *Echinochloa* and *Cyperus* was minimum when DSR was sown with seed rate of 50 kg/ha with 15-20 cm row spacing and it was maximum when lower seed rate of 20-30 kg/ha was used with wider row spacing of 30 cm. Weed biomass was significantly affected by seed rate, being maximum with lower seed rate usage of 20 kg/ha and decreased significantly with each successive increase in seed rate. With the increase in row spacing from 15 to 30 cm, weed biomass increased significantly. Maximum number of tillers was recorded when rice was sown with seed rate of 50 kg/ha with wider row spacing of 30 cm. The seed rates and row spacings did not have any significant effect on effective tillers and grain yield of dry-drilled rice.

Key words: Direct-seeded rice, Grain yield, Row spacing, Seed rate, Weed management

Rice is the most important cereal crop and is the staple diet of 70 per cent of the world's population. Due to receding water table, rising costs of labour for transplanting of paddy and the adverse effects of puddling on soil health, direct-seeded rice (DSR) is gaining popularity (Kumar and Ladha 2011). High seed rates are used in DSR generally to help smother weeds (Dixit *et al.* 2010), compensate for damage by rats and birds, partially overcome the adverse effects of herbicides and compensate for poor crop establishment (Payman and Singh 2008). Crop density and row arrangement also affect the weed growth. Higher crop density can put pressure on the availability of space for weed growth and make the crop more competitive against weeds (Phuong *et al.* 2005, Mahajan *et al.* 2006).

Higher than optimum initial seeding density for obtaining more panicles/m^2 is often accompanied by reduced panicle size, higher rate of spikelet sterility, nitrogen deficiency, reduced tillering, increased proportion of ineffective tillers, more lodging problem and increase chances of rat damage, insect attack and disease infection (Singh and Kumar 2009). There has been increased interest recently in the use of cultural methods in integrated weed management systems (Rao *et al.* 2007). Narrow crop row spacing could be considered as an agronomic tool for weed control. Narrower crop row spacing provided better competition of paddy crop against weeds due to early crop canopy cover which smothered weeds (Payman and Singh 2008, Chauhan and Johnson 2011) and gave rise to higher productive tillers (Lampayan *et al.* 2010) and grain yield of rice (Mahajan and Chauhan 2011). The present study was carried out to study the influence of different seed rates and row spacing of rice on weeds, growth and grain yield of dry-drilled seeded rice.

MATERIALS AND METHODS

The field experiment was conducted at Punjab Agricultural University, Ludhiana during *Kharif* seasons of 2009 and 2010. Ludhiana is situated in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangetic Alluvial plains at 30°56' N latitude, 75°52' E longitude and at an altitude of 247 m above mean sea level. The total rainfall of 818 and 627.6 mm were received during 2009 and 2010, respectively. Most of the rainfall was received in vegetative phase from 23rd (at sowing time) to 35th standard meteorological week (at 80 days after sowing). The soil of the experimental site was loamy sand (coarse loamy, mixed hyperthermic, Typic Ustipsamments) with normal soil reaction (pH 7.5) and electrical conductivity (0.16 dS/m). The soil was low in organic carbon (0.31%) and available N (251.7 kg/ha) and medium in available P (13.5 kg/ha) and K (164.1 kg/ha). Treatments comprised combinations of four seed rates (20, 30, 40 and 50 kg/ha) and four row to row spacings (15, 20, 25 and 30 cm) and were replicated thrice in a randomised complete block design. Sowing of rice cv. *'PAU 201'* was done during the first week of June using treated seed on

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fine seedbed with single row seed drill as per seed rate and row spacing. Recommended package of practice was followed for raising crop. The crop was harvested manually from net plot area of 3 × 2.40 m in first week of November. The data were statistically analyzed by using statistical procedures. The pooled analysis of two years was done and comparisons were made at 5 per cent level of significance.

RESULTS AND DISCUSSION

Effect on weed population and biomass

Weed flora of the experimental field consisted mainly of grasses, *viz. Echinochloa crusgalli* and *Echinochloa colona* and sedges, *viz. Cyperus iria, Cyperus compressus* and *Cyperus rotundus*. The pre-emergence spray of pendimethalin 0.75 kg/ha was done which controlled aerobic grasses and broad-leaf weeds associated with DSR. The weed data recorded before post-emergence spray of bispyribac-sodium 0.025 kg/ha at 30 DAS showed that with each increase in seed rate, weed count and biomass decreased significantly as seed rate determines the number of plants per unit area which shows competitive effect against weeds. The density of *Echinochloa* and *Cyperus* spp. was significantly lower with seed rate of 50 kg/ha as compared with 20, 30 and 40 kg/ha of seed rate resulting in low weed biomass. Density of *Echinochloa*/m^2 was significantly lower with seed rate of 40 kg/ha as compared with 20 and 30 kg/ha (Table 1). More weed density in lower seed rates might be due to the presence of gaps and greater space that encouraged the weeds growth. Walia *et al.* (2009) and Mahajan *et al.* (2010) reported that weed biomass decreased linearly with increased seed rates although increasing seed rate beyond the optimum level had no influence on weed density. Payman and Singh (2008) also reported that increasing seed rate from 40-60 kg/ha helped in suppressing the weed density at 30 and 60 DAS. Zhao *et al.* (2007) and Gill *et al.* (2006) also observed that weeds in plots with a lower seeding rate have a better chance to emerge, grow and build up a strong population. Weed biomass decreased linearly with increasing seeding rates from 15 to 125 kg/ha (Chauhan *et al.* 2011). Whereas, Mahajan *et al.* (2010) reported that rice seed rate did not influence density of *Echinochloa colonum*, while density of sedges was

Table 1. Interaction effects of seed rate and row spacings on weeds and growth of direct-seeded rice (mean data of two years)

Seed rate (kg/ha)	Row spacing (cm)				
	15	20	25	30	Mean
Density (no./m^2) of Echinochloa spp. at 30 DAS					
20	2.0	2.4	4.0	4.9	3.3
30	1.9	2.5	3.2	5.1	3.2
40	1.9	2.5	2.9	3.3	2.6
50	1.4	1.5	2.0	2.5	1.9
Mean	1.8	2.2	3.0	3.9	
LSD (P=0.05)	Seed rate: 0.3, row spacing: 0.3, interaction: 0.7				
Weed density (no./m^2) of Cyperus spp. at 30 DAS					
20	93.9	106.7	142.3	221.7	141.1
30	81.6	108.3	137.5	159.6	121.8
40	61.0	85.2	95.4	145.5	96.8
50	29.2	46.5	54.9	102.9	58.4
Mean	66.4	86.7	107.5	157.4	
LSD (P=0.05)	Seed rate: 7.3, row spacing: 7.3, interaction: 14.7				
Weed biomass (g/m^2) at 30 DAS					
20	26.5	27.2	27.9	37.4	29.7
30	16.1	24.5	27.4	31.6	24.9
40	17.1	16.2	18.5	20.3	18.0
50	13.6	14.2	17.8	20.3	16.4
Mean	18.3	20.5	22.9	27.4	
LSD (P=0.05)	Seed rate: 0.3, row spacing: 0.3, interaction: NS				
Rice tillers (no./m^2) at 90 DAS					
20	459.6	503.8	430.0	462.5	464.0
30	441.7	502.9	477.9	491.4	478.5
40	435.8	489.2	575.5	479.2	495.0
50	429.2	476.2	499.2	605.0	502.4
Mean	441.6	493. 0	495.6	509.5	
LSD (P=0.05)	Seed rate: NS, row spacing: 44.8, interaction: 89.5				

influenced resulting in decrease of 34.5 per cent with 240 kg as compared with 15 kg/ha. Density of *Echinochloa* and *Cyperus* spp. was maximum with 30 cm as compared with narrower row spacings of 15, 20 and 25 cm, resulting in more weed biomass.

Weed count was observed to be more due to more space available in wider row spacings. Chauhan and Johnson (2010, 2011) also reported that rice crop sown in wider spacing were vulnerable to weed competition for the longest period (49 days) as compared with narrower spacing (39 days) and had greater weed biomass. Weed population of *Echinochloa* and *Cyperus* was minimum when DSR was sown with seed rate of 50 kg/ha with 15-20 cm row spacing and it was maximum when lower seed rate of 20-30 kg/ha was used for sowing at wider row spacing of 30 cm. *Echinochloa* and *Cyperus* count was statistically similar when DSR was sown with higher seed rate of 50 kg/ha at wider row spacing of 30 cm with DSR sown at seed rate of 20 kg/ha under narrow row spacing of 15 cm. Thus, narrow row spacing under lower seed rate controlled weeds as effectively as higher seed rate of 50 kg/ha, thus by adopting cultural practice of narrow row spacing, additional cost of vital input-seed can be saved. After the application of post-emergence herbicide, no weed population was observed in further periodical observations.

Effect on rice growth

Rice plant height and number of tillers at 90 DAS were significantly affected by row to row spacing. The tiller number increased up to 90 DAS and later on decreased with the advancement of crop age due to mortality of ineffective tillers. Rice plants were significantly taller at narrow row spacing of 15 cm compared with wider row to row spacings of 25 and 30 cm but were statistically at par with 20 cm row spacing (Table 2). Rice plants elongated more for want of light in narrow row spacing. The number of tillers was significantly more when rice was seeded with wider row spacing of 20-30 cm than narrow row spacing of 15 cm (Table 1). Although there is no significant variation in number of tillers produced by direct-seeded rice with increase in seed rate from 20 to 50 kg/ha, but more tillers were produced when rice crop was sown with seed rate of 20-30 kg/ha and spaced at narrower row spacing of 15-20 cm. With increase in seed rate to 40-50 kg/ha, rice crop being seeded at wider row spacing of 25-30 cm produced more number of tillers. Crop dry matter accumulation increased with increase in seed rate and row spacing at 90 DAS although no significant variation was observed (Table 2). Phuong *et al.* (2005) and Chauhan *et al.* (2011) also observed that tillers and biomass of rice increased linearly with increase in seed rate under both weedy and weed-free environments.

Effect on yield of rice

The number of effective tillers tend to increase with increase in seed rate from 20-50 kg/ha but number of grains/panicle decreased, thus, no gain in grain yield was observed. With increase in row spacing from 15-30 cm, non-significant increase in number of effective tillers and grain/panicle was observed. Chauhan and Johnson (2010) observed that rice crop sown in wider spacing produced more grains/panicle. The grain weight/panicle decreased with the increase in seed rate from 20 to 50 kg/ha though the differences were non-significant (Table 2). Grain yield was not influenced statistically by different seed rates suggesting that direct-seeded rice can be drilled with lower seed rate without any yield losses under weed-free conditions and it saves the cost of vital input 'seed'. Payman and Singh (2008) also reported that increasing seed rate from 40 to 60 kg/ha did not influence the grain yield significantly. Similarly, Zhao *et al.* (2007) reported that under weedfree conditions, grain yield were not influenced by the seed rates within the range of 15 to 125

Table 2. Effect of seed rate and row spacings on growth and yield of direct-seeded rice (mean data of two years)

Treatment	Rice plant height (cm) at 90 DAS	Rice biomass (g/m^2) at 90 DAS	Effective tillers ($no./m^2$)	Grains/panicle (no.)	Grain weight/ panicle (g)	Grain yield (t/ha)
Seed rate (kg/ha)						
20	79.3	1317	312	87	2.2	5.4
30	80.4	1386	314	84	2.1	5.5
40	80.6	1389	320	84	2.1	5.5
50	82.2	1422	322	81	2.0	5.7
LSD (P=0.05)	NS	NS	NS	NS	NS	NS
Row spacing (cm)						
15	83.7	1314	311	83	2.1	5.8
20	81.6	1372	314	83	2.1	5.6
25	79.7	1383	321	85	2.1	5.5
30	77.4	1445	323	85	2.1	5.3
LSD (P=0.05)	3.0	NS	NS	NS	NS	NS

kg/ha. Chauhan *et al.* (2011) also observed that under weed free conditions, number of panicles and grain yield of rice was not influenced by seed rates but under weedy environments, these parameters increased in quadratic relation with increase in seed rate. Numerically, the lowest grain yield was obtained with wider row spacing of 30 cm as compared with narrow row spacings although the differences were non-significant, suggesting that direct-seeded rice can be drilled at 15 cm to 30 cm without any yield losses under weed-free conditions. Lampayan *et al.* (2010) also reported that the grain yield was similar for row spacings ranging from 25 to 35 cm. Whereas, Chauhan and Johnson (2011) reported that aerobic rice grown in 30 cm rows produced less grain yield as compared to that in 15 cm and 10-20-10 cm paired rows.

Thus, optimum seed rate for direct-seeding of rice is 20 kg/ha and optimum row to row spacing varied from 15-30 cm. Sowing rice at narrow row spacing resulted in lower weeds density and biomass in DSR.

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Effect of tillage and weed management practices on weed dynamics, weed seed bank and grain yield of wheat in rice-wheat system

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ABSTRACT

A field experiment was conducted during two consecutive *Rabi* season of 2005-06 and 2006-07 at NEB Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar on sandy loam soil to find out the effect of tillage and weed management practices on weeds, weed seed bank in soil and grain yield of wheat grown after rice. Zero till sown wheat had significantly lesser weed dry weight per unit area as compared to conventional sown wheat. *Phalaris minor, Melilotus indica* and *Chenopodium album* seed density in soil were significantly lower under zero tillage as compared to conventional tillage from 0 to 5, 5 to10 and 10 to 15 cm soil depths. Excellent suppression in weed density and dry weight and higher yield of wheat were obtained with two hand weeding under conventional tillage system. Under weedy situation, zero tillage was found better because of less weed emergence.

Key words: Conventional tillage, Isoproturon, Metsulfuron-methyl, Weed dynamics, Zero tillage

Rice-wheat is the most dominant cropping system in Indo-Gangatic Plains. Sowing of wheat in this tract is generally delayed due to the cultivation of long and medium duration rice varieties as well as time required in field preparation for wheat. Tillage practices after rice harvest also require more labour and energy which increase cost involves in field preparation. Zero and reduced tillage have an advantage of early planting, reduced cost of production as well as chances of green house gas emission (Hobbs 2002). Weed management is an important aspect in wheat production as 10 to 50% yield loss is common due to damage caused by associated weeds. For efficient and economic management of weeds in wheat, isoproturon has been found to be the most suitable herbicide for last two decades in India (Singh *et al.* 2001). The continuous use of single herbicide develops resistance in *P. minor* against this herbicide. Use of clodinafop-propargyl along with metsulfuron-methyl has been found promising against resistant *P. minor* biotype and non-grassy weeds. Therefore, the present investigation was conducted to study the influence of tillage and weed management practices on the weed dynamics and grain yield of wheat.

MATERIALS AND METHODS

A field experiment was conducted at NEB Crop Research Centre, G.B. Pant University of Agriculture & Technology, Pantnagar, during *Rabi* seasons of 2005-06 and 2006-07. The soil of experimental field was sandy loam in texture, medium in organic carbon (0.65%), low in available N (262 kg/ha), medium in available P (37.6 kg/ha) and high in K (260 kg/ha) contents with pH 7.8. The experiment was laid out in split-plot design with twelve treatments comprising three tillage methods, *viz*. zero tillage, reduced tillage and conventional tillage in main plots; and four weed management practices, *viz*. two hand weeding at 35 and 55 DAS (days after sowing), isoproturon 1.0 kg/ha, clodinafop-propargyl 60 g followed by metsulfuron-methyl 4 g/ha and weedy check, in sub-plots and was replicated thrice. Wheat variety '*PBW 343*' was sown in rows, 20 cm apart on 19 and 22 November in zero tillage and on 25 and 29 November in other tillage systems in 2005-06 and 2006-07, respectively. All the package and practices were applied to raise the crop except weed management. The fertilizer was applied at 120: 60: 40 kg N: P: K/ha and three irrigations were given at critical stages only by flooding method. Post-emergence application of isoproturon and clodinafop-propargyl was done 30 DAS while metsulfuron-methyl (MSM) was applied one week after first spray. The herbicides were applied using Maruti foot sprayer fitted with flat fan nozzle. Soil samples were collected from each plot separately before sowing and after harvesting of crop by using core sampler to determine the bulk density, organic matter and weed seed bank in soil, respectively. Data on density and dry matter of weeds were subjected to log transformation *i.e.* $\log_e (x+1)$ before statistical analysis.

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RESULTS AND DISCUSSION

Soil parameters

Zero tillage, which was at par with reduced tillage recorded significantly higher bulk density of soil as compared to conventional method of sowing. Higher bulk density in zero tillage might be due to the puddling in previous rice crop and repeated movement of heavy implements that compressed the soil. However, the same soil was loosened where harrowing were done in reduced and conventional tillage. This was in confirmation with the findings of Pandey *et al.* (2005). The organic carbon in zero till soil was also found higher than others but the differences were found non-significant. Greater oxidation of organic carbon in intensively tilled soil resulted in dilution of organic carbon concentration of the top soil. However, in untilled soil, organic carbon tended to accumulates near the surface of the soil (Kumar and Yadav 2005).

Effect on weeds

The major weed flora observed in the experimental field included *Phalaris minor* (50.4%), *Melilotus indica* (18.3%), *Chenopodium album* (8.6%), *Medicago denticulata* (7.7%) and *Rumex acetocella* (7.0%). Other minor weeds, *viz. Coronopus didymus, Lathyrus aphaca, Vicia sativa, Fumaria parviflora, Polygonum plebejum,* and *Cyperus rotundus* accounted for 8.0% of total weed population.

Total weed density was not influenced significantly by different tillage practices though numerically higher values were recorded under conventional followed by reduced tillage during both the year of experimentation (Table 1). Wheat sown with zero till drill exhibited significantly lower weed dry weight per unit area than conventional method of wheat sowing, however, it was found non-significant with reduced tillage. The similar trend was also observed by Prasad *et al.* (2005) and Sinha and Singh (2005).

Among the weed management practices, two hand weeding (35 and 55 DAS) provided excellent control of all the weed species in both the years, though the differences were non- significant with clodinafop *fb* MSM. The isoproturon also reduced weed infestation significantly than weedy but did not prove as promising as clodinafop *fb* MSM. The higher weed control efficiency (WCE) was recorded under hand weeding twice which was at par with clodinafop *fb* MSM during both the years. Bharat and Kachroo (2007) also reported superiority of clodinafop + MSM over isoproturon alone in broadening the spectrum of weed control.

Effect on crop

Wheat crop sown under zero and reduced tillage conditions recorded more dry matter accumulation, number of effective tillers/m^2 and spike length than that of conventional tillage yet the differences could not reach to the level of significance (Table 2). The number of grains/spike was significantly higher under conventional tillage as compared to zero and reduced tillage. Zero tillage being at par with reduced tillage recorded higher test weight than conventional tillage during second year. All the weed management practices accumulated significantly higher crop dry matter accumulation, effective tillers, and test weight than weedy check.

Table 1. Effect of tillage and weed management practices on bulk density, organic C and weeds

Treatment	Bulk density (mg/m^3) of soil before sowing		Organic C (%) of soil before sowing		Weed density/m^2 at 90 DAS		Dry weight of weeds (g/m^2) at 90 DAS		Weed control efficiency (%) at 90 DAS	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Tillage method										
Zero tillage	1.60	1.61	0.71	0.71	1.93(33.0)	1.86(34.0)	2.04(26.0)	2.19(29.6)	72.3	71.3
Reduced tillage	1.57	1.60	0.70	0.70	2.39(36.7)	2.64(39.0)	2.24(39.4)	2.30(37.2)	72.0	71.5
Conventional tillage	1.55	1.57	0.69	0.68	2.80(63.5)	2.76(60.7)	2.34(47.2)	2.50(49.5)	72.4	71.1
LSD(P=0.05)	0.04	0.02	NS	NS	NS	NS	0.20	0.17	NS	NS
Weed management practice										
Isoproturon 1.0 kg/ha	1.57	1.57	0.70	0.71	2.45(18.7)	2.88(20.0)	2.53(12.8)	2.87(17.4)	90.7	87.1
Clodinafop 60 g *fb* metsulfuron-methyl 4 g/ha	1.58	1.59	0.72	0.72	0.74(3.1)	1.21(6.7)	0.91(1.5)	0.96 (1.6)	98.8	98.7
Weedy	1.57	1.58	0.68	0.67	4.93(152)	4.94(143)	4.88(135)	4.89(135)	0.0	0.0
Hand weeding 35 and 55 DAS	1.56	1.59	0.71	0.70	1.38(4.0)	0.64(2.2)	0.52(0.7)	0.60 (0.8)	99.4	99.4
LSD (P=0.05)	NS	NS	0.02	0.02	0.9	0.85	0.25	0.14	1.88	1.25

*Original values are given in parentheses; DAS - Days after sowing

Table 2. Effect of tillage and weed control practices on dry matter and yield attributes of wheat

Treatment	Crop dry matter (g/m^2) at 120 DAS		Effective tillers/m^2		Ear length (cm)		Grains/ear		Test weight (g)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Tillage method										
Zero tillage	361.5	371.1	155.0	154.6	8.60	8.47	40.2	39.2	40.0	41.0
Reduced tillage	348.8	363.8	150.4	152.1	8.42	8.31	41.2	42.6	37.1	37.2
Conventional tillage	321.3	342.1	142.6	141.3	8.38	7.74	46.0	47.0	36.4	34.3
LSD(P=0.05)	NS	NS	NS	NS	NS	NS	4.2	2.5	NS	4.1
Weed management practice										
Isoproturon 1.0 kg/ha	347.0	350.5	154.4	154.5	8.47	8.29	42.1	42.2	37.2	37.5
Clodinafop 60 g *fb* metsulfuron-methyl 4 g/ha	360.4	389.0	158.9	157.2	8.58	8.40	43.4	45.0	38.5	38.7
Weedy	296.4	293.9	121.6	114.4	8.14	7.59	37.4	38.3	34.5	33.7
Hand weeding 35 and 55 DAS	371.6	402.4	162.4	171.1	8.67	8.41	46.5	46.3	39.7	40.2
LSD (P=0.05)	40.1	43.7	20.6	31.1	NS	NS	2.5	3.7	2.1	3.1

Table 3. Interaction effect of different treatments on grain yield (t/ha) of wheat

Wheat establishment method	Weed management practices				
	Hand weeding at 35 and 55 DAS	Isoproturon 1.0 kg/ha	Clodinafop 60 g *fb* metsulfuron-methyl 4 g/ha	Weedy	Mean
Zero tillage	4.8	4.5	4.6	3.1	4.3
Reduced tillage	4.9	4.6	4.6	2.2	4.0
Conventional tillage	4.9	4.5	4.7	1.4	3.9
Mean	4.9	4.5	4.6	2.2	

LSD (P=0.05) (a) main plot: 0.24, (b) Sub plot: 0.24, (c) Main plot at constant sub plot: 0.41,

(d) Sub plot at constant main plot: 0.43

Table 4. Seed bank of weed seeds (no./100 g soil) at different soil depths (pooled data of 2 years)

Treatment	0-5 cm				5-10 cm				10-15 cm			
	P. minor	*Melilotus-indica*	*C. album*	*R. acetosella*	*P. minor*	*Melilotus-indica*	*C. album*	*R. acetosella*	*P. minor*	*Melilotus-indica*	*C. album*	*R. acetosella*
Wheat establishment method												
Zero tillage	0.5	1.4	0.3	0.7	0.9	0.8	0.2	0.4	0.1	1.2	0.3	0.1
Reduced tillage	3.9	2.1	1.1	0.4	3.3	1.5	1.0	0.1	0.4	1.3	0.4	0.1
Conventional tillage	5.1	2.4	1.4	0.4	4.1	1.8	1.3	0.1	0.5	1.8	0.3	0.0
LSD (P=0.05)	1.2	0.2	0.5	0.3	0.8	0.4	0.6	0.1	0.2	0.4	NS	NS
Weed management practice												
Isoproturon 1.0 kg/ha	0.6	1.3	0.1	0.1	1.2	1.5	0.3	0.1	0.1	1.1	0.1	0.0
Clodinafop 60 g *fb* metsulfuron - methyl 4 g/ha	0.2	0.1	0.2	0.1	0.5	0.1	0.0	0.0	0.1	0.3	0.0	0.0
Weedy	11.6	3.4	3.4	0.9	9.0	3.7	2.9	0.5	0.8	3.7	1.2	0.2
HW 35 and 55 DAS	0.3	0.4	0.2	0.1	0.3	0.1	0.2	0.1	0.3	0.3	0.1	0.0
LSD (P=0.05)	1.3	0.8	0.6	0.2	1.1	0.7	0.4	0.2	0.4	0.6	0.4	0.1

The differences were non-significant if we compare different tillage and weed management practices (Table 3). Under weedy situation, grain yield increased significantly with each successive reduction in tillage practices. Zero till system was found better as inherently weed emergence was lesser numerically. Among the weed management practices hand weeding at 35 and 55 DAS proved excellent in controlling all weed species in both the years and thereby provided lowest dry matter and highest weed control efficiency as well as number of tillers and grain yield.

Effect on weed seed bank

Variations in seed density of different weed species were higher in 0 to 5 followed by 5 to 10 and 10 to 15 cm soil depth under different tillage methods (Table 4). The total number of seeds was recorded maximum in 0 to 5 cm and minimum in 10 to 15 cm soil depth under all the tillage methods.

Seed density of different major weed species, *viz. Phalaris minor, Melilotus indica, Chenopodium album* were significantly lower under zero tillage as compared to conventional tillage at all the soil depths. The differences under reduced and conventional tillage were significant only for *Melilotus indica* at 0 to 5 cm and 5 to 10 cm and *Chenopodium album* at 5 to 10 cm soil depth. The seed density of *R. acetosella* in soil was found higher in case of zero tillage than others but the differences were significant only at 5 to 10 cm soil depth. The variation in seed density of *Melilotus indica* under zero and reduced tillage were non- significant at 10 to 15 cm soil depth. However, *Phalaris minor* seed density under reduced and conventional tillage was comparable with each other.

On the basis of two year experimentation, it was concluded that hand weeding twice at 35 and 55 DAS resulted in maximum control of weeds and provided the maximum grain yield under conventional tillage system. Whereas under weedy conditions zero till system was found better showing inherently lesser weed emergence.

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Herbicidal control of problematic weeds in wheat

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ABSTRACT

On-farm trials were conducted at farmers' fields in Ropar and Ferozpur districts of Punjab to validate, refine and popularize the technology developed by Punjab Agricultural University, Ludhiana for managing grassy and broad-leaf weeds in wheat. The objective of the study was to test the effectiveness of clodinafop 60 g/ha and carfentrazone-ethtyl 20 g/ha over farmer practice of using un-recommended herbicides and brands on the infestation of weeds and profitability of wheat in central Punjab. Recommended practice of clodinafop followed by carfentrazone-ethyl resulted in significantly higher grain yield (4.56 and 4.69 t/ha) than other treatments including farmer practice. There was 14.4 and 17.9, 3.4 and 5.7 and 3.0 and 4.3 per cent increase in grain yield with recommended practice over control, metribuzin and farmers' practice, respectively. The population of grassy weeds was minimum with metribuzin 175 g/ha treatment, which was statistically at par with recommended practice but was significantly lower than other two treatments, whereas the number of broad-leaf weeds was significantly lower with recommended treatment. The herbicide efficiency index (HEI) was highest (16.8 and 21.8) with recommended practice indicating higher efficiency of this treatment in controlling weeds. A slight phytotoxicity was observed with metribuzin which resulted in significant reduction in effective tillers than other herbicidal treatments. Highest B: C ratio (2.45 and 2.77) and net returns (` 45.99 and 52.86 x 10^3 /ha) were recorded with recommended practice.

Key words: Clodinafop, Carfentrazone-ethyl, Herbicide efficiency index (HEI), Metribuzin, Weed density

Wheat (*Triticum aestivum*) with an area of 35 million ha is the most widely cultivated winter cereal in Punjab and occupies a significant position in the economy of the state. Several grassy and broad-leaf weeds compete with the crop during its growing period. Weed infestation is one of the main causes of low wheat yield all over the world, as it reduces wheat yield by 37 to 50% (Waheed *et al.* 2009). The reduction in productivity depends upon the type of weed flora and weed density (Balyan and Malik 1989, Afentouli and Eleftherohorinos 1996). Weeds are the most omnipresent class of pests that interfere with crop plants through competition and allelopathy, resulting in direct loss to quantity and quality of the product (Gupta 2004) and indirectly increasing production costs. Herbicidal weed control seems indispensable and has proved efficient in controlling weeds (Kahramanoglu and Uygur 2010) and hence presently about two-third, by volume, of the pesticides used worldwide in agricultural production are herbicides.

Introduction of semi dwarf genotypes of wheat coupled with better irrigation and fertilizer application has provided congenial growing conditions for weeds, particularly *Phalaris minor* predominantly in rice-wheat cropping system where it has emerged as major weed of wheat causing yield reduction to the level of 30-80% (Brar and Walia 1993, Singh *et al.* 1999). Dependence on only one herbicide isoproturon for very long period to control of *Phalaris minor* in wheat has resulted in problem of resistance to this herbicide (Malik and Singh 1995, Walia *et al.* 1997). Herbicides are the most important weed control tool for alleviating the infestation of weeds and getting higher yield in wheat as reported by Ashiq *et al.* 2007. Walia and Brar (2006) reported that in Punjab non-recommended herbicides were used by 13.6% farmers. More than 27 per cent farmers used non-recommended herbicides or unapproved brands of recommended herbicides, whereas more than 19% of the farmers used under or over doses of herbicide. The efficacy of these herbicides was found below satisfactory levels by more than 30% of the farmers. In the sub-mountainous zone of Punjab especially in district Ropar, the problem of weeds in wheat is even more serious leading to lower grain yields. *Malwa parviflora*, a broad-leaf weed with long tap root and capacity to withstand moisture stress, has increased its occurrence in wheat crop which is posing a serious challenge as it is not controlled by metsulfuron-methyl. This weed is con-

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trolled by carfentrazon-ethyl but farmers were unaware of this. They continued to use metsulfuron-methyl for its control. This often lead to poor control of weeds and also sometimes toxicity on the crop. The use of recommended and conventional herbicides provides more effective control of grassy and broad-leaf weeds in wheat and are also cost effective.

There was a need to evaluate the location specific efficacy of various post-emergence herbicides recommended by Punjab Agricultural University in order to alleviate the weed infestation in wheat. The present investigation (On-farm trial) was therefore conducted at selected farmers' fields with the objective to validate, assess and refine the improved and recommended technology of herbicidal weed management over traditional farmer's practice.

MATERIALS AND METHODS

Field Experiments were conducted at farmers' fields at ten different locations in district Ropar during *Rabi* 2010-11 and 2011-12 and in district Ferozpur on 8 locations during *Rabi* 2010-11. The climate of the experimental sites was sub-tropical characterized by hot summers with mean maximum temperature of 42±5 ^{0}C during June and cool winters with mean minimum temperature of 4±2 ^{0}C during December. The average annual rainfall (AAR) in the study area varied from 650 - 1300 mm of which 75 - 80 per cent was received during summer season extending from July to September and rest during the winter season. The soil of experiment locations was sandy loam to loam in texture, normal in soil reaction (pH 7.56 - 8.02) and electrical conductivity (0.136-0.320 dS/m), low to medium in OC (0.361-0.425 %), available P (11-24.5 kg/ha) and available K (116-166.7 kg/ha).

The experiment was laid out in randomized complete block design. Each location was considered as one block and replication. The weed control treatments thus replicated at different locations consisted recommended practice (clodinafop 60 g/ha *fb* carfentrazone-ethyl 20 g/ha); farmers practice (non-recommended herbicides/brands) metribuzin 175 g/ha and un-weeded control. Wheat variety '*DBW 17'* was sown in first fortnight of November using a seed rate of 100 kg/ha with conventional seed cum fertilizer drill. Light planking was done after sowing to cover the seeds properly with soil. Nitrogen (125 kg/ha), phosphorus (60 kg/ha) and potash (30 kg/ha) were applied through urea, diammonium phosphate (DAP) and muriate of potash (MOP), respectively. Half the dose of nitrogen and whole of phosphorus was applied at the time of sowing, while the remaining half dose of N was applied as broadcast after first irrigation. First irrigation was applied at Crown root initiation (CRI) stage. Clodinafop and metribuzin were sprayed at 35 (2010-11) and 39 (2011-12) days after sowing with knapsack sprayer fitted with flat fan nozzle. Spray of carfentrazone-ethyl was done a week after clodinafop to control broad-leaf weeds. The gross plot size was 500 m^2 (50 x 10 m). Soil reaction (pH) and E.C. were determined by using 1: 2 soil: water (w/v basis) ratio (Jackson 1967). Soil organic carbon content was determined by method of Walkley and Black (1934). The available P (Olsen-P) content in the soil samples was determined as described by Olsen *et al.* (1954). Available K was determined using 1 N, CH_3COONH_4 (pH=7.0) followed by flame photometric estimation. The density of weeds was recorded at 75 days after sowing with the help of a quadrate measuring 1 x 1 m. Data on yield attributes and yield was recorded at maturity of the crop to draw valid conclusions. Data on density of weeds was subjected to square root transformation before statistical analysis. Data was subjected to analysis as detailed by Cheema and Singh (1991) in statistical package CPCS-1. Herbicide efficiency index (HEI) was calculated by using standard formula.

RESULTS AND DISCUSSION

Effect on weeds

The main weed flora of experimental fields consisted of *Phalaris minor, Coronopus didymus, Anagallis arvensis*, *Melilotus indica*, *Medicago denticulata*, *Rumex dentatus*, *Rumex spinosus*, *Trigonella polycerata*, *Malwa parviflora* and *Chenopodium album*.

The density of weeds was significantly influenced by weed control treatments in both the years. The highest weed density both for grassy and broad-leaf was found in the control plots. All herbicides reduced the growth of weeds compared to those observed in control (Table 2). Data revealed that during 2010-11, the density of grassy weeds was minimum with metribuzin (175 g/ha) treatment which was statistically at par with recommended treatment of clodinafop (60 g/ha) followed by carfentrazone-ethyl (20 g/ha) but was however significantly lower than other two treatments. During 2011-12, significantly lowest number of grassy weeds were found with recommended treatment, which was statistically at par with metribuzin, but significantly lower than the other two. All the herbicidal treatments were significantly better in controlling grassy weeds than control treatment. Singh *et al.* 2002 also reported that clodinafop provides effective control of isoproturon resistant *Phalaris minor* biotypes.

Table 1. Effect of herbicidal weed management on growth, yield and yield attributes of wheat

Treatment	Dose (g /ha)	Plant height (cm)		Grains/ear		Effective tiller /m^2 row length		Test weight (g)		Grain yield (t/ha)		Herbicide efficiency index (HEI)	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Recommended practice													
Clodinafop followed by carfentrazone-ethyl	60, 20	84.2	85.2	46.8	47.6	77.0	79.5	40.8	40.7	4.56	4.69	16.8	21.8
Farmers practice													
non-recommended herbicides and brands	-	83.7	84.5	44.2	44.8	74.7	75.3	39.4	39.8	4.43	4.49	13.3	16.5
Metribuzin	175	82.2	84.7	43.6	44.0	72.6	73.0	38.9	39.2	4.41	4.42	12.9	14.9
Unweeded control	-	81.6	83.6	40.5	41.1	63.5	64.5	36.8	37.4	3.91	3.85	-	-
LSD (P= 0.05)		NS	NS	2.6	2.4	1.2	2.1	NS	NS	0.11	0.16	-	-

Table 2. Effect of herbicidal weed management on weed density (no./m^2) and dry weight (g/m^2) of wheat

Treatment	Dose (g/ha)	Weed density (no./m^2)				Weed dry weight (g/m^2)			
		Grassy weeds		Broad-leaf weeds		Grassy weeds		Broad-leaf weeds	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Recommended practice									
Clodinafop followed by carfentrazone-ethyl	60, 20	4.08 (15.9)	3.85 (14.7)	1.67 (2.0)	3.5 (1.83)	25.2	24.0	2.24	2.32
Farmers practice									
Non-recommended herbicides and brands	-	4.91 (23.3)	4.45 (22.6)	2.62 (6.12)	7.22 (2.68)	38.4	37.8	4.10	4.22
Metribuzin	175	4.06 (15.7)	4.02 (15.0)	2.05 (3.21)	2.98 (1.79)	26.7	27.2	2.40	2.33
Unweeded control	-	9.94 (98.1)	9.98 (100.5)	47.1 (6.89)	52.1 (6.84)	105.7	108.2	9.57	10.85
LSD (P=0.05)	-	0.28	0.33	0.35	0.47	6.8	10.4	1.63	1.71

*Original figures in parentheses were subjected to square root transformation

In 2010-11, significant reduction in number of broad-leaf weeds was observed with recommended treatment of clodinafop (60 g/ha) which was at par with metribuzin but was significantly lower than the other two treatments. During 2011-12, minimum number of weeds were recorded with metribuzin, which was at par with recommended treatment, but lower than other two. Farmers sprayed metsulfuraon-methyl for control of broad-leaf weeds, which effectively controlled all broad-leaf weeds except *Malwa parviflora* locally called 'Button buti'. This weed is controlled with carfentrazone-ethyl. Punia *et al.* (2006) also reported excellent control of broad-leaf weeds with application of carfentrazone-ethyl.

Effect on crop

The data revealed that the differences with respect to plant height were found to be non-significant during both years. Highest plant height (84.20 and 85.20 cm) was observed with recommended treatment of clodinafop (60 g/ha) *fb* carfentrazone-ethyl (20 g/ha). In 2010-11, ear length (8.97 cm) was maximum with recommended treatment, which was significantly higher than all other treatments. However in 2011-12, there was no effect on ear length. Number of grains and effective tillers, which are main determinants of grain yield, were significantly higher with recommended treatment during both years than all other treatments. The significant reduction in number of effective tillers in metribuzin treatment could be attributed to phytotoxicity of metribuzin on crop. The differences with respect to test weight were found to be non-significant in both the years (Table 2).

Application of clodinafop 60 g/ha *fb* carfentrazone-ethyl 20 g/ha recorded highest grain yield of wheat (4.56 and 4.69 t/ha) during both the years and was significantly higher than all other treatments. Lowest grain yield of wheat (3.91and 3.85 t/ha) was recorded with unweeded control due to highest infestation of grassy and broad-leaf weeds and relatively inferior yield attributes as compared to all other herbicidal treatments. There was 14.4 and 17.9, 3.4 and 5.7 and 3.0 and 4.3 per cent increase in grain yield with recommended practice over control, metribuzin and farmers practice, respectively. Chhokar and Malik (2002) also reported significantly higher grain yields of wheat with application of clodinafop.

Table 3. Economics of different weed management practices in wheat

Treatment	Dose (g/ha)	Production unit (t/ha)		Gross returns ($x10^3$ `/ha)		Cost of cultivation ($x10^3$ `/ha)		Net returns ($x10^3$ `/ha)		B:C Ratio	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Recommended practice											
Clodinafop followed by carfentrazone-ethyl	60, 20	4.56	4.69	64.78	71.96	18.79	19.10	45.99	52.86	2.45	2.77
Farmers practice											
Non-recommended herbicides and brands	-	4.43	4.49	62.84	68.84	18.50	18.68	44.34	50.16	2.40	2.69
Metribuzin	175	4.41	4.42	62.59	67.66	18.38	18.60	44.22	49.06	2.41	2.64
Control	-	3.91	3.85	55.45	59.07	17.35	17.74	38.10	41.33	2.20	2.33

Economics

Among different treatments, recommended treatment of clodinafop 60 g/ha *fb* application of carfentrazone-ethyl 20 g/ha recorded maximum net returns (` 45.99 and 52.86 x 10^3/ha) and benefit cost ratio (2.45 and 2.77) followed by metribuzin 175 g/ha and farmers practice which makes these herbicides economically feasible and cost effective for controlling weeds. The lowest net returns were however observed with unweeded control.

It was concluded that for obtaining sustainably higher wheat grain yields and effective control of weeds, use of recommended herbicides clodinafop 60 g/ha *fb* carfentrazone 20 g/ha was a viable solution. The use of non-recommended herbicides and brands could be avoided as they do not control the weeds effectively, which lowers the grain yield of wheat and ultimately net returns.

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Integrated weed management in maize-sunflower cropping system

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ABSTRACT

A field experiment was conducted during *Rabi and Kharif* season of 2012 and 2013 at Veppantattai to study the effect of tillage and weed management methods on weeds dynamics and yield of maize–sunflower cropping system. Results revealed that conventional tillage with disc plough followed by cultivator tillage twice and pre-emergence herbicide (atrazine 0.5 kg/ha for maize and pendimethalin 1.0 kg/ha for sunflower), followed by hand weeding on 40 DAS kept the weed density and weed dry weight below the economic threshold level and increased the productivity, net returns and benefit : cost ratio of maize-sunflower cropping system in clay loam soils under irrigated condition.

Key words: Maize, Sunflower, Tillage, Weed management, Weed density, Yield

In India, maize is grown in an area of 8.26 million ha with a production of 20.03 million tones. Sunflower is cultivated over an area of about 1.48 million ha with a production of 0.90 million tones. The productivity of sunflower is quite low compared to other sunflower growing countries. Uninhibited growth of weeds caused enormous loss of nutrients, which in turn reduced the yield of sunflower up to 64% (Legha *et al*. 1992). Continuous use of herbicides over a prolonged time leads to development of resistance in weeds making them difficult to control. The combination of herbicides with mechanical weeding is effective in controlling major weeds. The herbicide controls weeds in-row, whereas mechanical weeding removed weeds between the rows. The information on the influence of preparatory tillage methods on weed population and productivity of crops in a system approach are seldom available. Hence, a field experiment was conducted to develop information on weed population dynamics in maize-sunflower cropping system as influenced by preparatory tillage and weed management methods under irrigated condition.

MATERIALS AND METHODS

A field experiment was conducted during 2012 and 2013 at N block of Cotton Research Station, Veppantattai. The soil of the experimental farm is clay loam in texture with low in N, medium in P and K. The experiment was laid out in strip plot design with three replications. Main plot treatment consisted of three tillage methods, *viz.* conventional tillage, minimum tillage and zero tillage. Five weed management methods, *viz*. pre-emergence application of herbicide (atrazine 0.5 kg/ha for maize and pendimenthalin 1.0 kg/ha for sunflower) followed by hand weeding on 40 DAS, pre-emergence application of herbicide (atrazine 0.5 kg/ha for maize and pendimenthalin 1.0 kg/ha for sunflower) followed by power weeding on 40 DAS, hand weeding twice on 20 and 40 DAS, power weeding on 20 and 40 DAS along with an unweeded check for both the crops were the sub-plot treatments. The maize '*NK 6240*' and sunflower hybrid '*Sunbred*' were sown on 60 x 25 cm and 60 x 30 cm, respectively. Conventional tillage involved one disc ploughing, followed by two cultivator operations. One pass of cultivator ploughing and ridger operation were used for minimum tillage. In zero tillage, the seeds were dibbled in the stubbles of the previous crop without any tillage. For manual weeding treatments, two hand weeding were done on 20 and 40 DAS. Herbicide treated plots were applied with atrazine 0.5 kg/ha for maize as pre-emergence spray on third day after sowing, followed by a hand weeding on 40 DAS. Pendimethalin 1.0 kg/ha was applied in sunflower as pre-emergence spray on third day after sowing, followed by a hand weeding on 40 DAS. For power weeding plots, two weeding were given on 20 and 40 DAS with 'Garuda' power weeder in between rows and within the rows weeds were removed manually.

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RESULTS AND DISCUSSION

Effect on weeds

Dominant weed species were: *Dinebra retroflexa, Cynodon dactylon, Panicum repens, Chloris barbata, Cyperus roundus, Trianthema portulacastrum,* *Parthenium hysterophorus* and *Digera arvensis*. Both tillage and weed management methods significantly influenced the weed dry weight (Table 1). The lower weed density, weed dry weight were observed with conventional tillage due to the inversion of surface soil and burial of weed seeds by disc ploughing. Zero tillage was found to record higher total weed density and weed dry weight mainly due to the higher densities of both grasses and broad-leaved weeds resulted in deposition of more seeds and propagules of predominant annual and perennial weeds near the soil surface. Greater deposition of weed seeds at the soil surface with zero tillage and minimum tillage than conventional tillage was reported by Clements *et al.* (1996). Lower weed density and weed dry weight were recorded by conventional tillage in sunflower. Higher weed density and weed dry weight were recorded by zero tillage due to deposition of weed seeds in the upper layer of the soil. Increase in perennial and some annual weed species due to reduced tillage was also reported by Hume *et al.* (1991).

Lower density and dry weight of weeds were observed with pre-emergence application of atrazine 0.5 kg/ha for maize and pendimethalin 1.0 kg/ha for sunflower followed by hand weeding at 40 DAS. Application of herbicides was found to control grassy and broad-leaved weeds effectively. Unweeded control resulted in higher grasses, sedge and broad-leaved weeds. Interaction between tillage and weed management methods was found to be significant in altering the densities and dry weight of weeds. Pre-emergence application of herbicides combined with conventional tillage reduced the weed density and dry weight of weeds. It was due to better exposure of weeds to herbicides and manual removal in well distributed soil layers due to deep tillage. Higher weed density and weed dry weight were recoded with zero tillage combined with pre-emergence herbicide application due to the plant residues on the soil surface which might have intercepted the penetration of herbicides into the soil (Yenish *et al.* 1992).

Effect on crop yield

Grain yield of maize was significantly influenced by tillage and weed management methods (Table 2). Conventional tillage resulted in significantly higher yield compared with minimum and zero tillage, which is an indication for higher efficiency of deep tillage

Table 1. Effect of tillage and weed management practices on weed density and dry weight at 40 DAS in maize-sunflower cropping system

Treatment	Weed growth in maize				Weed growth in sunflower			
	Density (no./m^2)		Dry weight (kg/ha)		Density (no./m^2)		Dry weight (kg/ha)	
	2012	2013	2012	2013	2012	2013	2012	2013
Tillage								
Conventional tillage	6.8 (53.7)	6.8 (55.1)	13.1 (184.4)	13.8 (202.4)	13.0 (178.6)	5.0 (29.6)	13.0 (178.6)	13.6 (194.2)
Minimum tillage	7.5 (65.6)	7.6 (67.9)	15.5 (255.8)	13.5 (184.2)	14.5 (228.2)	5.9 (38.4)	14.5 (228.2)	14.8 (236.2)
Zero tillage	8.46 (82.8)	8.5 (84.5)	15.87 (276.0)	14.7 (236.2)	15.1 (252.6)	6.5 (47.3)	15.1 (252.6)	15.9 (277.2)
LSD (P=0.05)	0.53	0.19	0.49	0.19	0.34	0.17	0.34	0.45
Weed control								
Atrazine 0.5 kg/ha for maize and pendimenthalin 1.0 kg/ha for sunflower + hand weeding at 40 DAS	5.2 (27.6)	5.4 (29.6)	11.8 (141.3)	11.9 (145.0)	11.1 (126.0)	4.0 (16.1)	11.1 (126.0)	11.6 (137.3)
Atrazine 0.5 kg/ha for maize and pendimenthalin 1.0 kg/ha for sunflower + power weeding at 40 DAS	5.7 (33.3)	5.9 (35.09)	12.7 (164.6)	12.6 (160.7)	11.8 (140.6)	4.6 (21.8)	11.8 (140.6)	12.6 (160.6)
Hand weeding twice on 20 and 40 DAS	6.3 (40.6)	6.4 (41.5)	13.3 (180.0)	13.2 (176.0)	12.9 (169.6)	5.1 (27.0)	12.9 (169.6)	13.4 (181.6)
Power weeding at 20 and 40 DAS	7.1 (50.9)	7.01 (49.4)	14.3 (208.0)	13.9 (196.7)	13.8 (192.6)	5.7 (33.5)	13.8 (192.6)	14.4 (211.0)
Unweeded check	13.4 (184.4)	13.7 (190.8)	22.1 (499.6)	18.4 (359.7)	21.4 (470.0)	9.6 (93.6)	21.4 (470.0)	21.8 (488.6)
LSD (P=0.05)	0.48	0.35	0.89	0.56	0.58	0.58	0.58	0.82

Figures in parentheses are original values

Table 2. Effect of tillage and weed management practices on yield of maize-sunflower cropping system

Treatment	Maize				Sunflower seed yield (t/ha)	
	Grain yield (t/ha)		Stover yield (t/ha)			
	2012	2013	2012	2013	2012	2013
Tillage						
Conventional tillage	5.98	4.98	8.94	8.26	1.62	1.53
Minimum tillage	5.46	4.72	8.51	8.13	1.50	1.42
Zero tillage	504	4.35	7.87	7.60	1.28	1.21
LSD(P=0.05)	0.27	0.11	0.32	0.19	0.11	0.11
Weed control						
Atrazine 0.5 kg/ha for maize and pendimenthalin 1.0 kg/ha for sunflower + hand weeding at 40 DAS	6.23	5.30	9.25	8.76	1.64	1.56
Atrazine 0.5 kg/ha for maize and pendimenthalin 1.0 kg/ha for sunflower + power weeding at 40 DAS	5.96	5.08	8.65	8.28	1.54	1.38
Hand weeding twice at 20 and 40 DAS	5.70	4.86	8.43	8.03	1.46	1.45
Power weeding at 20 and 40 DAS	5.54	4.73	8.07	7.63	1.38	1.23
Unweeded check	4.03	3.44	7.79	7.28	1.33	1.24
LSD (P=0.05)	0.41	0.17	0.29	0.27	0.09	0.08

over a long cropping period. Higher grain yield of maize with conventional tillage was also reported by Bakhsh *et al*. (2000). Zero tillage resulted in lower grain yield due to poor growth parameters like shorter plants, lesser dry matter production and leaf area index and yield attributes. The compact layer of soil along with the greater competition of weeds was responsible for reduced root development and ultimately yield reduction (Cavalaris and Gemtos 2002). Higher grain yield of maize obtained with pre-emergence application of atrazine 0.5 kg/ha followed by hand weeding at 40 DAS was due to efficient control of weeds, higher weed control efficiency coupled with lower depletion of nutrients by weeds (Sharma *et al.* 1988).

Conventional tillage recorded higher yield of sunflower due to deep ploughing and pulverization of plough sole depth of soil layers. Raj and Yadav (1979) found higher grain yield in sunflower due to improved root development. The lower seed yield obtained with zero tillage was due to higher weed competition for nutrient, space and light offered by weed flora.

Higher seed yield of sunflower obtained with pre-emergence application of pendimethalin 1.0 kg/ha followed by hand weeding at 40 DAS was due to efficient weed control and increase in growth and yield parameters. Unchecked weed growth resulted in more weed density and thus reduced the seed yield of sunflower.

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Weed indices in chickpea + mustard intercropping system

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ABSTRACT

A field experiment consisted of four intercropping systems, *viz.* sole chickpea, sole mustard, chickpea + mustard (additive series) and chickpea + mustard (replacement series) and six weed management practices, *viz.* weedy check, weed free, pendimethalin 1 kg/ha as pre-emergence , fluchloralin 1 kg/ha as pre-plant incorporation (PPI), isoproturon 0.75 kg/ha as post-emergence and quizalofop-ethyl 50 ml/ha as post-emergence. Results revealed that weed species, *Medicago sativa, Anagallis arvensis* and *Cyperus rotundus* with higher relative weed density and dry weed weight were observed. The values of smothering efficiency were higher in additive as compared to replacement treatment. Maximum yield loss was in weedy check in comparison to weed-free plots. Application of pendimethalin at 1 kg/ha gave higher yield of chickpea and mustard along with maximum returns.

Key words: Intercropping, Relative weed density, Relative dry weed weight, Weed smothering efficiency, economic returns

Intercropping systems suppress weeds better than sole cropping, and provide an opportunity as tools of weed management. Besides, intercropping also reduces weeding cost and realizes higher total productivity of the system and monetary returns. Herbicidal weed management is in vague for most of the individual crops but in case of intercropping situations, the single crop recommendations do not hold good as the crop *vs* crop and crops *vs* weeds scenarios change drastically. No single method provides efficient weed management in chickpea + mustard intercropping system. The use of herbicides offers a good scope for timely and adequate control of weeds. Efficiency of weed control can be further enhanced if herbicidal treatments are coupled with intercropping, which plays a very significant role in suppression of weeds through their smothering effect. Chickpea is a poor competitor to weeds because of its slow growth and limited leaf area development at early stages of crop growth and establishment. Therefore, intercropping of mustard in chickpea coupled with effective weed control measures may help to realize the potential yield of chickpea with an additional yield of mustard.

MATERIALS AND METHODS

A field experiment was conducted at the Research Farm, Main Campus, Chatha of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during *Rabi* season of 2009-10 and 2010-11. The experimental soil was sandy-loam in texture, slightly alkaline in reaction, medium in organic C and available N, P and K. The experiment consisted of four intercropping systems, *viz.* sole chickpea (30 cm), sole mustard (30 cm), chickpea + mustard in additive series (an additional row was opened in between two rows of chickpea for sowing of mustard in additive series), and chickpea + mustard in replacement series (one row of chickpea was replaced with one row of mustard); and six weed management practices, *viz.* weedy check, weed free, pendimethalin 1 kg/ha as pre emergence (PE), fluchloralin 1 kg/ha as pre-plant incorporation (PPI), isoproturon 0.75 kg/ha as post-emergence (POE) and quizalofop-ethyl 50 ml/ha as post-emergence (POE) in a split-plot design with three replications. Furrows were opened manually with the help of liners at a specified row to row distance of 30 cm. The chickpea '*GNG-469'* and mustard '*RSPR 01'* were sown on 5 November 2009 and 31 October 2010, respectively. A seed rate of 70 kg and 5 kg/ha for chickpea and mustard was used in their sole plots and additive series, respectively, while 50% less seed was used for replacement series. Sowing was done in furrows by 'kera' method in sole stand, whereas an additional row was opened in between two rows of chickpea for sowing of mustard. Full dose of DAP as recommended for chickpea was applied as basal.

Weed population and weeds dry weight was recorded at 30 days interval and at harvest. The weed indices, *viz.* weeds smothering efficiency, relative weed density, relative dry weeds weight and summed dominance ratio were calculated.

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RESULTS AND DISCUSSION

Weed indices

The experimental site was infested with broad-leaved weeds (*Medicago sativa*, *Anagallis arvensis* and *Trachyspermum* spp.), followed by sedges (*Cyperus rotundus*) and grasses (*Cynodon dactylon* and *Poa annua*). Among the broad-leaved weeds, *Medicago sativa* was found to be the most dominant weed at 60 days after sowing and at harvest, which was followed by *Anagallis arvensis* and *Tracyspermum* spp. Among the grassy weeds, the infestation was dominated by *Cynodon dactylon*, followed by *Poa annua* and in the sedges category, *Cyperus rotundus* was found to be the only dominant weed. *Medicago sativa* accumulated higher dry matter, followed by *Anagallis arvensis* and *Tracyspermum* spp. at 60 DAS and at harvest (Table 1). Among the grassy weeds, *Cynodon dactylon* was followed by *Poa annua* in accumulating more dry matter at 60 DAS and harvest, whereas *Cyperus rotundus* recorded relatively higher weed dry matter among all the weed species under weedy situation. The most dominant weed species were ranked on the basis of their summed dominance ratio, and followed the order: *Medicago sativa* > *Anagallis arvensis* > *Cyperus rotundus* > *Trachyspermum* spp. > *Cynodon dacylon*. *Medicago sativa* was the top ranking dominant weed, followed by *Anagallis arvensis*.

Higher weed smothering efficiency was registered in additive as compared to replacement treatment (Table 2). This might have happened due to suppressed weed demography as a result of less availability of resources like space and light induced by competitive environment created by the overwhelming canopy of crop plants in a unit area which prevented the weeds to flourish and attain interfering growth in additive treatments. These findings were in close conformity with Shah *et al*. (2011).

Economics

Cost of cultivation varied due to the differences in the cost of seeds of chickpea and mustard, and weed management practices. Evidently, the lowest cost of cultivation was realized under weedy check. The highest net returns were obtained under additive treatment, followed by replacement treatment over sole chickpea and mustard. Tripathi *et al*. (2005) reported similar findings in respect of net returns in chickpea + mustard intercropping system.

Table 1. Relative dry weed weight and summed dominance ratio as encountered in weedy check

Treatment	Relative weed dry weight (%)				Summed dominance ratio			
	60 DAS		At harvest		60 DAS		At harvest	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Broad-leaf weeds								
Medicago sativa	31.1	32.8	26.2	28.2	32.8	34.3	29.7	31.4
Anagallis arvensis	24.5	25.8	20.7	22.1	25.9	26.9	23.4	24.6
Trachyspermum sp.	6.0	5.08	7.85	7.4	4.8	4.0	6.1	5.7
Grasses								
Cynodon dactylon	1.1	1.2	2.2	2.1	1.0	1.1	1.9	1.8
Poa annua	1.1	1.2	1.4	1.2	1.0	1.1	1.2	1.0
Sedges								
Cyperus rotundus	19.1	19.9	14.1	14.9	20.2	20.8	16.0	16.6
Others	16.8	13.9	27.2	23.8	13.9	11.4	21.4	18.6

Table 2. Periodic weeds smothering efficiency (%) as influenced by different intercropping treatments

Intercropping system	30 DAS		60 DAS		90 DAS		120 DAS		At harvest	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Chickpea + mustard (additive series)	29.4	30.7	23.3	28.6	20.6	24.3	18.9	22.2	20.2	26.0
Chickpea + mustard (replacement series)	15.0	19.0	11.9	14.6	10.5	12.4	10.0	11.3	3.20	4.00

Table 3. Influence of intercropping system and weed management practices on economics

Treatment	Cost of cultivation (x10^{3} `/ha)		Gross returns (x10^{3} `/ha)		Net returns (x10^{3} `/ha)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping						
Sole chickpea	14.74	14.37	25.07	26.47	10.32	12.10
Sole mustard	11.12	11.15	23.20	24.13	12.07	12.98
Chickpea + mustard (additive Series)	15.40	15.05	38.13	41.16	22.73	26.10
Chickpea + mustard (replacement Series)	12.93	12.76	29.59	33.28	16.66	20.52
Weed management						
Fluchloralin 1 kg/ha (PPI)	12.04	11.82	27.87	34.03	15.84	22.20
Pendimethalin 1 kg/ha (PE)	12.86	12.64	30.17	36.09	17.31	23.44
Isoproturon 0.75 kg/ha (POE)	11.64	11.42	24.54	31.21	12.91	19.79
Quizalofop-ethyl 50 g/ha (POE)	12.96	12.75	27.04	32.70	14.08	19.96
Weedy check	11.24	11.02	15.42	14.33	4.18	13.22
Weed free	20.56	20.35	32.69	39.20	12.12	18.85

It can be concluded that chickpea + mustard in additive treatment is the most promising intercropping system for resource rich farmers of Jammu region. However, for realizing higher returns, chickpea + mustard in replacement treatment can be recommended to resource-poor farmers. Pendimethalin as pre-emergence 1 kg/ha followed by fluchloralin as pre-plant incorporation 1 kg/ha can be recommended for efficient weed management practices in chickpea + mustard intercropping system under the sub-tropical conditions of Jammu.

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Nutrient uptake as influenced by weed management in winter maize + potato intercropping system

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ABSTRACT

A field experiment was conducted during *Rabi* 2009-10 and 2010-11 at research farm of Sher-e-Kashmir University of Agriculture Science and Technology, Jammu with four intercropping treatments, *viz.* sole maize, sole potato, maize + potato (additive Series) and maize + potato (replacement series) in main plots and six methods of weed control practices, *viz.* weedy check, weed free, alachlor1.5 kg/ha pre-emergence, atrazine 0.5 kg/ha pre-emergence, alachlor 2.0 kg/ha early post-emergence and atrazine 0.75 kg/ha post-emergence in sub plots to assess the productivity and profitability of winter maize + potato intercropping system.These treatments were evaluated under split plot design with three replications. Results revealed that sole stands of winter maize and potato removed highest amount of N, P and K which were followed by additive series and replacement series whereas among the weed management practices, highest amount of N, P and K was removed by weed free treatment *fb* atrazine PE 0.75 kg/ha and alachlor 1.5 kg/ha while the lowest N, P and K was removed by alachlor 2.0 kg/ha early post emergence. Among the different intercropping treatments, weeds removed significantly highest N, P and K from sole crops followed by additive series and replacement series. Among weed management practices, the uptake of N, P and K in weeds was found to be significantly less in all the weed management practices as compared to weedy check treatment.

Key words: Intercropping, Nutrient uptake, Potato, Weed management, Winter maize

The crop diversification involving maize in place of wheat during winter has been found an effective approach in minimizing weed competition especially of *Phalaris minor.* Maize is very susceptible to competition from weeds especially in the early stages of growth; therefore, efficient control at the pre- and early post-emergence stages is essential. Once, maize reaches approximately 0.5 m in height, weed control no longer affects yield (Marshall 2004). Weed competition not only results in crop losses but also increases insect pest damage, harvesting difficulties and crop contamination (Ohene 1998). Weeds are a constant source of concern for the successful growth and development of economic crop. They compete with crops for light, moisture, space and nutrients and consequently interfere with the normal growth of crops. Weed control therefore, is very essential in maize cultivation. Further, wide space provided to the maize, allows fast growth of variety of weed species causing a considerable reduction in yield by affecting the growth and yield attributing components. Thus, the extent of reduction in grain yield of maize has been reported to be in the range of 33 to 50% depending on type of weed species in standing crop (Shantveerayya and Agasimani 2012). The present study was, therefore, undertaken to assess the losses of nutrients caused by weeds in winter maize + potato intercropping and to minimize these losses by controlling them.

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MATERIALS AND METHODS

The field experiments were conducted during *Rabi* season of 2009-10 and 2010-11 at the research farm of Division of Agronomy, Sher-e-Kashmir University of Agriculture Science and Technology, Jammu situated at 32° 40¹ N latitude and 74⁰ 58¹ E longitude and at an altitude of 332 m above the mean sea level. The soil was sandy loam, neutral in reaction, low in organic carbon and available N, medium in available P and K. The experiment was conducted in spilt plot design with three replications in a fixed lay out. The main plot treatments consisted of four intercropping systems; (i) Sole maize (ii) Sole potato (iii) Maize + potato (additive Series) (iv) Maize + potato (replacement series) while the sub plot treatments were six methods of weed control practices (i) Weedy check (ii) Weed free (iii) Alachlor at1.5 kg/ha pre-emergence (2 days after sowing) (iv) atrazine at 0.5 kg/ha pre-emergence (2 DAS) (v) Alachlor at 2.0 kg/ha early post-emergence (10 DAS) and (vi) Atrazine at 0.75 kg/ha post-emergence 30 (DAS). Winter maize '*Bulland*' of 175 days duration and potato '*Kufri Sinduri*' of 120 days duration were sown at row to row spacing of 60 cm. Application of fertilizer in sole maize was 175-60-30 kg N-P-K /ha. Full dose of P and K along with one third of N were applied as basal dose at the time of sowing and rest of N was applied in two equal splits, one third in mid of January at knee high stage and the one third was applied at pre-tasseling stage, whereas in case of sole potato was 120-60-120 kg N-P-K/ha. Herbicides were sprayed by knapsack sprayer fitted with flat fan nozzle using a spray volume of 500 l/ha. Weedy check plots remained infested with native population of weeds till harvest. Observations on weeds were recorded with the help of quadrate (0.5 x 0.5 m) placed randomly at two spots in each plot at harvest. The data on weeds were subjected to square root transformation ($\sqrt{x + 0.5}$) to normalize their distribution. The total N, P and K content in crops and weeds (at harvest of crops) was determined by Kjeldahl method. The uptake of N, P and K by crops was calculated by multiplying with yield of crops while uptake of nutrients by weeds was calculated by multiplying with the dry matter accumulation of weeds at harvest by the respective percentage composition of N, P and K.

RESULTS AND DISCUSSION

The major weeds in experiment field were *Medicago sativa* (19.09%), *Anagallis arvensis* (10.12%), *Trachysperum* sp. (7.69%), *Phalaris minor* (7.27%), *Cyanodon dactylon* (8.28%) and *Cyperus rotundus* (32.7%) and other minor species are *Dacus carota*, *Melilotus alba*, *Chenopodium album*, *Poa annua* and *Convolvulus arvensis*. The annual monocot weeds dominated the weed flora throughout the crop growth seasons during both the years. Different intercropping system and sole potato proved significantly superior over sole maize in reducing weed density and weed dry matter at 120 days after sowing. Winter maize + potato (additive series) and sole potato were more effective in controlling weeds than winter maize + potato (replacement series) and sole maize. Additive series of maize + potato registered (20.32 and 21.00 %) and (28.60 and 30.99%) reduction in total dry matter over replacement series and sole winter maize, respectively (Table 1). Similar effects due to planting pattern were also reported by Singh *et al.* (2005). Highest population of weeds was observed in weedy check over weed free treatment. The weed control treatments significantly reduced the total number of weeds during both the years. Application of atrazine at 0.5 kg/ha pre-emergence was highly effective in controlling the weeds and the lowest weed population of all the species was registered under this application in comparison to other treatments during both the years (Table 1).

Productivity

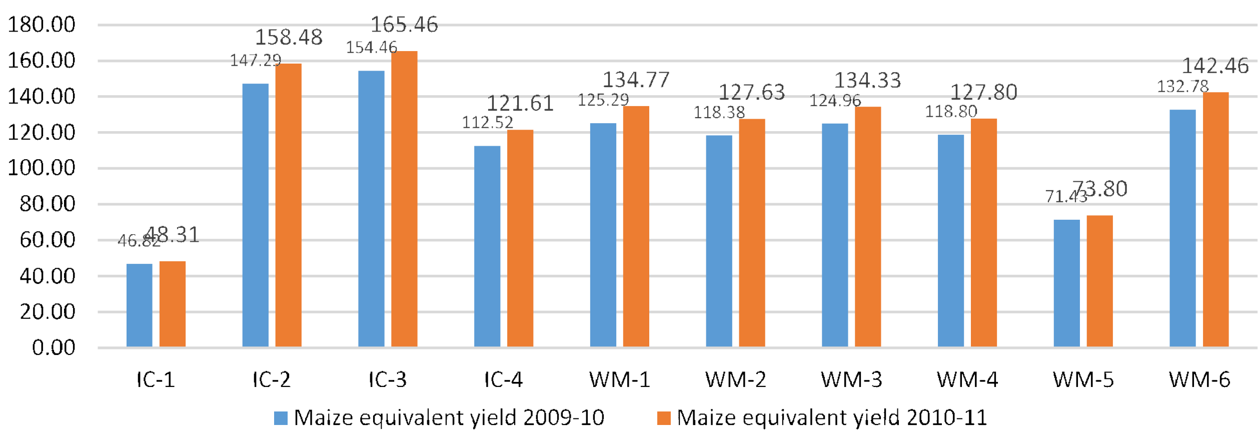
Winter maize: Among intercropping systems, winter maize in sole stand recorded significantly higher grain and stover yield and was followed by additive and replacement series which was probably because of more number of plants per unit area and less competition for sunlight, space, water and nutrients for sole crop as compared to intercropping treatments wherein the competition of crop plants might have curtailed efficient utilization of natural resources and restricted growth of winter maize from initial stages to harvest resulting in yield competition for main and intercrops. However, between additive and replacement treatments, significantly higher grain and stover yield of winter maize under additive series mainly might have happened due to significantly higher plant population as compared to replacement series (Table 1). Higher yield of maize under sole stand than intercropping was reported by Khola *et al.* (1999) and Singh and Singh (2001). The pronounced effect of increased yield after weed free treatment was observed with pre-emergence application of atrazine at 0.5 kg/ha. This treatment recorded significantly higher grain and stover yield which was statistically at par with post emergence application of atrazine at 0.75 kg/ha and pre emergence application of alachlor at 1.5 kg/ha.

The increase in yield under various weed-management treatments may be attributed to significant reduction in weed dry matter (Table 1), thereby reduction in crop weed competition which provided congenial environment to the crop for better expression of vegetative and reproductive potential. The lowest grain and stover yield of winter maize was noticed in weedy check as a consequence of stiff competition imposed by weeds resulting in poor source and sink development with poor yield contributing characters and higher weed index. The above results could be corroborated with the findings of Rout and Satapathy (1996) and Kolage *et al.* (2004). Highest maize equivalent yield was achieved higher in winter maize + potato (additive series) and was statistically at par with sole potato. Amongst the herbicidal treatments, significantly higher maize equivalent yield was recorded with pre-emergence application of alachlor 1.5 kg/ha which was statistically at par with pre-emergence application of atrazine 0.5 kg/ha due to superiority in yield attributes of crop components as a result of reduced crop-weed competition and increased water and nutrient availability (Roy *et al.* 2008) (Fig. 1).

Potato: Potato in sole stand also recorded significantly higher values of tuber and haulm yields as compared to intercropping systems. The optimum space as available for potato plants under sole stand reduced the com-

Table 1. Influence of weed management practices on weed growth and yield of winter maize and potato

Treatment	Weed density (no./m^2 at 120 DAS)		Weed dry weight (at 120 DAS) (g/m^2)		Grain yield of winter maize yield (t/ha)		Tuber yield of potato (t/ha)		Stover yield of winter maize yield (t/ha)		Haulm yield of potato (t/ha)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole maize	9.25 (110)	9.14 (107)	9.96 (124)	9.74 (119)	46.8	48.3	-	-	94.9	96.5	-	-
Sole potato	8.50 (91.50)	8.30 (87.0)	9.21 (102)	8.82 (97.9)	-	-	235.7	237.7	-	-	105.6	107.6
Winter maize + potato (additive series)	7.36 (71.50)	6.71 (50.3)	8.44 (88.5)	8.19 (82.6)	35.2	36.7	190.8	193.1	87.3	88.8	97.0	99.4
Winter maize + potato (replacement series)	9.12 (108)	8.26 (76.6)	9.39 (111)	9.06 (105)	22.5	24.1	144.0	146.2	72.1	73.5	69.5	71.1
LSD (P= 0.05)	0.15	0.51	0.22	0.23	2.43	2.45	14.89	15.11	2.69	2.67	3.38	2.80
Weed management												
Weedy check	16.90 (286)	14.3 (212)	16.48 (272)	16.25 (264)	17.9	17.1	123.8	121.9	57.4	55.8	64.4	62.8
Weed free	1.00 (0)	1.00 (0)	1.00 (0)	1.00 (0)	43.3	45.3	214.0	217.0	98.4	100.3	99.9	101.9
Alachlor pre- at 1.5 kg/ha	8.22 (67.7)	8.65 (74.7)	9.45 (87.5)	9.29 (85.6)	37.3	39.3	207.6	210.6	88.5	90.8	97.6	100.3
Alachlor early post at 2.0 kg/ha	10.3 (106)	9.31 (87.7)	11.44 (127)	11.85 (140)	32.9	34.9	199.9	202.9	82.7	84.8	94.9	97.7
Atrazine pre- at 0.5 kg/ha	6.80 (46.0)	6.82 (46.2)	7.89 (62.3)	7.05 (49.3)	39.3	41.3	203.8	206.8	91.4	93.8	96.5	98.8
Atrazine post- at 0.75 kg/ha	8.12 (66.2)	7.05 (51.7)	9.25 (89.8)	8.25 (67.2)	38.4	40.4	192.0	195.0	90.2	92.2	90.8	94.8
LSD (P = 0.05)	0.08	0.58	0.39	0.009	1.97	1.97	9.47	9.54	2.48	2.70	2.92	2.79



IC - Intercropping, WM - Weed management, IC_1- Sole maize, IC_2 - Sole potato, IC_3 -Winter maize + potato (additive series), IC_4 - Winter maize + potato (replacement series), WM_1 - Alachlor pre- 1.5 kg/ha, WM_2 - Alachlor early post 2.0 kg/ha, WM_3 - Atrazine pre 0.5 kg/ha, WM_4 - Atrazine post 0.75 kg/ha, WM_5 - Weedy check, WM_6 - Weed free

Fig. 1. Effect of different intercropping and weed control treatments on maize equivalent yield in winter maize potato intercropping system

petition for moisture, nutrients and light among the potato plants than other intercropping combinations which might be responsible for the production of higher yield attributes of sole crop of potato (Table 1). This indicated that inter-specific competition in intercropping was more than intra-specific competition of sole stand. Among different intercropping system, additive treatments recorded significantly higher potato yield than replacement treatment. The possible reason for higher yield of potato in additive treatment rather than the replacement treatment might have been achieved due to the fact besides the single plant yield remaining inferior in additive treatment. The overall yield per unit area improved due to cumulative effect of higher plant populations in additive treatment during first and second years of cropping.

Among the weed management practices, higher tuber and haulm yields of potato were recorded where weed free environment was provided to the crop throughout its crop growing period. The potato tuber yield reduced due to weed by 42.14% and 43.82% during 2009-10 and 2010-11, respectively. Among the herbicidal treatments, alachlor application at 1.5 kg/ha as pre-emergence resulted in highest potato tuber yield which was being significantly higher to application of atrazine at 0.75 kg/ha as post-emergence might be due to reduced crop-weed competition and enhancement in most of the crop growth parameters under the favourable environmental situation. These results were in conformity with the findings of Sinha *et al.* (1999). Under this treatment, weeds were unable to compete with the crop plants which resulted in better expression of yield attributing characters and thus gave higher tuber yield.

Nutrient removal by crops

Winter maize: Irrespective of the treatments, highest N, P and K removal from grain and stover of winter maize was recorded with sole stand followed by additive series and replacement series during both the cropping seasons of *Rabi* 2009-10 and 2010-11, respectively (Table 2). The higher removal of these nutrients by sole winter maize as compared to intercropping treatments probably happened due to vigorous growth and better root system under optimum spacing which had helped in adequate supply of these nutrients resulting in higher biological yield coupled with their effective transfer to the ultimate sink *i.e.* the grains thus leading to numerically higher winter maize grain nutrient contents of N, P and K. Obviously, this was due to lesser competition from weeds and ultimately better growth of crop. Among weed management practices, highest N, P and K removal from grain and stover of winter maize was removed from weed free treatment during 2009-10 and 2010-11, respectively. Similar result was also reported by Banga *et al.* (2002). Among the herbicides, highest N, P and K from grain and stover of winter maize was removed from atrazine pre-emergence 0.5 kg/ha followed by alachlor pre-emergence 1.5 kg/ha during both the seasons respectively. This could possibly be attributed to higher weed-control efficiency resulting in more favourable environment for growth and development of crop plants apparently due to the lesser weed competition. The results conformed to the findings of Srinivas and Satyanarayana (1996) and Mundra *et al.* (2002).

Potato (tuber and haulm): N removal by potato tuber was observed under sole stand of potato followed by additive series and replacement series which were seen to be significantly influenced by intercropping systems whereas numerically highest N and significantly higher P and K uptakein potato haulm was recorded with sole stand followed by additive series and replacement series which in turn P and K found significantly different to one another during 2009-10 and 2010-11, respectively (Table 3). Similar result was also reported by Sharma *et al.* (1998). Among the herbicidal treatments, significantly higher value of NPK uptake was recorded with pre-emergence application of alachlor1.5 kg/ha followed by atrazine pre-emergence 0.5 kg/ha. The possible reason for beneficial effect of the weed control treatments in reducing the nutrient drain by weeds was reflected in significantly increased uptake of N, P and K by potato tuber as compared to the weedy check plots. Similar findings were noticed by Banga *et al.* (2002).

Table 2. Influence of weed management treatments on uptake of N, P and K (kg/ha) of winter maize

Treatment	N				P				K			
	Grain		Stover		Grain		Stover		Grain		Stover	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole maize	42.9	45.1	18.1	19.3	10.0	11.3	16.6	18.3	12.4	12.8	51.5	54.5
Winter maize + potato (additive series)	32.1	34.2	12.1	13.9	7.3	8.4	12.0	13.3	8.6	8.77	45.1	48.6
Winter maize + potato (replacement series)	20.6	22.5	12.9	14.1	4.9	5.8	13.4	14.8	5.9	6.38	37.5	39.7
LSD (P=0.05)	2.38	2.53	1.86	0.67	0.60	0.66	0.73	0.24	0.72	1.30	1.92	4.60
Weed management												
Alachlor pre- at 1.5 kg/ha	33.8	36.4	15.1	16.5	9.0	9.0	15.1	16.2	9.7	10.5	48.6	50.5
Alachlor early post- at 2.0 kg/ha	30.1	32.6	9.4	11.5	8.1	8.1	12.9	15.3	8.1	8.8	42.0	47.8
Atrazine pre- at 0.5 kg/ha	36.4	39.1	18.6	19.9	9.7	9.8	15.8	17.1	10.3	11.1	52.0	53.3
Atrazine post- at 0.75 kg/ha	35.0	37.6	16.7	18.1	9.3	9.3	15.5	16.9	9.8	10.4	49.5	51.3
Weedy check	16.3	15.5	3.2	2.3	3.8	3.8	7.5	8.0	4.3	2.72	21.3	24.8
Weed free	39.8	42.5	23.3	25.4	10.9	10.9	17.3	19.1	11.5	12.4	54.9	57.8
LSD (P=0.05)	1.90	1.93	1.19	1.13	0.52	0.56	1.42		0.67	0.80	1.95	1.87

NPK uptake by weeds

At harvest, significantly higher N, P and K was removed by sole cropping of potato followed by sole cropping of winter maize, replacement and additive series during 2009-10 and 2010-11, respectively. This might have happened due to growing of intercrop in spaced winter maize rows which while utilizing the space efficiently reduced the intensity and dry matter of weeds leading to lower NPK uptake by weeds. The removal of N, P and K by weeds were reduced significantly by various herbicidal and manualweeding treatments and it was almost nil under weed free treatment whereas significantly highest N, P and K uptake by weeds was recorded in the weedy check treatment (Table 4). The results confirm to the findings of Rafey and Prasad (1992). The removal of N, P and K by weeds was reduced significantly by various herbicidal and manual weeding treatments and it was almost nil under weed free treatment whereas significantly highest N, P and K uptake by weeds was recorded in the weedy check treatment. This might be attributed to luxuriant growth of unchecked weeds in weedy check treatment which competed dominantly with the crop plants for nutrients. The results confirm the findings of Srinivas and Satyanarayana (1996) and Mundra *et al.* (2002). Among the herbicidal treatments, significantly lowest values of N, P and K uptake were recorded in atrazine pre-emergence 0.5 kg/ha followed by alachlor pre-emergence 1.5 kg/ha whereas, significantly highest values of N, P and K uptake by weeds were recorded with alachlor early post 2.0 kg/ha which showed relatively lower efficacy against weeds whose infestation was predominantly higher in these plots but not to the extent observed in weedy check plots.

Economics

Intercropping of maize with potato under different intercropping system resulted in higher net returns and benefit cost ratio than sole maize and sole potato (Table 4). The intercropping of maize with potato in additive treatment gave maximum net returns (` 80,585. and ` 1,03,590/ha) followed by replacement treatments. However, replacement treatment registered maximum B:C ratio (2.01 and 2.49) followed by additive and sole maize treatments. Padhi and Panigrahi (2006) and Pathak and Singh (2008) also reported the economic viability of intercropping systems over sole crops. All the weed control treatments were superior in terms of net returns and benefit cost ratio than unweeded check. Among weed management treatments, highest net returns and B: C ratio were obtained in treatment atrazine pre-emergence application 0.5 kg/ha followed by alachlor pre-emergence 1.5 kg/ha where as the lowest net returns and B: C ratio were observed in weedy check treatment followed by weed free treatment. Net return per rupee investment was more with herbicidal treatments than hand weeding and weedy check treatment due to lower cost involved under herbicidal treatments. Similar results were also reported by Prasad and Srivastava (1990) and Roy *et al.* (2008).

In conclusion, the study revealed that winter maize + potato intercropping system along with the application of atrazine pre-emergence 0.50 kg/ha and alachlor pre-emergence 1.5 kg/ha was found effective in reducing weed population and resulted in higher maize equivalent yield. The highest uptake by crops and lowest removal of nutrients by weeds was also with the application of atrazine pre-emergence 0.50

Table 3. Influence of weed management treatments on uptake of N, P and K (kg/ha) of potato

Treatment	N				P				K			
	Tuber		Haulm		Tuber		Haulm		Tuber		Haulm	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole potato	92.4	93.2	31.5	32.8	14.3	15.2	4.53	5.04	89.4	91.0	31.8	33.4
Winter maize + potato (additive series)	75.2	76.1	28.0	29.2	8.98	9.73	3.40	3.87	63.2	64.6	29.3	30.9
Winter maize + potato (replacement series)	57.3	58.2	23.2	24.2	6.75	7.35	2.73	3.08	57.1	58.5	20.5	21.7
LSD (P= 0.05)	5.71	5.80	4.01	3.74	1.59	1.46	0.77	0.79	6.71	6.53	1.37	1.70
Weed management												
Alachlor pre- at 1.5 kg/ha	82.0	83.2	30.9	31.6	11.9	12.8	4.18	4.62	78.0	79.9	30.3	31.4
Alachlor early post- at 2.0 kg/ha	77.7	78.9	27.2	29.1	9.55	10.3	3.37	3.92	71.7	73.5	27.4	29.7
Atrazine pre- at 0.5 kg/ha	79.2	80.3	29.2	30.4	10.9	11.7	3.73	4.21	75.2	77.0	29.0	30.4
Atrazine post- at 0.75 kg/ha	75.6	76.8	26.3	29.5	8.52	9.29	2.66	3.32	66.7	68.4	24.9	28.4
Weedy check	48.3	47.5	19.2	18.7	6.25	6.57	2.28	2.42	42.4	42.1	20.2	19.8
Weed free	87.0	88.2	32.9	33.2	13.0	13.9	5.10	5.49	85.3	87.2	31.4	32.2
LSD (P = 0.05)	4.52	4.56	1.34	1.12	1.33	1.35	0.51	0.50	3.64	3.75	1.29	1.12

Table 4. Influence of weed management treatments on uptake of N, P and K (kg/ha) of weeds and economics of the system

Treatment	N		P		K		Net returns (x10^3 `/ha)		B:C ratio	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping										
Sole maize	13.1	11.9	4.55	4.06	15.2	13.9	23.31	28.83	1.65	1.97
Sole potato	18.0	17.4	4.11	3.98	19.8	19.4	71.95	94.40	1.57	1.96
Winter maize + potato (additive series)	9.43	8.44	3.37	3.03	10.0	8.96	80.59	103.6	1.87	2.29
Winter maize + potato (replacement series)	11.3	10.7	4.16	3.93	14.1	13.3	60.12	78.12	2.01	2.49
LSD (P= 0.05)	0.93	0.56	0.42	0.38	1.86	1.53	-	-	-	-
Weed management										
Alachlor pre- at 1.5 kg/ha	10.5	9.70	3.21	2.86	10.9	9.97	68.46	87.76	2.15	2.62
Alachlor early post- at 2.0 kg/ha	14.6	16.8	4.94	5.24	16.3	18.9	62.61	80.10	1.95	2.39
Atrazine pre- at 0.5 kg/ha	7.39	5.16	2.12	1.46	8.39	5.87	68.90	88.06	2.22	2.68
Atrazine post- at 0.75 kg/ha	11.7	7.45	3.30	2.32	12.7	8.24	63.83	82.04	2.05	2.49
Weedy check	33.7	33.5	10.7	10.6	40.4	40.2	26.36	34.21	0.86	1.06
Weed free	0.00	0.00	0.00	0.00	0.00	0.00	63.78	84.35	1.50	1.92
LSD (P= 0.05)	0.94	0.75	0.33	0.31	1.18	0.93	-	-	-	-

kg/ha and alachlor pre-emergence 1.5 kg/ha. Therefore, for efficient utilization of applied nutrients the weed should be kept under control.

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Management of nutsedge in sugarcane by ethoxysulfuron

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ABSTRACT

Field investigion was carried out for two consecutive years 2009-10 and 2010-11 at Pantnagar (Uttarakhand) to study the bio-efficacy of ethoxysulfuron for the control of *Cyperus rotundus* (nutsedge) in sugarcane. Experiment consisted of six treatments, *viz.* doses of ethoxysulfuron 46.87, 56.25 and 60 g/ha, 2,4-D Na salt 1000 g/ha, three hoeing 30, 60 and 90 days after planting (DAP) of sugarcane and untreed control was laid out in randomized block design with three replicions. Ethoxysulfuron and 2,4-D Na salt were applied at 3-4 leaf stage of *Cyperus rotundus*. Among the herbicidal treatments, the lowest weed density as well as dry weight of total weeds was observed with ethoxysulfuron 60 g/ha 3-4 leaf stage of *C. rotundus* at both the stages at 30 and 60 DAA though the differences were non-significant when compared with its lower dose 56.25 g/ha, 30 and 60 DAA and 46.87 g/ha 60 DAA during both the year. Application of ethoxysulfuron 3-4 leaf stage of *C. rotundus* effectively controlled *C. rotundus* and broad-leaved weeds, *viz. Trianthema monogyna, Digera arvensis, Cleome viscosa* and *Ipomoea* spp. This herbicide any rate was not effective against grassy weeds. The highest cane yield was recorded with the execution of three hoeing at 30, 60 and 90 days after planting (DAP). Among the herbicidal trements, ethoxysulfuron 60 g/ ha at 3-4 leaf stage of *C. rotundus* recorded maximum cane yield (82.3 and 86.8 t/ha), although it was at par with its lower dose 56.25 g/ha. The lowest cane yield was recorded with control.

Key words: Bio-efficacy, *Cyperus rotundus,* Herbicide, Hoeing, Nutsedge, Spring-planted Sugarcane

Sugarcane, being a slow growth at atinitial stage and a long duration crop faces severe competition with annual grasses, broad-leaved and perennials weeds like *Cyperus rotundus* between 60 to 120 days of its planting, which causes heavy reduction in cane yield ranging from 40 to 67% (Chauhan and Srivastva 2002, Singh *et al.* 2011). Management practices play an important role in realizing potential yield of sugarcane. Sugarcane, being a widely spaced crop, allows wide range of weed flora to grow profusely in the interspaces between the rows. Frequent irrig ions and fertilizer applicion during early growth stages increase the weed menace by many folds (Singh *et al.* 2008). To escape yield loss and to achieve maximum yield of sugarcane, a weed free environment during the critical period of crop-weed competition is essential which could be achieved by the applicion of effective herbicides (Singh 1980). It is well established fact that cultural method of weed management is most effective to control weeds but in present scenario, timely availability of agricultural labours is a big problem in agriculture and day by day increasing labour charges further increase the cost of cultivion. Therefore, herbicidal control of weeds has been suggested to be economical in sugarcane (Chauhan *et al.* 1994, Sarala *et al.* 2011). Several herbicides have, however been tried in sugarcane but successful control of *Cyperus* spp. could not be achieved. The present investigation was therefore, undertaken to study the bio-efficacy of ethoxysulfuron for control of *Cyperus rotundus* (nutsedge) in sugarcane.

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MATERIALS AND METHODS

A field experiment was conducted during 2009-10 and 2010-11 at N. E. Borlaug Crop Research Center of GBPUA&T, Pantnagar, Uttarakhand to evaluate the bio-efficacy of ethoxysulfuron for the control of *Cyperus rotundus* in sugarcane. Soil of the experimental field was silty loam in texture, medium in organic carbon (0.67%), available phosphorus (29.6 kg/ha) and potassium (176.4 kg/ha) with pH 7.2. Experiment with six treatments comprised of three doses of ethoxysulfuron 46.87 g/ha, 56.25 and 60 g/ha at 3-4 leaf stage of *C. rotundus*, 2,4-D sodium salt 80 WP 1000 g/ha, three hoeing at 30, 60 and 90 days after planting (DAP) of sugarcane crop and untreated control was laid out in randomized block design with three replications. Ethoxysulfuron 15 WG and 2,4-D (Na salt) were applied at 3-4 leaf stage of *C. rotundus* by using Maruti foot sprayer fitted with flat fan nozzle using water volume of 500 liters per hectare. Three budded setts of sugarcane variety *'CoP 90223'* were planted keeping a row spacing of 75 cm on March 3, 2009 and April 9, 2010. Recommended package of practices were adopted to raise the crop. The sugarcane crop was harvested on 7 December, 2009 during first year and 13 December, 2010 during second year. Observations on density and dry weight of weeds were recorded at 30 and 60 days after execution of treatments. Data pertaining to density and dry matter accumulation of total weeds were subjected to log transformation by adding 1.0 to original values prior to statistical analysis.

RESULTS AND DISCUSSION

Effect on weeds

The major weed flora in experimental field comprised of *Cyperus rotundus*, *Echinochloa* spp., *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Trianthema monogyna*, *Digera arvensis* and *Ipomoea* spp. in both the years. Besides these, *Brachiaria reptans* and *Cleome viscosa* were also observed as major weeds during 2010. All the weed control treatments caused significant reduction in the dry weight of *Cyperus rotundus* and density and dry weight of total weeds over untreated control during both the year. The highest reduction in the density and dry weight of total weeds was recorded with the execution of three hoeing at 30, 60 and 90 days after planting (DAP). Among the herbicidal treatments, the lowest weed density and dry weight of total weeds were observed with ethoxysulfuron 60 g/ha, though the differences were non-significant when compared with its lower dose of 56.25 30 at 60 DAA and 46.87 g/ha at 60 DAA during both the years. Application of ethoxysulfuron of all the doses effectively controlled the *C. rotundus* and broad-leaved weeds, *viz. Trianthema monogyna, Digera arvensis, Cleome viscosa* and *Ipomoea* spp. This herbicide was not found effective against grassy weeds such as *Echinochloa* spp., *Digitaria sanguinalis*, *Dactyloctenium aegyptium* and *Brachiaria reptans*.

Yield parameters

All the weed control treatments showed significantly positive influence on cane length, number of millable canes and cane yield over unweeded control. Cane girth indices showed non-significant differences among all the treatments. The highest cane length (277 cm) was recorded with three hoeing at 30, 60 and 90 DAP which was significantly superior than 2,4 -D Na salt 80 WP 1000 g/ha and was at par with different doses of ethoxysulfuron except unweeded control which recorded lowest cane length (225 cm). Significantly more millable canes were recorded under three hoeing at 30, 60 and 90 DAP which remained statistically at par with all herbicidal treatments. Among the tested herbicides, ethoxysulfuron 60 g/ha recorded the highest cane length (272 cm), number of millable canes (70.55 thousand/ha) and cane yield (84.55 t/ha) during both the years. This might be due to effective weed control with application of ethoxysulfuron 60 g/ha which resulted increased yield promoting tributes. These results were in agreement with the findings of Singh *et al.* (2011). Pel *et al.* (2013) also reported that all the weed control treatments favourably influenced the yield tributing characters such as number of millable canes, cane length and cane diameter except unweeded check. The highest cane yield (102.0 and 108.3 t/ha) was recorded with three hoeing 30, 60 and 90 DAP during 2009 and 2010. Among the herbicidal treatments, application of ethoxysulfuron 56.25 and 60 g/

Table 1. Weed density (no./m^2) at 30 DAA as influenced by ethoxysulfuron in sugarcane

Treatment	*C. rotundus*		*Echinochloa* spp.		*D. sanguinalis*		*B. reptans*		*D. aegyptium*		*T. monogyna*		*D. arvensis*		*C. viscosa*		*Ipomoea* spp.	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Ethoxysulfuron	2.34	2.60	2.60	2.60	2.00	2.65	0.0	1.81	1.27	0.54	1.07	0.54	1.07	0.54	0.0	1.07	0.0	0.0
(46.87 g/ha)	(10)	(13)	(13)	(13)	(7)	(13)	(0)	(5)	(4)	(1)	(3)	(1)	(3)	(1)	(0)	(3)	(0)	(0)
Ethoxysulfuron	1.80	2.12	2.81	2.87	1.80	2.21	0.0	1.27	1.07	0.54	1.07	0.0	0.54	0.0	0.0	0.54	0.0	0.0
(56.25 g/ha)	(5)	(8)	(16)	(17)	(5)	(9)	(0)	(4)	(3)	(1)	(3)	(0)	(1)	(0)	(0)	(1)	(0)	(0)
Ethoxysulfuron	1.07	1.81	2.53	2.69	2.12	2.34	0.0	1.07	0.73	0.54	0.54	0.0	0.00	0.0	0.0	0.0	0.0	0.0
(60.00 g/ha)	(3)	(5)	(12)	(15)	(8)	(11)	(0)	(3)	(3)	(1)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
2,4-D Na salt	3.74	3.49	2.74	2.90	2.00	2.41	0.0	1.27	1.27	1.07	1.59	1.07	0.54	0.0	0.0	0.54	0.0	0.54
(1000 g/ha)	(43)	(32)	(15)	(17)	(7)	(12)	(0)	(4)	(4)	(2)	(7)	(3)	(1)	(0)	(0)	(1)	(0)	(1)
Three hoseings at	2.81	2.94	1.07	0.54	0.00	1.07	0.0	0.0	0.54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30, 60 and 90 DAP	(16)	(19)	(3)	(1)	(0)	(3)	(0)	(0)	(1)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Untreated control	4.53	4.27	2.70	2.87	2.12	2.34	0.0	1.46	1.07	1.81	3.34	3.18	2.53	2.21	0.0	1.27	1.27	1.07
	(92)	(71)	(15)	(17)	(8)	(11)	(0)	(5)	(3)	(5)	(28)	(24)	(12)	(9)	(0)	(4)	(4)	(3)
LSD (P=0.05)	0.94	0.61	0.92	0.87	0.73	NS	0.0	NS	2.06	NS	1.70	0.98	1.22	0.89	0.0	NS	0.84	NS

Figures in parentheses indicate original values which were transformed to $\log_e$ (x+1)

Table 2. Weed density (no./m²) at 60 DAA as influenced by ethoxysulfuron in sugarcane

Treatment	*C. rotundus*		*Echinochloa* spp.		*D. sanguinalis*		*B. reptans*		*D. aegyptium*		*T. monogyna*		*D. arvensis*		*C. viscosa*		*Ipomoea* spp.	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Ethoxysulfuron (46.87 g/ha)	1.80 (5)	1.8 (5)	3.48 (32)	3.22 (25)	2.00 (7)	2.81 (16)	0.0 (0)	1.39 (5)	1.87 (4)	1.13 (1)	1.07 (3)	0.54 (1)	1.07 (3)	0.0 (0)	0.0 (0)	1.07 (3)	0.54 (1)	0.0 (0)
Ethoxysulfuron (56.25 g/ha)	0.0 (0)	0.0 (0)	3.30 (27)	3.08 (21)	2.21 (9)	2.62 (13)	0.0 (0)	1.93 (7)	1.07 (5)	0.0 (0)	0.0 (0)	0.0 (0)	0.54 (1)	0.0 (0)	0.0 (0)	0.54 (1)	0.0 (0)	0.0 (0)
Ethoxysulfuron (60.00 g/ha)	0.54 (1)	0.0 (0)	3.38 (29)	3.14 (23)	2.33 (11)	2.69 (15)	0.0 (0)	1.39 (5)	1.80 (3)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
2,4-D Na salt (1000 g/ha)	2.92 (19)	2.53 (12)	3.44 (31)	3.18 (24)	2.21 (9)	2.87 (17)	0.0 (0)	1.39 (5)	0.73 (5)	1.07 (3)	1.27 (4)	1.07 (3)	0.54 (1)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)
Three hoeings at 30, 60 and 90 DAP	1.01 (3)	1.27 (4)	0.54 (1)	1.07 (3)	0.0 (0)	0.54 (1)	0.0 (0)	0.0 (0)	0.73 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.54 (1)	0.0 (0)
Untreated control	3.80 (45)	3.37 (29)	3.38 (29)	3.30 (27)	2.53 (12)	2.69 (15)	0.0 (0)	2.00 (7)	1.27 (5)	1.39 (9)	2.53 (12)	2.32 (9)	1.59 (7)	0.0 (0)	0.0 (0)	1.80 (5)	1.80 (5)	1.59 (7)
LSD (P=0.05)	0.98	0.78	0.83	0.63	0.92	0.69	0.0	1.17	NS	NS	1.18	1.08	1.72	0.0	0.0	1.43	1.09	1.08

Figures in parentheses indicate original values which were transformed to $\log_e$ (x+1)

Table 3. Weed dry weight (g/m²) as influenced by ethoxysulfuron in sugarcane

Treatment	Dose (g/ha)	30DAA						60 DAA					
		2009			2010			2009			2010		
		C. rotundus	Total	WCE (%)	*C. rotundus*	Total	WCE (%)	*C. rotundus*	Total	WCE (%)	*C. rotundus*	Total	WCE (%)
Ethoxysulfuron	46.87	1.36 (2.9)	3.91 (49)	57.5	1.46 (3.3)	4.04 (55.7)	47.7	0.79 (1.2)	4.48 (86.8)	39.8	0.83 (1.3)	4.63 (101.2)	31.3
Ethoxysulfuron	56.25	0.83 (1.3)	3.84 (46)	60.1	1.06 (1.9)	3.96 (51.4)	51.7	0.53 (0.7)	4.41 (81.1)	43.7	0.00 (0)	4.52 (90.4)	38.7
Ethoxysulfuron	60.00	0.53 (0.7)	3.78 (42.8)	62.9	0.74 (1.1)	3.86 (46.3)	56.5	0.18 (0.2)	4.40 (80.6)	44.1	0.00 (0)	4.49 (88.5)	40.0
2,4-D Na salt	1000.0	2.80 (15.5)	4.17 (63.9)	44.6	2.66 (13.3)	4.23 (67.9)	36.2	1.44 (3.2)	4.57 (95.7)	33.6	1.39 (3)	4.62 (100.4)	31.9
Three hoeings at 30, 60 and 90 DAP	-	1.13 (2.1)	1.31 (2.7)	97.6	1.19 (2.3)	1.39 (3)	97.2	0.41 (0.5)	0.69 (1)	99.3	0.41 (0.5)	0.83 (1.3)	99.1
Untreated control	-	3.69 (39.2)	4.76 (115.3)	-	3.36 (27.9)	4.68 (106.5)	-	2.84 (16.2)	4.98 (144.1)	-	2.61 (12.6)	5.00 (147.4)	-
LSD (P=0.05)	-	0.29	0.32	-	0.21	0.23	-	0.33	0.35	-	0.28	0.37	-

Figures in parentheses indicate original values which were transformed to $\log_e$ (x+1)

ha being statistically similar resulted in significantly higher cane yield compared to ethoxysulfuron 46.87 g/ha 2,4-D Na salt during 2009 and 2010, respectively. The higher cane yield under these treatments might be due to higher weed control efficiency with higher cane length and higher number of millable cane per hectare. Singh *et al.* (2011) and Suganthi *et al.* (2013) observed higher cane length number of internodes and cane weight with weed free situations.

Weed control efficiency

Highest weed control efficiency of 97.6 and 97.2% was recorded with three hoeing at 30, 60 and 90 DAP 30 DAA and 99.3 and 99.1% at 60 DAA during 2009 and 2010, respectively. This might be due to effective weed control which resulted in lower weed dry weight. In herbicidal treatments, application of ethoxysulfuron 60 g/ha recorded higher weed control efficiency of 62.9 and 56.5% in three hoeing at 30 DAA and 44.1 and 40.0% at 60 DAA during 2009 and 2010, respectively. This was also comparable with ethoxysulfuron 56.25 g/ha where a weed control efficiency of 60.1 and 51.7% at 30 DAA and 43.7 and 38.7% at 60 DAA was recorded, respectively during both the years. Highest cane yield was recorded with three hoeing at 30, 60 and 90 DAP followed by ethoxysulfuron 60 g/ha (82.3 and 86.8 t/ha). This can be attributed to effective control of weeds by hoeing which provide more soil aeration, enhanced uptake of nutrients by crop coupled with improvement

Table 4. Yield at tributes and yields of sugarcane as influenced by ethoxysulfuron

Treatment	Dose (g/ha)	Cane length (cm)		Cane girth (cm)		No. of millable canes (x10^3 `/ha)		Cane yield (t/ha)		Weed Index (%)
		2009	2010	2009	2010	2009	2010	2009	2010	
Ethoxysulfuron	46.87	256	258	8.5	8.5	60.5	63.5	69.2	72.3	32.7
Ethoxysulfuron	56.25	260	267	8.6	8.7	64.5	67.2	76.8	80.6	25.1
Ethoxysulfuron	60.00	271	274	8.8	8.8	68.6	72.5	82.3	86.8	19.6
2,4-D Na salt	1000	251	255	8.4	8.3	56.0	58.0	68.3	70.0	34.2
Three hoeings at 30, 60 and 90 DAP	-	274	280	8.9	9.3	90.4	96.4	102.0	108.3	00.0
Untreated control	-	215	235	6.7	7.8	38.6	40.0	47.5	48.7	54.2
LSD (P=0.05)	-	21	23	NS	NS	13.83	11.07	6.8	7.2	-

in growth and yield contributing characters. Similiar results have also been reported by Almubarak *et al.* (2012). Chauhan and Srivastava (2002) recorded increase in cane yield up to 52% in weed free conditions due to better crop environment. This might be due to effective control of weeds, which provide congenial environment for the crop. Similar results were also obtained by EI- Shafai *et al.* (2010).

The weed index was zero by three hoeing at 30, 60 and 90 DAP whereas, in herbicidal treatments, it was lower in treatments of ethoxysulfuron at 60 g/ha, which recorded weed index of 19.6%. Kalayarasi (2012) also reported lower weed index in herbicide applied plots when compared to unweeded control. This might be due to effective control of weeds, which enhanced the yield of the crop in three hoeing at 30, 60 and 90 DAP and ethoxysulfuron at 60 g/ha (Table 4).

It can be concluded the application of ethoxysulfuron at 60 g/ha or 56.25 g/ha at 3-4 leaf stages of *C. rotundus* was found more effective for controlling this weed as well as broad-leaf weeds, *viz. Trianthema monogyna, Digera arvensis, Cleome viscosa* and *Ipomoea* sp.

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Weed management in sugarcane ratoon crop

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ABSTRACT

A field experiment was conducted on ratoon crop of sugarcane to develop suitable weed management practices during spring seasons of 2008-09, 2009-10 and 2010-11 at Sugarcane Experimental Area, (Ladhowal), Punjab Agricultural University, Ludhiana. A total of fourteen treatments including weedy check was tested in randomized block design with three replication. Herbicidal treatments were applied to ratoon crop immediately after harvesting of plant crop in the I[st] week of February every year under moist conditions. The highest weed dry weight of 182.7 g/m^2 was recorded in weedy check. All the weed control treatments recorded significantly less weed dry weight as compared to the weedy check. The highest pooled cane yield of 74.3 t/ha was obtained with pre-emergence application of metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 days after ratoon initiation (DARI). The weed dry weight was significantly reduced to less than one third (54.3 g/m^2) with pre-emergence application of metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 DARI compared to weedy check. Atrazine applied as pre-emergence at 2 kg/ha *fb* 2,4-D 1.0 kg/ha at 45 DARI proved equally effective as pre-emergence metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 DARI. In sugarcane ratoon crop, pre-emergence application of metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 DARI or atrazine 2 kg/ha *fb* 2,4-D 1.0 kg at 45 DARI gave net returns of ` 84,820/- and ` 84,497/- which was 61.7% and 61.1% higher over control, respectively.

Key words: Cane yield, Economics, Growth, Ratoon, Sugarcane, Weed density, Weed Management

Weeds infestation in sugarcane ratoon crop is entirely different and is a specific problem when compared with any other crop. In sugarcane, weeds have been estimated to cause yield losses from 10% to total crop failure depending upon composition, diversity of weeds and duration of competition (Mehra *et al.* 1990, Srivasatva and Chauhan 2002). This fact can be understood by specific reasons like establishment of weeds in plant crop as eradication of weeds from plant crop is not possible at affordable cost, wider row spacing (60-120 cm), slow initial growth (90-120 days), heavy fertilization and frequent irrigations. All these factors are responsible for weed infestation which in turn offers a great competition for crop growth in terms of space and inputs.

The efficiency of some of the recommended herbicides for weed control is for a lesser duration (may be between 7-8 weeks after application) which are not able to control weeds up to canopy formation stage. This has made to supplement the herbicides with either hand weeding or application of post-emergence herbicide, which is adding of another cost to crop production. If not controlled timely, the weeds at later stages become almost impossible to control either through chemical or mechanical methods resulting poor crop growth and losses in cane yield. To realize the main advantage of ratoon ability of sugarcane, timely weed management is one of the most important factor otherwise there are chances of great loss to farmers from ratoon crop in terms of time and money. Since the work done on weed management in ratoon crop is very limited, the experiment was conducted to find out the efficacy of different herbicides on weeds associated with ratoon crop of sugarcane.

MATERIALS AND METHODS

The experiment was conducted on sugarcane ratoon crop during spring season of 2008-09, 2009-10 and 2010-11 on sandy loam soil at Sugarcane Experimental Area, (Ladhowal), Punjab Agricultural University, Ludhiana to study the effect of different weed control treatments on sugarcane ratoon crop. The plant crop was raised using recommended package and practices of Punjab. The weeds in plant crop were managed through manual weeding. The experiment comprised of fourteen treatments (Table 1) were tested in a randomized block design with three replications. Treatment atrazine 1 kg/ha as PE *fb* 2,4-D 1.6 kg/ha at 45 DARI, metribuzin 1.4 kg /ha PE *fb* 2,4-D 1.6 kg/ ha at 45 DARI and diuron 1.6 kg/ha *fb* 2,4-D 1.6 kg / ha at 45 DARI were recommended practices in plant crop under Punjab conditions. Sugarcane variety '*CoJ*

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88' was planted in spring seasons of 2008-09, 2009-10 and 2010-11. Ratooning was initiated in the first week of February in subsequent year, respectively in three years of experimentation. All the treatments except trash mulching in alternative rows *fb* 1 hoeing at 1st and 6th WARI and trash mulching between all rows were applied after giving irrigation immediately after harvesting of plant crop. Data on weed count and dry matter accumulation were recorded from two places in each plot by using a quadrate of 45 x 45 cm^2. Ratoon crop was harvested in the end of December during all the three years. For quality parameters, *i.e.* Pol % juice and CCS %, a representative sample of 10 stalks from each plot were crushed with vertical three roller laboratory cane crusher to extract the juice. The juice was analyzed by standard method as described by Chen (1985). Commercial cane sugar (CCS %) was calculated using winter's formula (Chen 1985). Other agronomic practices to raise the ratoon crop were followed as per the standard recommendations.

RESULTS AND DISCUSSION

The mean data of three years study (2008-09, 2009-10 and 2010-11) on various aspects of sugarcane ratoon crop are given in Table 1, 2 and 3.

Effect on weed density

Population and dry weight of weeds reduced significantly under all the weed control treatments compared with the weedy check (Table 1). The decrease in weed population ranged from 83.6% with three hoeings to 35.8% with the application of glyphosate 0.4 kg/ha as directed spray at 3 weeks stage. The reduction in weed dry weight also followed the similar trend. The highest reduction of 74.3% in dry weight was observed in three hoeings while the lowest reduction of 35.3% was observed with glyphosate 0.4 kg/ha as directed spray at 3 weeks stage. Among different herbicidal treatments (Table 1), pre-emergence application of metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 days after ratoon initiation (DARI) was found most effective by recording the lowest weed population and dry weight thus showed highest weed control efficiency (WCE). Comparing with weedy check, this treatment showed reduction to the extent of 80.1 and 70.3% in population and dry weight of weeds, respectively, although being statistically at par with pre-emergence application of atrazine 2.0 kg/ha and metribuzin 1.0 kg /ha both followed either by 2,4-D 1.0 kg /ha or by one hoeing at 45 DARI but significantly better than all the herbicidal treatments and the treatment where trash mulch was applied. Suyal and Saini (1987) and Singh *et al.* (2001) also reported the effectiveness of metribuzin in controlling weeds of sugarcane. It has also been observed that pre-emergence application of atrazine 1.0 kg/ha or diuron 1.6 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 DARI which is otherwise a recommendation for the plant crop of sugarcane did not found much effective in controlling weeds in ratoon crop as the weeds get sufficient time to prove their vigour and competitiveness after the plant crop was harvested and left for ratoon.

Effect on growth and yield

All the weed control treatments significantly increased the number of tillers as compared to weedy check (Table 2). Pre-emergence (PE) application of metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 DARI recorded maximum increase of 66.7% in number of tillers over weedy check and proved significantly bet-

Table 1. Effect of different weed control treatments on weed population and weed dry weight

Treatment	Weed count/m^2	Weed dry weight (g/m^2)	WCE (%)
Three hoeing at 1st, 4th & 7th WARI	31.3	47.0	74.3
Atrazine 2 kg/ha as PE *fb* 2,4-D 1 kg/ha at 45 DARI	52.3	62.0	66.1
Atrazine 2 kg/ha as PE *fb* 1 hoeing at 45 DARI	45.0	59.3	67.5
Atrazine 1 kg/ha as PE *fb* 2,4-D 1.6 kg/ha at 45 DARI	100.0	110.0	39.8
Metribuzin 1.4 kg /ha PE *fb* 2,4-D 1.6 kg/ha at 45 DARI	38.0	54.3	70.3
Metribuzin 1 kg/ha as PE *fb* 2,4-D 1 kg/ha at 45 DARI	49.0	60.3	67.0
Metribuzin 1 kg/ha as PE *fb* 1 hoeing at 45 DARI	42.7	55.3	69.7
Glyphosate 0.4 kg/ha at 3 weeks stage as directed spray	122.6	118.3	35.2
Glyphosate 0.4 kg/ha at 3 weeks *fb* 1 hoeing at 60 DARI	105.3	96.7	47.1
Trash mulching in alt rows *fb* 1 hoeing at 1st & 6th WARI	97.0	87.6	52.1
Trash mulching between all rows	102.3	91.3	50.0
Diuron 1.6 kg/ha *fb* 2,4-D 1.6 kg /ha at 45 DARI	81.3	90.4	50.5
Diuron 1.6 kg/ha *fb* 1 hoeing at 45 DARI	73.3	82.3	55.0
Weedy check (no. hoeing and no herbicide application)	191.0	182.7	-
LSD (P=0.05)	11.6	10.5	-

DARI- Days after ratoon initiation; WARI - Week after ratoon initiation

Table 2. Effect of different treatments on growth, yield and quality of sugarcane ratoon crop

Treatment	Tiller count ($x10^3$/ha)	NMC ($x10^3$/ha)	Cane yield (t/ha)	PoL (%)	CCS (%)
Three hoeing at 1^{st}, 4^{th} & 7^{th} WARI	183.7	95.3	73.3	18.9	13.1
Atrazine 2 kg/ha as PE *fb* 2,4-D 1.0 kg/ha at 45 DARI	178.3	97.0	72.0	19.0	13.1
Atrazine 2 kg/ha as PE *fb* 1 hoeing at 45 DARI	180.3	92.3	71.3	18.8	13.0
Atrazine 1 kg/ha as PE *fb* 2,4-D 1.6 kg/ha at 45 DARI	164.3	74.0	57.6	18.9	13.1
Metribuzin 1.4 kg/ha PE *fb* 2,4-D 1.6 kg /ha at 45 DARI	205.0	105.0	74.3	18.7	13.0
Metribuzin 1 kg/ha as PE *fb* 2,4-D 1.0 kg /ha at 45 DARI	171.0	88.3	69.7	18.9	13.1
Metribuzin 1 kg/ha as PE *fb* 1 hoeing at 45 DARI	171.0	88.7	72.0	18.7	13.0
Glyphosate 0.4 kg/ha at 3 weeks stage as directed spray	147.0	72.3	54.7	18.8	13.1
Glyphosate 0.4 kg/ha at 3 weeks *fb* 1 hoeing at 60 DARI	151.7	79.0	62.0	19.1	13.3
Trash mulching in alt rows *fb* 1 hoeing at 1^{st} & 6^{th} WARI	156.7	81.7	64.7	18.4	12.8
Trash mulching between all rows	161.0	82.3	66.3	19.0	13.2
Diuron 1.6 kg/ha *fb* 2,4-D 1.6 kg /ha at 45 DARI	162.3	80.0	63.0	19.1	13.2
Diuron 1.6 kg/ha *fb* 1 hoeing at 45 DARI	166.3	82.3	66.6	19.0	13.3
Weedy check (no. hoeing and no herbicide application)	123.0	69.0	53.3	18.6	12.8
LSD (P=0.05)	14.4	8.7	7.6	NS	NS

Table 3. Economics of different weed control treatments in sugarcane ratoon

Treatment	Gross returns (10^3 `/ha)	Expenditure (10^3 `/ha)	Net returns (10^3 `/ha)
Three hoeing at 1^{st}, 4^{th} and 7^{th} WARI	132.09	54.47	77.62
Atrazine 2 kg/ha as PE *fb* 2,4-D 1.0 kg/ha at 45 DARI	130.00	45.51	84.50
Atrazine 2 kg/ha as PE *fb* 1 hoeing at 45 DARI	129.09	48.67	80.41
Atrazine 1 kg/ha as PE *fb* 2,4-D 1.6 kg/ha at 45 DARI	105.95	45.05	60.89
Metribuzin 1.4 kg/ha PE *fb* 2,4-D 1.6 kg/ha at 45 DARI	133.23	48.41	84.82
Metribuzin 1 kg/ha as PE *fb* 2,4-D 1 kg/ha at 45 DARI	124.77	47.09	77.69
Metribuzin 1 kg/ha as PE *fb* 1 hoeing at 45 DARI	128.69	50.25	78.43
Glyphosate 0.4 kg /ha at 3 weeks stage as directed spray	98.32	44.05	54.27
Glyphosate 0.4 kg/ha at 3 weeks *fb* 1 hoeing at 60 DARI	111.95	47.65	64.29
Trash mulching in alt rows *fb* 1 hoeing at 1^{st} & 6^{th} WARI	116.36	48.77	67.59
Trash mulching between all rows	119.16	46.67	72.49
Diuron 1.6 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 DARI	113.06	45.11	67.94
Diuron 1.6 kg/ha *fb* 1 hoeing at 45 DARI	120.00	48.09	71.91
Weedy check (no. hoeing and no herbicide application)	96.11	43.67	52.44

ter than all other treatments. This treatment also recorded 11.6% increase in tiller numbers over the treatment given three hoeing at 1^{st}, 4^{th} and 7^{th} week after ratoon initiation (WARI) thus exhibiting better control of weeds through use of chemicals rather than performing manual operations (Table 2). The increase in tillers with different weed control treatments except where glyphosate 0.4 kg/ha at 3 weeks stage as directed spray and atrazine 1.0 kg/ha as PE *fb* 2,4-D 1.6 kg/ ha at 45 DARI, also led to significant increase in number of millable canes and cane yield over weedy check. Application of metribuzin 1.4 kg/ha PE *fb* 2,4-D 1.6 kg/ha at 45 DARI was found most effective and recorded 52 % increase in the number of millable cane over weedy check. It was followed by pre-emergence application of atrazine 2 kg/ha *fb* 2,4-D 1 kg/ha at 45 DARI and three hoeing at 1^{st}, 4^{th} and 7^{th} WARI. Weed control with metribuzin applied at 1.4 kg/ha as PE *fb* 2,4-D 1.6 kg/ha at 45 DARI also recorded significant increase of 10.2% in number of millable canes over three hoeing given at 1^{st}, 4^{th} and 7^{th} WARI but was at par with the pre-emergence application of atrazine 2 kg/ha *fb* either 2,4-D 1.0 kg/ha or one hoeing at 45 DARI.

All the weed control treatments except where glyphosate 0.4 kg/ha at 3 weeks stage as directed spray and atrazine 1.0 kg/ha as PE *fb* 2,4-D 1.6 kg/ha at 45 DARI yielded significantly higher than the unweeded control. The highest cane yield of 74.3 t/ha was obtained with pre-emergence application of metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 DARI, which was significantly better than the treatments where weed control was performed using glyphosate 0.4 kg/ha, diuron at 1.6 kg/ha, atrazine 1.0 kg /ha and trash mulching either in all or in alternate rows. Bains *et al* (1980) and Nadagonder and Lokshwar (1981) have also reported superiority of metribuzin over other herbicides for controlling weeds in sugarcane. Pratap (2013) concluded that application of metribuzin at 0.88 kg/ha at 3 DAR followed by one hand weeding at 45 DAR followed by 2,4-D at 0.75 kg/ha at 2-4-D leaf stage of broad-leaved weeds of ratoon crop was found most effective for controlling the weeds of sugarcane ratoon crop. The treatments where metribuzin were applied either 1.4 kg /ha or 1.0 kg/ha followed by one hoeing or 2,4-D at 45 DARI and where atrazine 2.0 kg/ha as PE *fb* either 2,4-D 1.0 kg/ha or one hoeing at 45 DARI along with the treatment given three hoeings were statistically at par to each other. Effective control of weeds might have reduced their competition with the crop for different resources like nutrients, moisture and sunlight and led to enhanced tillering, formation of millable canes and cane yield. Treatments where atrazine 1.0 kg/ha or glyphosate 0.4 kg/ha or trash mulch or diuron 1.6 kg/ha were applied, recorded significantly lower cane yield when compared with the treatment of three hoeing. The reduction in cane yield under these treatments was due to their low weed control efficiency. The different weed management practices could not affect the cane quality significantly in terms of Pol % and CCS %. This may be due to the fact that juice quality is the inherent ability of genotype.

Economics

All the weed control treatments registered higher net returns than the weedy check (Table 3). Pre-emergence application of metribuzin 1.4 kg/ha *fb* 2,4-D 1.6 kg/ha at 45 DARI or atrazine 2 kg/ha *fb* 2,4-D 1.0 kg at 45 DARI gave net returns of ` 84,820 and 84,497/ha, respectively which was 61.7 and 61.1% higher over weedy check. Applying metribuzin 1.4 kg/ha as pre-emergence *fb* 2,4-D 1.6 kg/ha and atrazine 2 kg/ha *fb* 2,4–D 1.0 kg/ha also recorded 9.3 and 8.9% higher net returns, respectively over crop given 3 hoeing at 1st , 4th and 7th week after ratoon initiation. In spite of recoding the highest weed control efficiency and providing good cane yield, the treatment of three hoeings at 1st, 4th and 7th week after ratoon initiation could not found economical because of higher expenditure incurred on engaging labourers.

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Chemical and mechanical weed management for increased yield of French bean

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ABSTRACT

Field experiments were conducted during *Kharif* 2010 and 2011 to study the effect of weed management practices on French bean in temperate region of Kashmir, India. Among different weed control treatments, pre-plant incorporation and pre-emergence application of fluchloralin and pendimethalin 1.00 kg/ha significantly reduced the population of different weeds than weedy check and other herbicide treatments. These resulted in significant increase in growth and yield attributes, *viz*. plant height, number of branches, dry matter accumulation, seed and straw yield of French bean. Maximum seed yield was obtained with fluchloralin 1.00 kg/ha and pendimethalin 1.00 kg/ha treatments with a corresponding value 1.11 and 1.10 t/ha. These also increased the nutrient uptake by French bean crop at various crop growth stages over weedy check and other treatments during both the years. Application of fluchloralin 1.00 kg/ha and pendimethalin 1.00 kg/ha significantly increased the net return over weedy check, with B:C ratio of 1.18 and 1.12 during two cropping seasons.

Key words: Chemical control, Cropping system, Economics, French bean, Mechanical control, N uptake, Weed management

French bean (*Phaseolus vulgaris* L.) is an important and highly profitable among pulse crop in hilly tracts of Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh and parts of Maharashtra in *Kharif* season due to its specific adaption to a cool and long growing season (Tripathi *et al.* 1986 and Sood *et al.* 2003). In India, French bean covers an area of 1.1 million hectares with production of 4.8 MT. In spite of its popularity, its productivity in India is very low being only 450.9 kg/ha as compared to the world average of 777.4 kg/ha (Anonymous 2010). The initial growth rate of French bean is very slow and the interspaces are infested with many weeds. It has been estimated that losses due to weeds alone can reduce the seed yield upto 20 - 60 per cent (Anonymous 2009). Keeping in view the above facts in mind, the present study was undertaken to improve the seed yield of French bean by effective chemical weed control.

MATERIALS AND METHODS

Field experiment was conducted at the experimental farm of KVK, Pulwama during *Kharif* 2010 and 2011. The soil of the location was silty clay loam, neutral in reaction (pH 7.07) having organic carbon (10.02 g/kg), available N (248.6 kg/ha), P (14.7 kg/ha) and K (250.3 kg/ha). French bean '*Selection-3*' was sown in 30 cm inter-row and 10 cm intra-row spacing in first fortnight of April during both the years of experimentation using 120 kg seed/ha. Recommended dose of 120 kg N, 60 kg P and 50 kg K were uniformly applied to all the treatments. Full dose of P and K and half dose of N were applied as basal at the time of sowing and rest half of the N total as per treatment was applied before second irrigation at 47 DAS. Twelve treatments comprising of weedy check, hand weeding at at 30 DAS, weed free, fluchloralin 0.75 kg/ha, fluchloralin 1.00 kg/ha, fluchloralin 0.75 kg/ha + hand weeding at 30 DAS, pendimethalin 0.75 kg/ha, pendimethalin 1.00 kg/ha, pendimethalin 0.75 kg/ha + hand weeding at 30 DAS, oxyfluorfen 0.15 kg/ha, oxyfluorfen 0.20 kg/ha, oxyfluorfen 0.15 kg/ha + hand weeding 30 DAS were tested in randomized block design with three replications. All the herbicide treatments were applied pre-planting and pre-emergence with the help of knapsack sprayer fitted with flat fan T-jet nozzle at a spray volume of 500 litre/ha. In weed free plots, weeds were removed manually as and when required with the help of khurpi (hand tool to remove weeds). Observations were recorded on the dry matter of weeds (g/m^2), weed control efficiency (%), seed yield (t/ha), plant height (cm), number of branches/plant, dry matter accumulation/plant (g/m^2), straw yield (t/ha), total N-uptake (kg/ha) and relative economics of the crop was also calculated. The data were statistically analyzed following standard procedure.

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RESULTS AND DISCUSSION

Weed growth

The dominant weeds in French bean were *Euphorbia prosta*, *Cyprus esculentus*, *Cyprus rotundus*, *Anagallis arvensis*, *Trifolium* spp. and *Phalaris minor*.

Weed biomass

The dry weight of weeds was significantly affected in French bean by different weed management practices. During first year, fluchloralin 1.00 kg/ha and pendimethalin 1.00 kg/ha were comparable for weed dry weight over weedy check and hand weeding at 30 DAS. Dry matter of weeds was minimum (3.84 g/m^2) with fluchloralin 1.00 kg/ha and had higher weed control efficiency (80.48 %). But during second year, fluchloralin 1.00 kg/ha (3.34 g/m^2) was closely followed by pendimethalin 1.00 kg/ha in ascending order, respectively (Table 1). All other treatments were also significantly superior to weedy check and had higher weed control efficiencies.

Seed yield and growth characters

The weed control measures exhibited significant variation in yield and growth parameters. Maximum yield (1.11 t/ha and 0.97 t/ha) was recorded in the fluchloralin 1.00 kg/ha in both the years which was statistically at par with pendimethalin 1.00 kg/ha and minimum yield was recorded in weedy check. Fluchloralin 1.00 kg/ha produced taller (26.83 cm) plants which was closely followed by pendimethalin 1.00 kg/ha (26.64 cm). The superiority of fluchloralin 1.00 kg/ha and pendimethalin 1.00 kg/ha at 90 DAS stage in term of shoot height might have accrued to better weed control (Table 2). Mishra *et al.* (1998) also reported similar results while working with few similar herbicides on French Bean. The maximum dry matter (10.01 g) in the first year was recorded under fluchloralin (1.00 kg/ha) which was statistically at par with fluchloralin (0.75 kg/ha + HW 30 DAS), pendimethalin (1.00 kg/ha) and pendimethalin (0.75 kg/ha + HW 30 DAS), however, in the second year the maximum dry matter (9.93 g/m^2) was registered by pendimethalin (1.00 kg/ha), which was closely fol-

Table 1. Effect of various treatments on dry matter of weeds in French bean at 60 DAS and seed yield

Treatment	Dry matter of weeds (g/m^2)		WCE	Seed yield (t/ha)	
	2010	2011	(%)	2010	2011
Fluchloralin (0.75 kg/ha)	6.98 (2.73)	5.92 (2.53)	63.21	0.86	0.65
Fluchloralin (1.00 kg/ha)	3.84 (2.08)	3.34 (1.88)	80.48	1.11	0.97
Fluchloralin (0.75 kg/ha + HW 30 DAS)	4.98 (2.34)	4.16 (2.16)	73.93	0.95	0.78
Pendimethalin (0.75 kg/ha)	7.62 (2.85)	6.13 (2.57)	60.78	0.85	0.65
Pendimethalin (1.00 kg/ha)	4.03 (2.13)	3.55(2.01)	78.38	1.10	0.96
Pendimethalin (0.75 kg/ha + HW 30 DAS)	5.65 (2.48)	4.78 (2.30)	70.25	0.94	0.77
Oxyfluorfen (0.15 kg/ha)	8.84 (3.06)	7.08 (2.75)	54.59	0.69	0.50
Oxyfluorfen (0.20 kg/ha)	5.89 (2.53)	5.14 (2.37)	68.54	0.91	0.72
Oxyfluorfen (0.15 kg/ha + HW 30 DAS)	6.38 (2.62)	5.61 (2.47)	65.80	0.86	0.65
Weedy check	18.4 (4.36)	16.5 (4.13)		0.64	0.43
Hand weeding at 30 DAS	14.2 (3.84)	12.2 (3.56)	24.56	0.67	0.49
Weed free	0.00 (0.71)	0.0 (0.71)	100.00	1.13	0.99
LSD(P=0.05)	0.20	0.31	4.27	1.08	0.78

Table 2. Growth attributes of French bean at 90 DAS as influenced by various herbicides

Treatment	Plant height (cm)		No. of branches /plant		Dry matter accumulation/plant (g)		Stover yield (t/ha)	
	2010	2011	2010	2011	2010	2011	2010	2011
Fluchloralin (0.75 kg/ha)	24.4	24.4	5.14	5.00	7.56	7.20	1.26	1.22
Fluchloralin (1.00 kg/ha)	26.8	26.6	6.11	6.05	10.0	9.92	1.58	1.56
Fluchloralin (0.75 kg/ha + HW 30 DAS)	25.0	25.4	5.62	5.89	9.69	9.55	1.50	1.49
Pendimethalin (0.75 kg/ha)	24.6	24.7	5.27	5.53	8.31	7.90	1.26	1.22
Pendimethalin (1.00 kg/ha)	25.6	26.2	6.05	5.98	9.99	9.93	1.58	1.56
Pendimethalin (0.75 kg/ha + HW 30 DAS)	24.9	25.3	5.58	5.78	9.71	9.58	1.50	1.49
Oxyfluorfen (0.15 kg/ha)	23.0	24.4	5.47	5.47	7.52	7.14	1.18	1.13
Oxyfluorfen (0.20 kg/ha)	24.9	25.1	5.44	5.55	8.52	8.14	1.48	1.46
Oxyfluorfen (0.15 kg/ha + HW 30 DAS)	23.2	25.1	5.35	5.47	8.56	8.16	1.29	1.26
Weedy check	20.6	19.5	4.19	4.00	7.16	6.86	1.09	1.03
Hand weeding at 30 DAS	23.1	22.2	4.83	4.75	7.36	7.02	1.13	1.12
Weed free	27.5	27.1	6.53	6.44	10.0	9.97	1.60	1.58
LSD (P=0.05)	1.86	1.28	0.54	0.32	0.98	1.05	0.94	0.92

Table 3. Relative economics of different weed control treatments in French bean

Treatment	2010			2011		
	Cost of cultivation ($x10^3$ `/ha)	Net returns ($x10^3$ `/ha)	B:C ratio	Cost of cultivation ($x10^3$ `/ha)	Net returns ($x10^3$ `/ha)	B:C ratio
Fluchloralin (0.75 kg/ha)	22.69	15.82	0.70	22.69	11.89	0.52
Fluchloralin (1.00 kg/ha)	22.94	27.09	1.18	22.94	25.77	1.12
Fluchloralin (0.75 kg/ha + HW 30 DAS)	23.74	18.91	0.80	23.74	16.47	0.69
Pendimethalin (0.75 kg/ha)	23.08	15.25	0.66	23.08	11.41	0.49
Pendimethalin (1.00 kg/ha)	23.43	26.43	1.13	23.43	25.11	1.07
Pendimethalin (0.75 kg/ha + HW 30 DAS)	24.13	18.34	0.76	24.13	15.67	0.65
Oxyfluorfen (0.15 kg/ha)	23.14	8.00	0.34	23.14	4.88	0.21
Oxyfluorfen (0.20 kg/ha)	23.19	17.84	0.73	23.19	13.63	0.59
Oxyfluorfen (0.15 kg/ha + HW 30 DAS)	24.19	14.69	0.61	24.19	10.58	0.44
Weedy check	22.09	6.61	0.30	22.09	2.55	0.11
Hand weeding at 30 DAS	23.14	6.96	0.30	23.14	3.97	0.17
Weed free	26.29	24.37	0.93	26.29	23.59	0.90

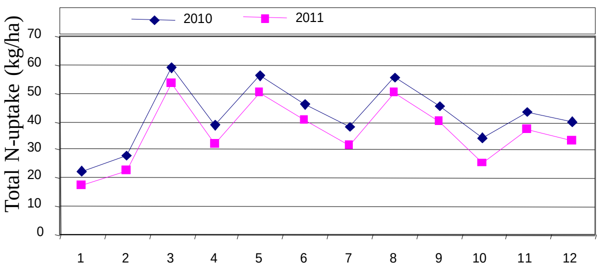

Fig. 1. Total N uptake of French bean as influenced by various herbicides at harvest stage

lowed by fluchloralin (1.00 kg/ha), pendimethalin (0.75 kg/ha + HW 30 DAS) and fluchloralin (0.75 kg/ha + HW 30 DAS). The minimum dry matter was recorded under weedy check. Fluchloralin (1.00 kg/ha) registered maximum number of branches (6.11 and 6.05) in both the years which were statistically at par with pendimethalin (1.00 kg/ha) in the first year and pendimethalin (1.00 kg/ha), fluchloralin (0.75 kg/ha + HW 30 DAS) and pendimethalin (0.75 kg/ha + HW 30 DAS) in the second year. Maximum straw yield (1.58 t/ha and 1.56 t/ha) was obtained in fluchloralin (1.00 kg/ha) which was closely followed by pendimethalin (1.00 kg/ha) in both the years of study. Less competition among weeds thereby results in more photosynthesis and hence better translocation of photosynthates besides larger sink and stronger reproductive in weed control treatments (Dhanpal *et al.* 1989, Rao *et al.* 1997).

Due to least crop-weed competition and higher growth, development and yield, fluchloralin 1.00 kg/ha and pendimethalin 1.00 kg/ha had resulted significantly higher total nitrogen uptake (55.95 and 49.95 kg/ha) in 2010 and 2011 (55.32 and 49.72 kg/ha) in French bean, responsibility. (Fig 1).

Economics

Economic returns as a function of seed yield and sale price varied during different years. More returns during 2008 were obtained due to high sale price and higher seed yield. The maximum gross returns of ` 50,040 and ` 49,860 per hectare and net returns of ` 27,095 and ` 26,432 per hectare and B:C ratio of 1.18 and 1.13 were recorded with fluchloralin 1.00 kg/ha and pendimethalin 1.00 kg/ha, respectively. (Table 3).

Thus, the results of two year study clearly indicated that fluchloralin 1.00 kg/ha and pendimethalin 1.00 kg/ha were the effective treatments for satisfactory weed control and higher productivity and profitability in French bean cultivation.

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Weed managemet in tea with herbicides mixture

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ABSTRACT

A field experiment was conducted in a permanent layout during 2009 and 2010 on farmer's field at Palampur to evaluate BCS AA 10717 – 2% + glyphosate 40 – 42% SC in tea (*Camellia sinensis* [L.] Kuntze) crop. *Ageratum conyzoides* and *A. houstonianum* (17 and 25.9%, during 2009 and 2010, respectively), *Bidens pilosa* (19 and 13%), *Erigeron canadensis* (2 and 16.2%) and *Chromolaena adenophorum* (9.1 and 9.7%) were the major weeds found infesting tea crop during both the years. BCS AA 10717 + glyphosate, glyphosate and diuron + glyphosate effectively reduced the infestation of *Ageratum* sp, *B. pilosa*, and *E. canadensis*. BCSAA 10717 and hand weeding were not effective against *E. canadensis* and *B. pilosa* and paraquat against *B. pilosa. Hackelia uncinata* was completely eliminated under BCS AA 10717 + glyphosate, glyphosate and diuron + glyphosate. Wild strawberry (*Fragaria vesca*) was completely eliminated under all the treatments. BCSAA 10717 + glyphosate at higher dose (> 50+1000 g/ha) and diuron + glyphosate were found effective against *Cynodon dactylon*. All treatments except hand weeding and BCSAA10717 37.5 + glyphosate 750 g/ha had significantly lower count of local grass than untreated check. BCSAA 10717 37.5-140 + glyphosate 750-2800 g/ha, glyphosate alone and diuron + glyphosate effectively reduced the count of *C. adenophorum*. Total weed count and total weed dry weight were significantly reduced under BCSAA10717 50-140 + glyphosate 1000-2800 g/ha, glyphosate and diuron + glyphosate. BCSAA10717 50-140 + glyphosate 1000-2800 g/ha, glyphosate and diuron + glyphosate had higher weed control efficiency than the hand weeding treatment. There were no phytotoxicity symptoms of BCS AA 10717 + glyphosate on tea. The tea green leaf yield was not influenced by the weed control treatments.

Key words: Chemical control, Diuron, Glyphosate, Hand weeding, paraquat, Tea, Weed management

Tea is one of the main export commodities of India. During 2013, 211.86 million kg of tea worth Rs 4211.49 million was exported to different countries (Tea Board of India 2014). It covers an area of 2348 ha with production of 769 thousand kg in Kangra and Mandi districts of Himachal Pradesh. Tea can be grown at elevations ranging from 900-1400 meters above mean sea level and having temperatures ranging from 13-35 ^{0}C. The yearly precipitation should be 250-330 cm uniformly distributed throughout the growing season. The reduction in tea leaves yield due to weeds can be as high as 12 to 21% (Ilango *et al.* 2010) depending upon the management practices followed. Besides competing for nutrient, water, light and space, weeds harbour crop pests and pose many operational hazards in tea crop. Thus, weeding is an important practice for efficient management and sustenance of production in tea crop. Manual and mechanical methods do not present a better option because of time, season and expense involved. Chemical control scores over other methods (Prematilake *et al.* 2004, Rajkhowa *et al.* 2005, Ilango *et al.* 2010, Mirghasemi *et al.* 2012) due to their efficiency, cost effectiveness and ease of operation. Glyphosate is widely acceptable herbicide in tea. However, keeping in view the diverse weed species infesting tea crop, new chemical or chemical mixture are required for effective weed management in tea. The present investigation was aimed at evaluating the BCS AA 10717 – 2% + glyphosate 40– 42% SC against weeds in tea crop.

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MATERIALS AND METHODS

A field experiment was conducted in a permanent layout during summer 2009 and 2010 in a pre-established farmers' tea garden at Palampur in randomized block design with three replications. The experiment was conducted with 10 treatments consisting of BCA AA 10717-2% + glyphosate 40 - 42% SC (37.5 + 750, 50 + 1000, 70 + 1400 and 140 + 2800 g/ha), BCA AA 10717 SC 500 (50 g/ha), glyphosate 41 SL 1025 g/ha, paraquat 24 WSC 600 g/ha, diuron 80 WP + glyphosate 41 SL (Tank mix) (800 + 512.5 g/ha), hand weeding at 30 days interval and untreated control. The experimental soil was silty clay loam, acidic in reaction, medium in available nitrogen, phosphorus and high in available potassium. Herbicides were applied on 4 July 2009 and 1 July 2010 with knapsack power sprayer using 600 L water per hectare. The observations on weed density and dry weight were recorded at monthly interval starting 30 days after spray. The count and dry weight of weeds were analyzed after subjecting the original data to square root transformation ($\sqrt{x+1}$). Phytotoxicity rating was done at 0-10 scale, where scale : 0-No phytotoxicity, scale 1: 1-10% phytotoxicity, scale 2: 11-20% phytotoxicity, scale 3: 21-30% phytotoxicity scale 4: 31-40% phytotoxicity, scale 5: 41-50% phytotoxicity, scale 6: 51-60% phytotoxicity, scale 7: 61-70% phytotoxicity, scale 8: 71-80% phytotoxicity, scale 9: 81-90% phytotoxicity, scale 10: 91-100% phytotoxicity. Weed control efficiency was worked out based on weed population and weed dry weight as per the formula outlined by Mishra and Tosh (1979), respectively.

RESULTS AND DISCUSSION

Local grasses constituted the major flora of the experimental field with 18.9 and 29.2%, during 2009 and 2010, respectively. *Ageratum conyzoides* and *A houstonianum* (17 and 25.9%), *Bidens pilosa* (19 and 13%), *Erigeron canadensis* (2 and 16.2%) and *Chromolaena adenophorum* (9.1 and 9.7%) were the major weeds infested tea crop during both the years. *Ipomoea* (6.5%), *Fragaria vesca* (2.6%), *Cynodon dactylon* (5.2%), *Achyranthus* (2.6%), *Lantana camara* (5.2%), *Polygonum alatum* (1.3%) and *Imperata cylindrica* (10.5%) infested the field during the first year only while *Hackelia uncinata*, 6.0% was present during the second year. *Oxalis latifolia*, *Echinochloa colona*, *Polygonum barbatum*, and *Trifolium repens* (white clover) also infested the experiment field.

Ageratum was recorded at all the stages of observation during both the years. Weed control treatments brought significant variation in *Ageratum* sp. count at 60 and 90 days after spray (DAS) during 2009 and at all observation stages during 2010 (Table 1). BCS AA 10717 + glyphosate, glyphosate and diuron + glyphosate effectively reduced the count of *Ageratum* sp. at all the stages during 2010. However, results were not very conspicuous during 2009 because *Ageratum* appeared in several flushes during summer season under Palampur conditions. As *Ageratum* spp. appears in large number and in several flushes, the results indicated that hand weeding was not an effective mean to manage this weed. The contact herbicide, paraquat was also not effective against *Ageratum* spp. especially during 2010. Like *Ageratum*, *B. pilosa* was present at all the stages of observation. However, weed control treatments did not significantly influence its count during 2009. BCS AA 10717 +

Table 1. Effect of weed control treatments on weed count (no./m^2) in tea

Treatment	Dose (g/ha)	*Ageratum* sp.						*Bidens pilosa*			
		2009		2010				2010			
		60*	90	30	60	90	120	30	60	90	120
BCS AA 10717 +	37.5 +	2.0	5.5	1.0	2.7	2.7	2.5	1.0	1.0	2.2	2.2
glyphosate	750	(5.3)	(38.7)	(0.0)	(6.7)	(6.7)	(5.3)	(0.0)	(0.0)	(4.0)	(4.0)
BCS AA 10717 +	50 + 1000	3.7	1.0	1.0	2.5	2.5	2.2	1.0	1.0	2.2	2.2
glyphosate		(16.0)	(0.00)	(0.0)	(5.3)	(5.3)	(4.0)	(0.0)	(0.0)	(4.0)	(4.0)
BCS AA 10717 +	70 + 1400	4.8	4.7	1.0	2.2	2.2	2.2	1.0	1.0	2.2	2.4
glyphosate		(22.6)	(21.3)	(0.0)	(4.0)	(4.0)	(4.0)	(0.0)	(0.0)	(4.0)	(4.7)
BCS AA 10717 +	140 +	1.9	4.2	1.0	1.4	1.8	1.4	1.0	1.0	1.0	1.8
glyphosate	2800	(4.0)	(21.3)	(0.0)	(1.3)	(2.7)	(1.3)	(0.0)	(0.0)	(0.0)	(2.7)
BCS AA 10717	50	4.0	1.0	1.8	3.2	4.3	3.8	1.0	3.0	3.0	3.0
		(19.3)	(0.0)	(2.7)	(9.3)	(17.3)	(13.3)	(0.0)	(8.0)	(8.0)	(8.0)
Glyphosate	1025	1.0	9.2	1.0	1.8	2.2	1.8	1.0	1.0	1.8	2.2
		(0.0)	(84.0)	(0.0)	(2.7)	(4.0)	(2.7)	(0.0)	(0.0)	(2.7)	(4.0)
Paraquat	600	1.9	1.0	2.9	3.6	3.8	3.4	2.7	3.0	2.7	2.7
		(4.0)	(0.0)	(8.0)	(12.0)	(13.3)	(10.7)	(6.7)	(8.0)	(6.7)	(6.7)
Diuron + glyphosate	800 +	2.0	4.8	1.4	2.2	2.5	2.2	1.0	1.0	1.8	1.8
	1025	(5.3)	(29.3)	(1.3)	(4.0)	(5.3)	(4.0)	(0.0)	(0.0)	(2.7)	(2.7)
Hand weeded		3.4	2.8	3.0	2.5	4.1	3.2	2.5	1.8	3.0	2.2
		(13.3)	(13.3)	(8.0)	(5.3)	(16.0)	(9.3)	(5.3)	(2.7)	(8.0)	(4.0)
Untreated check	-	3.2	2.7	3.6	4.1	4.6	4.1	2.5	2.7	3.4	3.2
		(12.0)	(8.0)	(12.0)	(16.0)	(20.0)	(16.0)	(5.3)	(6.7)	(10.7)	(9.3)
LSD (P=0.05)		1.2	3.7	0.8	0.9	0.8	0.7	0.4	0.4	0.6	0.7

*Days after spray; Values given in parentheses are original means

Table 2. Effect of different treatments on weed count (no./m^2) in tea

Treatment	Dose (g/ha)	*Erigeron canadensis* 2009 30 DAS	*Erigeron canadensis* 2010 30 DAS	*Erigeron canadensis* 2010 60 DAS	*Erigeron canadensis* 2010 90 DAS	*Erigeron canadensis* 2010 120 DAS	*Hackelia uncinata* 2010 60 DAS	*Hackelia uncinata* 2010 90 DAS	*Hackelia uncinata* 2010 120 DAS	*F. vesca* 2009 30 DAS	*Cynodon* 2009 30 DAS
Untreated check	-	1.9 (4.0)	2.7 (6.7)	3.4 (10.7)	4.6 (20.0)	3.4 (10.7)	1.8 (2.7)	2.7 (6.7)	2.5 (5.3)	2.3 (5.3)	2.2 (6.6)
BCS AA 10717 + glyphosate	37.5+ 750	1.4 (1.3)	1.0 (0.0)	1.8 (2.7)	2.7 (6.7)	1.8 (2.7)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.9 (4.0)
BCS AA 10717 + glyphosate	50+1000	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	2.5 (5.3)	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
BCS AA 10717 + glyphosate	70+1400	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.2 (4.0)	1.8 (2.7)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
BCS AA 10717 + glyphosate	140+ 2800	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
BCS AA 10717	50	1.7 (2.6)	1.4 (1.3)	2.5 (5.3)	4.3 (17.3)	3.0 (8.0)	2.2 (4.0)	1.8 (2.7)	1.8 (2.7)	1.0 (0.0)	2.2 (6.6)
Glyphosate	1025	1.7 (2.6)	1.0 (0.0)	1.0 (0.0)	2.2 (4.0)	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.9 (4.0)
Paraquat	600	1.7 (2.6)	1.8 (2.7)	2.5 (5.3)	3.8 (13.3)	2.5 (5.3)	1.8 (2.7)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.2 (6.6)
Diuron + glyphosate	800+ 1025	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	2.5 (5.3)	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Hand weeded		1.7 (2.6)	1.8 (2.7)	2.2 (4.0)	4.1 (16.0)	2.7 (6.7)	1.4 (1.3)	1.4 (1.3)	1.4 (1.3)	1.0 (0.0)	2.2 (6.6)
LSD (P=0.05)		0.5	0.9	0.6	0.8	0.9	0.6	0.6	0.6	0.5	0.7

Values given in parentheses are original means

Table 3. Effect of different treatments on weed count (no./m^2) in tea

Treatment	Dose (g/ha)	*Ipomoea* spp. 2009 60 DAS	*Ipomoea* spp. 2010 60 DAS	*Ipomoea* spp. 2010 90 DAS	*Ipomoea* spp. 2010 120 DAS	Local grasses 2009 60 DAS	Local grasses 2010 30 DAS	Local grasses 2010 60 DAS	Local grasses 2010 90 DAS	Local grasses 2010 120 DAS	*Chromolaena adenophorum* 2010 30 DAS	*Chromolaena adenophorum* 2010 60 DAS	*Chromolaena adenophorum* 2010 90 DAS
BCS AA 10717 + Glyphosate	37.50 + 750	1.7 (2.6)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	3.2 (9.3)	2.9 (8.0)	2.7 (6.7)	1.0 (0.0)	1.8 (2.7)	2.5 (5.3)
BCS AA 10717 + Glyphosate	50 + 1000	1.8 (2.6)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.7 (8.0)	1.0 (0.0)	2.5 (5.3)	2.7 (6.7)	2.2 (4.0)	1.0 (0.0)	1.8 (2.7)	2.2 (4.0)
BCS AA 10717 + Glyphosate	70 + 1400	2.1 (4.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.0 (5.3)	1.0 (0.0)	2.5 (5.3)	2.7 (6.7)	2.2 (4.0)	1.0 (0.0)	1.0 (0.0)	2.2 (4.0)
BCS AA 10717 + Glyphosate	140 + 2800	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.2 (6.6)	1.0 (0.0)	1.4 (1.3)	2.2 (4.0)	2.2 (4.0)	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)
BCS AA 10717	50	1.7 (2.6)	1.8 (2.7)	2.5 (5.3)	2.2 (4.0)	1.0 (0.0)	2.7 (6.7)	3.0 (8.0)	3.4 (10.7)	2.7 (6.7)	1.8 (2.7)	2.2 (4.0)	3.0 (8.0)
Glyphosate	1025	1.8 (2.6)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.9 (9.3)	1.0 (0.0)	1.4 (1.3)	1.8 (2.7)	2.2 (4.0)	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)
Paraquat	600	2.1 (4.0)	1.8 (2.7)	1.8 (2.7)	1.8 (2.7)	3.1 (10.6)	3.8 (13.3)	3.0 (8.0)	3.0 (8.0)	2.7 (6.7)	2.2 (4.0)	2.2 (4.0)	3.0 (8.0)
Diuron + Glyphosate	800 + 1025	1.0 (0.0)	1.8 (2.7)	1.0 (0.0)	1.0 (0.0)	2.9 (9.3)	1.0 (0.0)	1.8 (2.7)	1.8 (2.7)	1.8 (2.7)	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)
Hand weeded		2.5 (5.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.5 (9.3)	3.9 (14.0)	2.7 (6.7)	3.0 (8.0)	2.7 (6.7)	1.8 (2.7)	2.2 (4.0)	3.0 (8.0)
Untreated check	-	3.2 (9.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	3.6 (12.0)	3.9 (14.7)	5.1 (25.3)	4.6 (20.0)	2.2 (4.0)	2.7 (6.7)	3.0 (8.0)
LSD (P=0.05)		1.1	0.7	0.5	0.4	1.1	0.5	0.8	0.8	0.6	0.5	0.6	0.7

Values given in parentheses are original means

glyphosate, glyphosate and diuron + glyphosate effectively reduced its count upto 120 DAS during 2010. Hand weeding at 30 days interval, paraquat and BCSAA 10717 were not effective at one or the other stage against *B. pilosa*. Bhattacharya *et al.* (2003) have reported that paraquat significantly reduced weed density immediately after its application, but its efficacy persisted only up to two weeks.

Table 4. Effect of different treatments on total weed count (no./m²) in tea

Treatment	Dose (g/ha)	2009 30 DAS	2009 60 DAS	2009 90 DAS	2009 120 DAS	2010 30 DAS	2010 60 DAS	2010 90 DAS	2010 120 DAS
BCS AA 10717 + glyphosate	37.50 + 750	4.2 (21.3)	8.4 (72.0)	7.9 (90.6)	4.5 (25.3)	1.0 (0.0)	3.9 (14.7)	4.9 (22.7)	4.1 (16.0)
BCS AA 10717 + glyphosate	50 + 1000	5.0 (33.3)	7.5 (56.0)	1.0 (0.0)	4.8 (32.0)	1.0 (0.0)	3.2 (9.3)	4.7 (21.3)	4.3 (18.0)
BCS AA 10717 + glyphosate	70 + 1400	5.5 (33.3)	7.4 (56.0)	2.2 (6.6)	6.4 (41.3)	1.0 (0.0)	2.2 (4.0)	3.6 (12.0)	3.9 (14.7)
BCS AA 10717 + glyphosate	140 + 2800	2.2 (6.6)	7.8 (62.6)	6.7 (62.6)	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)	3.6 (12.0)	3.4 (10.7)
BCS AA 10717	50	6.1 (53.1)	7.8 (63.3)	8.8 (77.3)	5.7 (44.0)	4.1 (16.0)	6.5 (41.3)	7.9 (61.3)	7.0 (48.0)
Glyphosate	1025	3.7 (17.3)	6.2 (37.3)	12.7 (164.0)	3.0 (16.0)	1.0 (0.0)	4.7 (21.3)	5.4 (28.0)	4.9 (22.7)
Paraquat	600	5.3 (36.0)	7.5 (56.0)	2.9 (14.6)	4.6 (28.0)	6.1 (36.0)	6.6 (42.7)	6.8 (45.3)	5.9 (34.7)
Diuron + glyphosate	800 + 1025	3.7 (17.3)	7.5 (56.0)	7.9 (66.6)	2.5 (9.3)	1.9 (4.0)	3.2 (9.3)	3.6 (13.3)	3.5 (12.0)
Hand weeded		7.5 (56.0)	7.6 (58.6)	3.3 (19.8)	4.6 (26.6)	5.8 (32.7)	5.0 (24.0)	7.0 (48.0)	5.9 (33.3)
Untreated check	-	7.1 (60.0)	8.7 (76.0)	6.1 (53.3)	3.5 (24.0)	6.4 (40.0)	7.6 (57.3)	9.1 (82.7)	8.2 (66.7)
LSD (P=0.05)		1.8	1.3	3.1	3.2	1.0	0.7	0.8	0.9

Values given in parentheses are original means

Table 5. Effect of different treatments on total weed dry weight (g/m²) and weed control efficiency (%) in tea

Treatment	Dose (g/ha)	2009 30 DAS	2009 60 DAS	2009 90 DAS	2009 120 DAS	2010 30 DAS	2010 60 DAS	2010 90 DAS	2010 120 DAS	Weed control efficiency (%) 30 DAS	60 DAS	90 DAS	120 DAS
BCS AA 10717 + glyphosate	37.50 + 750	2.2 (4.7)	5.1 (27.2)	5.0 (33.3)	2.4 (4.6)	1.0 (0.0)	2.2 (4.3)	4.4 (18.0)	4.0 (15.1)	89.2	60.0	41.8	77.5
BCS AA 10717 + glyphosate	50 + 1000	2.7 (8.3)	4.2 (18.7)	1.0 (0.0)	2.2 (3.8)	1.0 (0.0)	1.5 (1.3)	4.2 (16.4)	3.5 (12.0)	81.0	74.4	89.7	81.7
BCS AA 10717 + glyphosate	70 + 1400	2.8 (8.2)	3.9 (14.7)	1.8 (3.4)	2.2 (3.80)	1.0 (0.0)	1.2 (0.5)	3.3 (10.3)	3.1 (9.1)	81.3	80.4	92.4	83.5
BCS AA 10717 + glyphosate	140 + 2800	1.4 (1.1)	3.3 (10.6)	3.5 (11.0)	1.0 (0.1)	1.0 (0.0)	1.1 (0.3)	2.9 (7.7)	2.7 (6.3)	97.4	86.0	79.1	95.8
BCS AA 10717	50	2.5 (6.1)	4.8 (22.8)	4.3 (24.6)	2.5 (5.4)	3.5 (11.7)	6.2 (37.3)	8.7 (74.1)	6.9 (46.7)	64.2	27.8	16.7	54.9
Glyphosate	1025	1.6 (1.9)	3.8 (17.0)	2.4 (8.9)	1.8 (2.4)	1.0 (0.0)	2.8 (6.9)	5.1 (24.9)	5.0 (24.0)	95.6	70.1	71.1	77.6
Paraquat	600	3.1 (12.6)	4.7 (22.0)	4.6 (26.8)	2.9 (7.5)	4.0 (14.7)	5.0 (23.7)	6.9 (47.2)	5.0 (23.7)	43.8	44.4	30.2	64.2
Diuron + glyphosate	800 + 1025	1.5 (1.5)	3.7 (12.5)	5.2 (27.4)	1.5 (1.3)	3.1 (8.5)	2.2 (4.3)	3.3 (11.2)	3.2 (9.3)	80.7	78.9	51.8	90.2
Hand weeded		3.1 (9.6)	4.5 (20.8)	2.4 (8.3)	2.7 (6.2)	1.0 (0.0)	3.2 (9.5)	5.9 (34.0)	5.3 (26.9)	78.1	62.1	66.2	65.5
Untreated check	-	4.3 (21.9)	5.2 (28.6)	5.6 (31.3)	4.4 (18.3)	5.3 (26.8)	6.7 (43.7)	8.9 (79.9)	8.8 (77.2)	-	-	-	-
LSD (P=0.05)		1.3	1.4	1.8	0.1	0.3	0.6	1.0	0.8				

Values given in parentheses are original means

E. canadensis has been a new introduction in this area. In the present investigation, its introduction was noted at 30 DAS during 2009 and at all the stages during 2010. BCS AA 10717 + glyphosate, glyphosate, diuron + glyphosate significantly reduced its count at all the stages of observation over the untreated check (Table 2). BCSAA 10717 and hand weeding were not effective against *E. canadensis* as its count under the treatments was not significantly different from untreated check at one or the other stage. Presence of *Hackelia uncinata* was noted during 2010 only. Population of *Hackelia uncinata* was completely eliminated under BCS AA 10717 + glyphosate, glyphosate and diuron + glyphosate.

F. vesca and *Cynodon* were recorded at 30 and 60 DAS during 2009 only. All treatments completely controlled *F. vesca* at 30 DAS during 2009. BCSAA 10717 + glyphosate at doses higher than 50 + 1000 g/ha and diuron + glyphosate effectively reduced the count of *Cynodon* at 30 DAS during 2009. BCSAA 10717, paraquat and hand weeding were not effective against *Cynodon*.

All treatments except hand weeding resulted in significantly lower count of *Ipomoea* sp. at 60 DAS during 2009 (Table 3), however paraquat, diuron + glyphosate and BCSAA10717 had higher count of *Ipomoea* sp. over all other treatments including the weedy check during 2010. All treatments except hand weeding and BCSAA10717 37.5 + glyphosate 750 g/ha had significantly lower count of local grass than untreated check at all the stages of observation during 2010. BCSAA10717 37.5-140 + glyphosate 750-2800 g/ha, glyphosate alone and diuron + glyphosate effectively reduced the count of *Chromolaena* during 2010.

Total weed count and dry matter accumulation were significantly reduced under BCSAA10717 50-140 + glyphosate 1000-2800 g/ha, glyphosate and diuron + glyphosate upto 30 DAS during 2009 and upto 120 DAS during 2010 (Table 4 and 5). Ilango (2003) has reported 85% control of weeds with glyphosate alone or with carfentrazone-ethyl. Superiority of glyphosate + diuron against weeds in tea has also been documented (Saikia *et al.* 1998). BCSAA10717 50-140 + glyphosate 1000-2800 g/ha (81.7-89.6%), glyphosate (78.6%) and diuron + glyphosate (75.4%) had higher weed control efficiency over the hand weeding treatment. Prematilake *et al.* (2004), Ilango *et al.* (2010), Rajkhowa *et al.* (2005), Mirghasemi *et al.* (2012) reported effective control of weeds with glyphosate alone and in combination with other herbicides.

BCS AA 10717 -2% + glyphosate -40% : 42 SC (upto 140 + 2800 g ai/ha) was safe to tea crop when observed at 7, 15, 30, 45 and 60 days after application during 2009 and 2010. The tea green leaf yield was not significantly influenced under different weed control treatments during both the years (data not shown).

The results of the present study revealed that application of BCS AA 10717 -2% + glyphosate 40- 42% SC was quite effective in providing acceptable weed control without any phytotoxicity in tea.

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Bioefficacy of potassium salt of glyphosate in Bt cotton and its residual effect on succeeding crops

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ABSTRACT

A field experiment was conducted to evaluate potassium salt of glyphosate (MON 76366) in Roundup Ready Bt cotton hybrid at PAU, Ludhiana during 2009 and 2010. Potassium salt of glyphosate 50 EC at 900, 1350, 1800, 2700, 3600 and 5400 g/ha was applied twice (after one and three months of sowing) as post-emergence. All the treatments except glyphosate 900 g/ha and weedy check gave effective control of weeds. Application of K salt of glyphosate at 1350 to 5400 g/ha recorded the weed control efficiency (WCE) ranging from 96.8 -99.8%, and produced higher seed cotton yield. The performance of succeeding crops of wheat, barley and raya sown after cotton was not affected, indicating no residual toxicity of K-salt of glyphosate.

Key words: Glyphosate, Roundup ready cotton, Seed cotton yield, Weeds, Weed management

Cotton is the third major crop after wheat and rice in semi-arid sub tropical region of India including Punjab, Haryana and Rajasthan states. Due to its long duration, early slow growth and wider spacing, there is heavy infestation by weeds (Rajeswari and Chayulu 1996). Being a rainy season and long-duration crop, weeds flourish in many flushes and compete with the crop for nutrients, moisture, light, space *etc*. and also harbour insects, pests and diseases (Anderson 1983). Herbicides available for use in cotton, control only narrow range of weeds and even sequential applications of herbicides fail to provide effective control of weeds.

Glyphosate resistant cotton has provided number of alternatives to the farmers to use glyphosate as and when required. Glyphosate-resistant (GR) cotton cultivars have proved to be a boon for the cotton farmers as the glyphosate (MON 76366), trade name Roundup Ready(R) gave excellent weed control in this crop (Webster and Sosnoskie 2010). This technology provides superior broad spectrum control of weeds, better control of hardy weeds in wide row configurations, direct applications on target weeds and controls many flushes of weeds. However, the herbicides, when applied to the field not only control targeted weeds, but may also leave unwanted residues in the soil, which are ecologically harmful (Riaz *et al*. 2007). Cotton being an important crop of Punjab and normally the succeeding crops like wheat, barley and raya are sown by the farmers during *Rabi* season after this crop. A field study was done to study the efficacy of potassium salt of glyphosate as post-emergence blanket application in transgenic stack cotton hybrid, and its residual effect on succeeding crops of wheat, barley and raya.

MATERIALS AND METHODS

The experiment was carried out at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, India during *Kharif* 2009 and 2010 with eight treatments in randomized block design with test hybrid '*MRC 8017 BG II RRF*' (Bt) and '*MRC 7347 BG-II RRF*' (non Bt) which was sown on 25 June, 2009 and 3 May, 2010 after preparing fine seed bed. Crop was sown with row to row spacing of 67.5 cm and plant to plant spacing of 90 cm. 90 kg N and 30 kg P_2O_5/ha was applied to the crop.All phosphorus was drilled at the time of sowing. Half N was applied at thinning and the remaining at the appearance of the first flower. Potassium salt of glyphosate 50 EC at 900, 1350, 1800, 2700, 3600 and 5400 g/ha was applied twice as post-emergence (blanket application) at one and three months after sowing. The knap sack sprayer fitted with flat fan nozzle with discharge rate of 250 l/ha was used.

Succeeding crops of wheat, barley and raya were taken during *Rabi* 2009-10 and 2010-11 by dividing the plot to find out the residual effects of potassium salt of glyphosate. These studies were continued in fixed lay out without disturbing the soil. The weeds were removed manually in these crops.

Species wise weed count was done for the dominant weeds at 14 and 21 days after spray and dry weight of weeds at 130 DAS. Weeds were cut from the ground

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level, dried in sun and then oven dried at 60 °C for three days and then weighed. The experimental data were subjected to analysis using CPCS1, software developed by Cheema and Singh (1991). All the comparisons were made at 5% level of significance.

RESULTS AND DISCUSSION

Effect on weeds

Weed flora included grass, broad-leaf weeds and sedges, *viz. Acrachne racemose*, *Eleusine indica, Dactyloctenium aegyptiacum, Echinochloa colona, Digitaria sanguinalis, Cynodon dactylon, Eragrostis tenella*, *Trianthema portulacastrum*, *Mollugo nudicaulis*, *Commelina benghalensis*, *Phyllanthus niruri, Euphorbia hirta*, *Euphorbia microphylla, Digera arvensis*, *Amaranthus viridis*, *Rhyncosia capitata, Cucumis trigonus* and *Cyperus rotundus*.

No significant injury on Bt cotton was observed in any herbicide treatment, which indicated that the herbicide was safe for Bt cotton. Post-emergence application of K salt of glyphosate at 900, 1350, 1800, 2700, 3600 and 5400 g/ha showed no phytotoxicity to cotton with both the sprays when observations were recorded after 4, 7 and 14 days after application. On the second day after herbicide application, the leaves of weeds started rolling, yellowing started after third day, and on the fourth day, complete kill of weeds was observed. Only *Cynodon dactylon* remained green where K salt of glyphosate at 900 g/ha was applied but yellowing of leaves started few days of application.

Visually complete kill of all grasses, broad-leaved, perennial weeds and sedges was observed 10-11 days after spray, except in lower dose of potassium salt (900 g/ha). No regeneration of weeds was noticed at 14 or 21 days after first application of K salt of glyphosate. Similar findings were recorded when K salt of glyphosate was re-sprayed after three months of sowing.

All the herbicidal treatments controlled the weeds effectively as the population of different weeds and their dry matter of weeds recorded was significantly less as compared to unweeded check. All the herbicidal treatments at 1350, 1800, 2700, 3600 and 5400 g/ha were at par with respect to the control of weed species. Similar results were reported by Chinnusamy *et al.* (2013). Higher weed control efficiency of 99.8% was recorded with glyphosate at 2700 and 5400 g/ha, followed by 3600 g/ha (99.6%) (Table 1).

Effect on yield

Seed yield of cotton was significantly higher at all the doses of K salt of glyphosate than manual weeding and unweeded check (Table 1). The difference in seed yield in two years was due to late sowing in 2009. The increase in yield was 36.1, 77.8, 69.4, 66.6, 63.9 and 55.5% where K salt of glyphosate was applied at 900, 1350, 1800, 2700, 3600 and 5400 g/ha, and 16.7, 52.4, 45.2, 42.9, 40.5, 33.3% over two manual weedings. However, the seed yield differed significantly (0.49 t/ha) where herbicide was applied at 900 g/ha with the manual weeding but it was higher than unweeded plot. Similar results were obtained in the second year. Chinnusamy *et al.* (2013) also registered high seed cotton yield with glyphosate at 2700 g/ha.

Higher seed cotton yield with 1350, 1800, 2700, 3600 and 5400 g/ha of potassium salt of glyphosate was mainly due to effective control of wide weed flora. Untreated control resulted in poor growth and ultimately reduced the seed cotton yield. The seed cotton yield was at par when potassium salt of glyphosate was applied at 1350, 1800, 2700, 3600 and 5400 g/ha, and all these treatments produced significantly higher seed cotton yield than 900 g/ha. The performance of all the doses of K salt of glyphosate was at par and significantly better than manual weeding and unweeded check.

Table 1. Effect of different treatments on weed dry matter and seed cotton yield

Treatment	Dose (g/ha)	Weed dry matter (14 days after 1st spray) (g/m²)	Weed dry matter (14 days after 2nd spray) (g/m²)	Weed dry matter at 130 DAS (g/m²)		WCE at 130 DAS (%)		Boll weight (g)		Seed cotton yield (t/ha)	
				2009	2010	2009	2010	2009	2010	2009	2010
K-salt of glyphosate	900	1.0 (0)	1.0 (0)	2.8 (7)	2.8 (7)	94.4	93.6	6.23	14.4	0.49	1.75
K-salt of glyphosate	1350	1.0 (0)	1.0 (0)	2.2 (4)	2.1 (3)	96.8	97.3	6.80	18.3	0.64	2.22
K-salt of glyphosate	1800	1.0 (0)	1.0 (0)	1.4 (1)	1.3 (0.7)	99.2	99.4	5.80	16.9	0.61	2.08
K-salt of glyphosate	2700	1.0 (0)	1.0 (0)	1.1 (0.3)	1.1 (0.2)	99.8	99.8	5.68	16.1	0.60	2.00
K-salt of glyphosate	3600	1.0 (0)	1.0 (0)	1.2 (0.5)	1.1 (0.2)	99.6	99.8	5.52	15.4	0.59	2.11
K-salt of glyphosate	5400	1.0 (0)	1.0 (0)	1.1 (0.3)	1.1 (0.3)	99.8	99.7	5.48	14.5	0.56	2.03
Manual weeding	-	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	64.3	41.5	6.67	19.0	0.42	1.59
Unweeded	-	8.7 (74)	9.5 (90)	11.2 (124)	10.6 (111)	-	-	4.33	10.9	0.36	1.42
LSD (P=0.05)		0.15	0.17	0.46	0.28	-	-	0.30	1.9	0.1	0.25

Table 2. Residual effect of K salt of glyphosate on growth (30 DAS) and yield of following rabi crops (pooled data of two years)

Treatment	Dose (g/ha)	Wheat			Barley			Raya		
		Plant height (cm)	Dry matter (g/m^2)	Grain yield (t/ha)	Plant height (cm)	Dry matter (g/m^2)	Grain yield (t/ha)	Plant height (cm)	Dry matter (g/m^2)	Seed yield (t/ha)
K-salt of glyphosate	900	13.9	94.7	4.34	19.2	123.4	3.62	11.8	75.0	1.35
K-salt of glyphosate	1350	12.9	85.3	4.07	19.9	151.4	3.67	11.2	74.2	1.26
K-salt of glyphosate	1800	12.8	93.1	3.91	20.7	149.0	3.52	12.6	88.6	1.28
K-salt of glyphosate	2700	12.9	90.6	3.90	17.8	144.9	3.89	10.1	68.7	1.37
K-salt of glyphosate	3600	12.6	86.2	3.64	20.0	131.7	3.64	12.7	84.5	1.25
K-salt of glyphosate	5400	12.5	77.2	3.77	17.8	136.8	3.30	10.1	69.7	1.23
Manual weeding		12.5	87.8	4.12	17.7	136.0	3.48	12.0	79.7	1.33
Unweeded	-	13.4	80.4	3.58	18.2	136.3	3.33	10.2	66.4	1.37
LSD (P=0.05)	-	NS	9.5	NS	NS	NS	NS	2.1	NS	NS

Residual effect

No phytotoxicity due to residues of K salt of glyphosate was recorded on wheat, barley and raya. The plant height at 30 days after sowing was not affected but dry matter accumulation of crops at 30 DAS was comparatively less in unweeded control as compared to glyphosate (Table 2). This indicated no residual carryover of K salt of glyphosate in the soil. In fact, the yield of succeeding crops was found to be marginally higher in glyphosate treatments as compared to unweeded control.

It was concluded that the transgenic stack of Bt cotton hybrid was tolerant to K salt of glyphosate, which also did not affect growth and yield of succeeding crops of wheat, barley and raya.

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Heavy metal extracting potential of common aquatic weeds

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ABSTRACT

The various ponds receive untreated sewage effluents from residential areas in Jabalpur city affecting water quality of the ponds. The very survival of aquatic weed species in contaminated water is testimony of ability of accumulating heavy metals. A survey was made to identify weed species grown in various ponds of Jabalpur for assessing their heavy metal potential. The heavy metals exhibited the sequence of their concentration in pond water as Fe > Cd > Mn >Ni >Cu. Among the weeds, *Eichhornia crassipes* accumulated higher concentration of cadmium, nickel, iron and manganese in their roots than shoots whereas *Alternanathera philoxeroides* accumulated higher metals in shoots than its root parts. Except nickel, higher bioaccumulation factor of Fe, Cd, Mn, Ni, Cu was exhibited by *Alternanthera philoxeroides* followed by *Eichhornia crassipes*. These observations may be exploited while selecting plant species for removal of heavy metals from contaminated water in an artificial wetland system.

Key words: *Alternanthera philoxeroides*, Cadmium, *Eichhornia crassipes*, Heavy metals, Iron, Manganese, Nickel

The contamination by heavy metals is serious concern for surface water and ultimately for animal and human health (Hammer and Keller 2002). The use of shoot part of *Alternanthera philoxeroides* as a cattle fodder due to high nutritional value in the region is the major concern which could find metal entry into human food chain (Sushilkumar and Vishwakarma 2005). Heavy metals, unlike organic pollutants can not be destroyed or changed to forms that are harmless. Treatments for remediation of polluted waters, should therefore aim at extracting these substances from water and concentrating them before final disposal. Among macrophytes, weeds are more suited to remove heavy metals from water due to its fast growth resulting high biomass. Therefore, phytoremediation of heavy metals using locally available potential weeds get more attention as remedial measures in present context.

Among the aquatic plants, *Eichhornia crassipes*, (water hyacinth) is a common aquatic weed in many tropical countries which has the ability to take up and accumulate elements from water and has been successfully used as indicator of heavy metal pollution (Pleiffer *et al*. 1986). *Alternanthera philoxeroides* (alligator weed) is also a serious weed grown both in aquatic and terrestrial environment which were also found to be the potential scavengers of heavy metals from aquatic environment (Bingzhong *et al*. 2007). However, distribution of heavy metals in plant body depends on their concentrations, species or even the population and part of the plants. For instance, roots usually show higher heavy metal content than shoots as they come into contact with the toxic metals (Breckle 1991). Moreover, *Alternanthera philoxeroides* is commonly used as a green fodder to feed milch animals in the region. Very few reports are available on metal removal by weeds grown in agro-climatic situations of Central India and most are confined to studies on nutrient uptake. Therefore, the present investigation was carried out for identification of locally available weeds for phytoremediation of heavy metal contaminated pond water of Jabalpur, India.

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MATERIALS AND METHODS

Different aquatic weed species and water samples were collected from various pond sites such as Ranital, Gullowa, Mansingh, Mahanadda, and Adhartal in Jabalpur, during winter 2008 and 2009. Five composite water samples were collected randomly from the ponds on which the test plants were growing. The five water samples were mixed, filtered through 0.45 micron membrane filter for analysis. For each plant species, five plants were collected randomly at the maturity stage. The plant samples were thoroughly washed and dried at 70 ^{0}C for 48 hours, ground and mixed for metal analysis. Weed samples (1 g) were digested in concentrated nitric and perchloric acid (5:1) till a clear solution was obtained. The solution was filtered, reconstituted to the desired volume and analysed by atomic absorption spectrophotometer make Thermo Solar S4.

RESULTS AND DISCUSSION

The contaminated water in drain was neutral in reaction with pH values ranging between 7.08 to 7.46 (Table 1) and thereby being well within the permissible limits of pH (Patel *et al.* 1990). The electrical conductivity (EC) values of 395 to 1678 µS/cm were also within critical limits recommended by United States Salinity Diagramme (1954). The dissolved oxygen (DO) varied from 1.75 at Gullowa to 3.3 mg/L at Ranital Pond. The chloride content was above the permissible limit at Mahanadda, Ranital and Gullowa except at Mansing and Adhartal pond. The heavy metals exhibited the sequence of their concentration in pond water in the order of Fe > Cd > Mn >Ni >Cu.The concentration of nickel, copper and manganese in water was far below from the critical limit of 0.2, 1.5 and 0.5 mg/L for public uses, respectively.

The dominant weeds in ponds were *Alternanthera philoxeroides, Eichhornia crassipes* and *Canna indica*. *Eichhornia crassipes* was dominant in Ranital and Gulluwa pond, *Alternanthera philoxeroides* in Mansing and Mahanadda and *Canna indica* in Mahanadda and Adhartal pond.There were marked differences in metal uptake among weed species growing on the ponds. Among the weeds, *Eichhornia crassipes* accumulated higher average concentration of nickel, cadmium, copper, iron and manganese to the extent of 20.9, 1.14, 59.5 (Fig. 1a) 6171 and 352 mg/kg (Fig. 1b), respectively. The elevated metal accumulation in *Eichhornia crassipes* growing in the pond waters indicated as a potential source of bio-monitoring of copper (Barman *et al.* 2001). The higher accumulation of nickel, iron and manganese by water hyacinth may be due to its strong metal absorbing ability. Depending on the element, the metal concentration in water hyacinth found much higher than in water which resulted higher heavy metal ratio between water and water hyacinth (Table 2). The concentration ratio of cadmium, copper, iron and manganese were observed higher in water hyacinth roots as compared to *Alternanthera philoxeroides* and *Canna indica* roots. Similar observations were reported by Wolverton and Mc Donald (1976). In case of cadmium transfer from water to root of water hyacinth, the free site of uptake of these substances might have helped to bind metal to root which is absorbed and accumulated by tissues of water hyacinth root (Hardy and Keeffe, 1985).

Alternanathera philoxeroides absorbed higher concentration of nickel from water and translocated to the shoot portion. Contrary to metal accumulation pattern of water hyacinth, *A. philoxeroides* exhibited 79.4 per cent of cadmium translocation from root to the shoot part (Table 3). This trend were found in conformity with the findings of Naqvism (1993) and Lokeshwari (2007). Apart from cadmium, the translocation of iron, manganese and nickel also exhibited higher translocation to the tune of 439, 148 and 136 per cent, respectively. Higher accumulation of iron by the *Alternanthera sessilis* was also reported

Table 1. Water quality and heavy metal concentration in ponds of Jabalpur

Parameter	Contaminated sites					
	Ranital	Gullowa	Mansing	Mahanadda	Adhatal	Mean
pH (µS/cm)	7.15	7.26	7.16	7.46	7.08	7.22
EC (mg/L)	938	1150	591	1678	395	950
DO (mg/ L)	3.3	1.75	2.52	1.32	3.2	2.42
Chlorides (mg/ L)	190	180	130	225	100	165
Nickel (mg/ L)	0.158	0.092	0.12	0.03	0.126	0.105
Copper (mg/ L)	0.06	0.002	0.02	0.09	0.005	0.035
Iron (mg/ L)	1.27	0.108	0.14	1.10	0.168	0.557
Cadmium (mg/ L)	0.043	0.077	0.62	0.17	0.020	0.186
Manganese (mg/ L)	0.130	0.109	0.08	0.096	0.111	0.105

Table 2. Heavy metal concentration plant parts of aquatic weeds

Weed	Plant part	Heavy metals (mg/kg)				
		Ni	Cd	Cu	Fe	Mn
Alternanthera philoxeroides	Shoot	441	16.4	2448	3586	1666
	Root	149	12.0	2839	569	1196
Eichhornia crassipes	Shoot	56.8	1.44	552	2645	1014
	Root	253	21.8	2868	6576	6624
Canna indica	Shoot	392	0.63	445	1414	951
	Root	465	4.24	719	959	2173

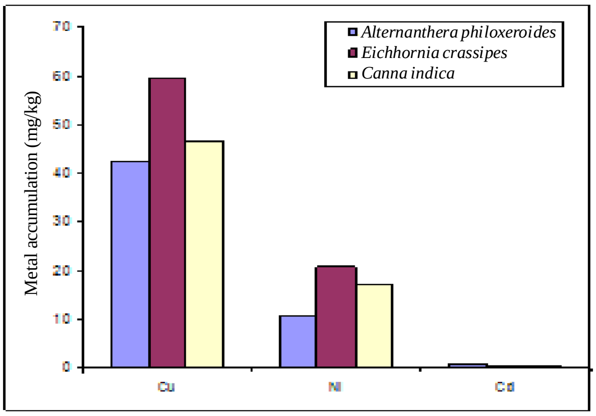

Fig. 1(a). Accumulation of copper and nickel by aquatic weeds

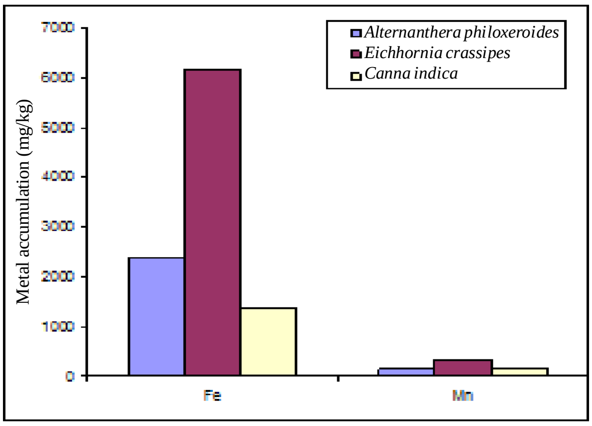

Fig 1(b). Accumulation of iron and manganese by aquatic weeds

Table 3. Percentage of heavy metal translocation from root to shoot of aquatic weeds

Weed species	Ni	Cd	Cu	Fe	Mn
Alternanthera philoxeroides	136.2	79.4	34.4	439.2	148.1
Eichhornia crassipes	22.9	15.8	15.2	41.9	17.2
Canna indica	84.4	9.52	53.1	147.2	45.3

by Barman *et al* (2000). The *Canna indica* exhibited 53.1 per cent copper translocation from its root to the shoot. In view of the bio-magnification of heavy metals in the food chain, the higher toxic metal content such as cadmium and nickel in the shoot of *A. philoxeroides* were higher than the permissible level. Regular consumption of *A. philoxeroides* by milk animals may cause health problems in long term. The average normal concentration of cadmium is 0.05 µg/g (Elinder, 1988) and nickel is 1.5 ug/g of dry weight (PFA 1954).

Among the weed species, *E. crassipes* accumulated higher concentration of cadmium, nickel, iron and manganese. However, relatively higher metal concentration were found in roots of water hyacinth than its shoots whereas *A. philoxeroides* accumulated higher concentration of heavy metals in shoots than root part of the plants. In order to extract the heavy metals from water, both the plant species have utility for exploiting root of water hyacinth from lower layer of water and alligator shoot from top layer of water.

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Phosphate solubilising diazotrophic bacteria associated with rhizosphere of weedy grasses

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ABSTRACT

The present investigation hypothesizes that the weedy grass species grown in different physiographic regions do harbour potential microbes and shows lot of scope for the identification of novel functional microbes. In the present study, diazotrophic bacteria were isolated from rhizosphere of ten selected grass species and identified using 16S rRNA gene sequencing. The isolates were belonging to the members of alpha Proteobacteria and Firmicutes. Phosphorus solubilizing traits of all the selected diazotrophic isolates were analysed and results revealed that all the diazotrophs were found to solubilise phosphorous in qualitative assay. Influence of phosphorus solubilizing organisms on the pH, titrable acidity, available phosphorus and phosphatase enzyme production were studied. Maximum amount of available phosphorus and phosphatase activity was observed in *Klebsiella* sp. (OR7) (0.96 ± 0.09 µg/ml) and *Staphylococcus saprophyticus* (OR5) (12.9 ±0.10 µg of PNP released/ml/day) respectively. The present compilation of diverse diazotrophs along with phosphorous solubilisation potential suggests that these particular organisms can promote plant growth by more than one mechanism and that these traits could be better exploited as bio-inoculants.

Key words: Bacteria, Diazotrophs, Phosphate solubilising microbes, Weedy grasses

The search for diverse plant growth-promoting (PGP) diazotrophic bacteria is gaining momentum as efforts are made to exploit them as bio-inoculants for various economically important crops. There is a considerable number of rhizospheric microbial species that may have beneficial effects on plant growth and yield. These groups of species, which are known as plant growth-promoting bacteria (PGPB) (Bowen and Rovira 1999) play an important role in soils by transforming some nutrients, which are normally present in less available forms, into bio-available forms. One of the action mechanisms of PGPB to promote plant growth is the solubilization of insoluble phosphates (Rodriguezet *et al*. 2006). Phosphorus (P) is an essential element for all living beings as part of proteins, nucleic acids, membranes, and energy molecules, such as ATP, GTP, and NADPH. Depending on some environmental and biological factors, it can be the main growth-limiting nutrient (Azziz *et al*. 2012). Bacteria of the genera *Pseudomonas, Enterobacter, Bacillus, Proteus, Citrobacter, Klebsiella,* and *Serratia* and some soil filamentous fungi, such as *Aspergillus* and *Penicillium* (Rodríguez and Fraga 1999), solubilize phosphates through mechanisms that involve the production of organic and inorganic acids and the excretion of protons to the media during the assimilation of the NH_4^+. Together, these mechanisms transform insoluble forms of phosphorus into monobasic and dibasic phosphate (HPO_4^{-2}, $H_2PO_4^{-}$) available to plants (Whitelaw 1999). In addition, PGPB can promote plant growth by supplying the plant with other nutrients, such as nitrogen; by bio-controlling host plant diseases; byproducing phytostimulators; or by promoting the growth of cellulolytic microorganisms, which are important for nutrient cycling in the soil (Lugtenberg and Kamilova 2009). Despite the agronomic benefits that may be provided by phosphate solubilizing microorganisms (PSMs), their abundance in soil is not always sufficient to compete with other microorganisms established in the rhizosphere. This situation requires the inoculation of plants with PSMs to increase the density found in the soil and to take advantage of their properties in order to increase the productivity of the agricultural ecosystems.

There are numerous studies on PSMs (Chen *et al.* 2006, Azziz *et al.* 2012), related to their abundance, diversity, and phosphate solubilization potential of microorganisms associated with economically important crop plants but studies are lacking on weed. Weedy grass species normally thrive in adverse conditions and act as potential habitats for the diverse groups of elite bacteria with multiple beneficial characters. A more complete understanding of the diver-

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sity and functioning of rhizobacterial microorganisms, especially those that have symbiotic relationships with grass species is of great value for agricultural research and application. The aim of this study is to screen native population from the selected grass species rhizosphere for the isolation of nitrogen fixing and mineral solubilizing bacteria.

MATERIALS AND METHODS

Rhizosphere sampling and isolation of diazotrophs

Ten different grass species along with rhizosphere soil were collected from different physiographic regions (*Brachiaria reptans*, *Cenchrus glaucus*, *Saccharum spontaneum*, *Panicum repens*, *Cyperus rotundus*, *Dactyloctenium aegyptium*, *Chloris barbata*, *Oryza rufipogon*, *Cyanodon dactylon* and *Setaria verticillata*) (Table 1). Plants were uprooted carefully and the soil adhering to the root was separated in a sterile Petridish and mixed thoroughly so as to make a composite sample for microbiological analysis. Plant samples and soil samples collected were transported to laboratory in ice box for further analysis. The samples were used immediately for preliminary analyses and stored at 4 °C in a refrigerator for further studies (Pramer and Schmidt 1966). Diazotrophic microorganisms isolated using serial dilution technique (10^{-6} dilution) on selective N-free malate medium (NFM) (Piao *et al.* 2005). After required incubation period, colonies growing on N-free media were counted and grouped according to their morphological characteristics. Single colonies from rhizosphere soil samples picked from NFM plates and sub-cultured several times in same medium to obtain pure cultures and stored as glycerol stocks at -20 ºC.

Identification of diazotrophs by 16S rRNA gene sequencing

Nearly full-length of 16S rRNA gene was amplified from elite isolates as described earlier using universal eubacterial primers, FD1 and RP2 (Weisburg *et al.* 1991) and the band of expected size was gel-purified using spin columns (Bangalore genei, India) according to the manufacturer's instructions and cloned using pTZ57R/T vector supplied with TA cloning kit (Fermentas, USA) prior to sequencing. Sequencing reactions were performed using ABI prism terminator cycle sequencing ready reaction kit and electrophoresis of the products were carried out on an Applied Biosystems (Model 3100) automated sequencer. The identity of 16S rDNA sequence was established by performing a similarity search against the GenBank database (http://www.ncbi.nih.gov/BLAST).

In vitro determination of phosphate solubilising activity

The bacterial cultures were inoculated in to hydroxyapetite medium (*Sperber* 1958). The test organisms were inoculated on these media and incubated (Lab Companion, Korea) at 30°C for 48 h. The diameter of the clearing zones around the colonies were measured. The solubilizing efficiency was calculated as indicated below (Srivastav *et al*. 2004).

$$\text{Solubilization efficiency (\%)} = \frac{\text{Diameter of solubilization zone} - \text{colony diameter}}{\text{Colony diameter}} \times 100$$

One ml of the culture containing 10^9 cell/ml was inoculated into the flasks of Pikovaskaya's broth containing 100 mg of tricalcium phosphate. An uninoculated control was maintained. After 7 days incubation, the contents were centrifuged at 7000 rpm for 10 min and clear supernatant was used for soluble P estimation following method described by Olsen *et al.* (1954). One ml of the culture filtrate was pipette into a 25 ml volumetric flask and diluted to 20 ml with water. Four ml of reagent (1.056 g of ascorbic acid in 200 ml of reagent A) was added and the volume was made up to 25 ml with distilled water. The intensity of blue colour was read in spectrophotometer (Cary 50 Bio, Varian) at 660 nm. The standard curve was prepared with orthophosphate (KH_2PO_4) and amount of P solubilized was calculated by referring to standard graph. The phosphorus content was expressed in terms of mg of phosphorus/ml. Influence of phosphorus solubilizing organisms on the pH and titrable acidity of growth medium was also analyzed.

Phosphatase activity

The phosphatase activity was determined based on the liberation of p-nitrophenol from p-nitrophenol phosphate by colorimetric method (Morton 1952). The phosphatase activity was estimated by adding 1 ml of substrate solution (100 mg of p-nitrophenol phosphate in 100 ml distilled water), 10 ml of acetate buffer and 2 ml of enzyme source. The contents were thoroughly mixed and incubated at room temperature. After 24 h of incubation, 10 ml of assay mixture was withdrawn, centrifuged at 5000 rpm for 15 min. 1 ml of supernatant was mixed with 1 ml of fresh Folin's reagent (prepared by mixing one part of Folin-ciocalteau reagent and one part of distilled water) and 2 ml of 20 per cent sodium carbonate were added and boiled exactly for 1 min. It was immediately removed and the volume was made up to 10 ml and the colour was read in spectrophotometer (Cary 50 Bio, Varian) at 600 nm. The phosphatase activity was calculated and expressed as µg of p-nitrophenol released per ml of culture filtrate.

Statistical analyses

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

RESULTS AND DISCUSSION

Soil microorganisms play an important role in soil processes that determine plant productivity. Rhizosphere microbial communities are influenced by the plant exudates, roots as mechanical support and competition for nutrients. Equally, plants are affected by rhizosphere microbial communities through their participation in fast soil nutrients cycle, water dependence and growth promoting metabolites (Buscot and Varma 2005). One of the various mechanisms by which rhizobacteria promote plant growth is by solubilization of insoluble minerals.

Altogether sixty diazotrophic isolates were obtained by using four N-free media after 5 days of incubation. Out of 60 isolates, there were about 16 unique bacterial colonies from different grass species were further reconfirmed as putative diazotrophs by polymerase chain reaction. Based on such data, 16 isolates were selected for further study.

Identification of rhizosphere isolates by 16S rRNA gene sequence homology

The total genomic DNA of all the 16 isolates from rhizosphere were and the 16S rRNA gene of all the isolates was amplified using universal primers FD1 and RP2. All amplified products produced a single band with approximately 1500 bp length and the differences among them were not visible in 1 per cent agarose gel. Comparative BLAST analyses which include the closest species and per cent homology of full length 16S rRNA revealed the presence of diversity of Gamma proteobacteria and Firmicutes (Table 2).

Nearly 19% of diazotrophic isolates showed similarity to *Klebsiella* sp. and *K. pneumonia* respectively. Chelius and Triplett (2000) reported that *K. pneumoniae* as an endophyte in maize. In wheat, Iniquez *et al.* (2004) demonstrated and confirmed the nitrogen fixing activity of *K. pneumoniae*. The nitrogen fixing activity of *K. pneumoniae* isolates were again confirmed by our work. Among the diazotrophic isolates *Serratia* sp. accounted for 12% of which, 6% of isolates belonged to *S. marcescens*. Diverse species of *Serratia* have been isolated from cotton and sweet corn, rice rhizosphere rice seed.

In the present work, firmicutes were mainly dominated by different groups of *Bacillus*, which have been isolated from selected grass species is in accordance with the findings of Chowdhury *et al.* (2009). In the present investigation, *Enterobacter* sp. accounts for 12% of the total diazotrophs members of enterobateriales are known N_2-fixers and one of the most universal of endophytic genera. *Enterobacter* has been identified as endophytes of several plants such as *Citrus sinensis*, soybean, sweet potato and maize Kuklinsky-Sobral *et al.* 2004). Among the diazotrophs, one isolate from *Saccharum spontaneum* (SS4) identified as *Stenotrophomonas* sp. is ubiqui-

Table 1. Grass species from different physiographical regions of India used for the present study

Grass species	Sampling site	Latitude	Longitude	Physiographic region
Brachiaria reptans (water grass)	Barrackpur, Kolkata,West Bengal	88° 34´ 5.1” E	22° 19´ 49.6” N	Indo Gangetic alluvial plain
Cenchrus glaucus (buffel grass)	Chadrapur Ganjam, Orissa	88° 24´ 22.8” E	19° 24´ 21.09” N	Eastern Ghats
Saccharum spontaneum (Wild sugarcane)	Madan Mahal, Jabalpur, Madhya Pradesh	79° 40´ 50.33” E	22° 51´ 17.03” N	Central highlands
Panicum repens (torpedo grass)	Maruteru, West Godaveri, Andrapradesh	80° 59´ 38.86” E	16° 30´ 39.7” N	Deccan Plateau
Cyperus rotundus (nut grass)	Chickarasinikere, Mandya, Karnataka	77° 3´ 35.9” E	12° 17´ 34.78” N	Reverain land form
Dactyloctenium aegyptium (crowfoot grass)	Kasargod, Kerala	75° 7´ 59.81” E	12° 24´ 31.4” N	Kerala plains
*Chloris barbata (*finger grass*)*	Thavalakuppam, Pudhucherry	76° 46´ 54.7” E	11° 23´ 12.6” N	Coastal plains
Oryza rufipogon (wild rice)	Gudalur, Ooty, Tamil Nadu	79° 51´ 33.1” E	11° 54´ 32.52” N	Western Ghats
Cyanodon dactylon (bermuda grass)	Navalurkutapattu, Trichy, Tamil Nadu	79° 46´ 34.9” E	10° 33´ 21.32” N	Reverain land form
Setaria verticillata (bristly foxtail)	Thirupoondi, Nagapattinam, Tamil Nadu	79° 53´ 37.6” E	10° 46´ 25.67” N	Coastal plains

Table 2. Authentication of diazotrophic isolates from grass species of different physiographic regions by 16S rRNA gene sequence homology

Isolate	Grass species	Species homology[a]	Percent homology[b]	Gen bank accession no.
BR1	*B. repens*	*Enterobacter* sp.	99	KF906826
CG1	*C. glaucus*	*Klebsiella* sp.	94	KF906827
CG3	*C. glaucus*	*Enterobacter* sp.	98	KF906828
CG5	*C. glaucus*	*Bacillus* sp.	99	KF906830
SS4	*S. spontaneum*	*Stenotrophomonas* sp.	98	NS
CR2	*C. rotundus*	*Klebsiella pneumoniae*	98	NS
CR3	*C. rotundus*	*Klebsiella pneumoniae*	99	KF906829
CB2	*C. barbata*	*Serratia* sp.	99	KF906831
CB3	*C. barbata*	*Bacillus subtilis*	98	NS
CB4	*C. barbata*	*Klebsiella* sp.	98	NS
OR3	*O. rufipogon*	*Serratia* sp.	96	KF906832
OR5	*O. rufipogon*	*Staphylococcus saprophyticus*	99	KF906833
OR7	*O. rufipogon*	*Klebsiella* sp.	98	KF906834
CD1	*C. dactylon*	*Serratia marcescens*	97	KF906835
CD2	*C. dactylon*	*Bacillus* sp.	99	NS
SV1	*S.verticillata*	*Klebsiella pneumoniae*	99	KF906836

[a]Species identified based on the 16S rRNAgene sequence similarity by BLAST ; [b] Per cent similarity of the isolate's sequence in BLAST result; NS-Sequence not submitted

Table 3. Mineral solubilizing potential of diazotrophs isolated from selected grass species collected from different physiographic regions

Isolate	Colony diameter (mm)	Solubilization zone (mm)	Solubilization efficiency (%)
Enterobacter sp.(BR1)	5.0	12	140 (± 11.64)^{ef}
Klebsiella sp.(CG1)	9.0	12	33 (± 0.98)^{j}
Enterobacter sp.(CG3)	4.0	6.0	50 (± 2.17)^{ij}
Bacillus sp. (CG5)	5.0	8.0	60 (± 1.14)^{ij}
Stenotrophomonas sp. (SS4)	4.0	13	225 (± 12.16)^{ab}
K. pneumonia (CR2)	3.0	9.0	200 (± 2.64)^{bc}
K. pneumonia (CR3)	4.0	10	150 (± 11.19)^{def}
Serratia sp. (CB2)	4.0	14	250 (± 13.53)^{a}
B. subtilis (CB3)	4.0	9.0	125 (± 11.29)^{fg}
Klebsiella sp.(CB4)	4.0	10	150 (± 12.10)^{def}
Serratia sp.(OR3)	3.0	10	233 (±1 3.10)^{a}
S. saprophyticus (OR5)	3.0	8.0	167 (± 11.54)^{de}
Klebsiella sp.(OR7)	3.0	9.0	200 (± 12.64)^{bc}
S. marcescens (CD1)	8.0	14	75(±1.14)^{hi}
Bacillus sp.(CD2)	5.0	10	100 (± 13.19)^{gh}
K. pneumonia (SV1)	3.0	8.0	167 (± 12.63)^{de}
P. fluorescens (Pf1)*	5.0	15	200 (± 12.69)^{bc}

ND- Solubilization not detected. Values are mean (± SE) (n=3) and values followed by the same letter in each column are not significantly different from each other as detected by DMRT (p=0.05); *Standard strain

tous and often associated with plants has reportedly been isolated from rhizosphere of grass, wheat, oat, cucumber, maize, oilseed rape, potato and lettuce. It is not yet defined as nitrogen fixing bacteria despite their nitrogen fixing activities have been investigated and confirmed (Liu *et al*. 2007). Cibichakravarthy *et al*. (2011) isolated the diazotroph *Stenotrophomonas maltophila* from the rhizosphere of *Prosopis*. Roots of *Spartina alterniflora*, a common smooth cordgrass growing in salt marsh of North America harboured several gamma proteobacterial diazotrophs (Bagwell and Lovell 2000).

In vitro phosphorus solubilizing potential of diazotrophic isolates

A survey of Indian soils revealed that 98 per cent of these need phosphorus fertilization either in the form of chemical or biological fertilizer. Application of

Table 4. ***In vitro*** **P-solubilizing potential of diazotrophic isolates from the rhizosphere of grass species collected from different physiographic regions**

Isolate	pH	TA (%)	Available P (µg/ml)	Phosphatase (µg of PNP released/ml/day)
Enterobacter sp.(BR1)	4.0 (± 0.04)^{a}	2.4 (± 0.01)$^{c-g}$	0.47 (± 0.04)^{ghi}	5.8 (± 0.16)^{def}
Klebsiella sp.(CG1)	4.0 (± 0.03)^{a}	3.0 (± 0.03)^{abc}	0.69 (± 0.03)^{cde}	5.3 (± 0.10)^{def}
Enterobacter sp.(CG3)	4.0 (± 0.04)^{a}	2.1 (± 0.05)^{fgh}	0.81 (± 0.01)^{ab}	5.3 (± 0.11)^{def}
Bacillus sp. (CG5)	4.4 (± 0.04)^{a}	1.8 (± 0.01)^{gh}	0.36 (± 0.03)^{hij}	5.3 (± 0.15)^{def}
Stenotrophomonas sp. (SS4)	4.0 (± 0.01)^{a}	1.9 (± 0.01)^{gh}	0.68 (± 0.02)$^{c-f}$	2.4 (± 0.14)^{g}
K. pneumoniae (CR2)	4.0 (± 0.01)^{a}	1.8 (± 0.04)^{gh}	0.56 (± 0.06)^{efg}	4.5 (± 0.11)^{f}
K. pneumoniae (CR3)	4.0 (± 0.00)^{a}	2.9 (± 0.04)$^{a-d}$	0.86 (± 0.01)^{ab}	6.5 (± 0.08)^{cd}
Serratia sp. (CB2)	4.2(± .001)^{a}	2.3 (± 0.03)$^{d-g}$	0.68 (± 0.04)$^{c-f}$	5.4 (± 0.34)^{def}
B. subtilis (CB3)	4.3 (± 0.01)^{a}	3.1 (± 0.14)^{ab}	0.54 (± 0.01)^{efg}	4.4 (± 0.21)^{f}
Klebsiella sp.(CB4)	4.0 (± 0.04)^{a}	2.2 (±0.05)$^{e-h}$	0.25 (± 0.01)^{j}	5.6 (± 0.26)^{def}
Serratia sp.(OR3)	4.0 (± 0.04)^{a}	3.4 (± 0.01)^{a}	0.26 (± 0.01)^{j}	5.3 (± 0.25)^{def}
S. saprophyticus (OR5)	4.0 (± 0.06)^{a}	2.9 (± 0.04) $^{a-d}$	0.35 (± 0.03)^{ij}	4.5 (± 0.04)^{f}
Klebsiella sp. (OR7)	4.0 (± 0.14)^{a}	3.2 (± 0.02)^{ab}	0.36 (± 0.02)^{hij}	4.4 (±0.16)^{f}
S. marcescens (CD1)	4.0 (± 0.01)^{a}	2.3 (± 0.05)$^{d-g}$	0.85 (± 0.04)^{ab}	12.9 (± 0.10)^{a}
Bacillus sp.(CD2)	4.0 (± 0.05)^{a}	3.1 (± 0.06)^{ab}	0.96 (± 0.09)^{a}	10.9 (± 0.29)^{b}
K. pneumoniae (SV1)	4.0 (± 0.07)^{a}	2.8 (± 0.08)$^{a-e}$	0.48 (± 0.03)^{ghi}	7.5 (± 0.24)^{c}
P. fluorescens (Pf1)*	4.0 (± 0.03)^{a}	2.3 (± 0.02)$^{d-g}$	0.75 (± 0.01)^{bcd}	5.6 (± 0.08)^{def}
Control	6.6 (± 0.01)^{b}	0.2 (± 0.06)^{i}	0.02 (± 0.04)^{k}	0.05 (± 0.02)^{h}

Values are mean (± SE) (n=3) and values followed by the same letter in each column are not significantly different from each other as detected by DMRT (p=0.05); *Standard strain

chemical phosphatic fertilizers is practised though a majority of the soil P reaction products are only sparingly soluble. Under such conditions, microorganisms offer a biological rescue system capable of solubilizing the insoluble inorganic P of soil and make it available to the plants. P solubilization by plant-associated bacteria has been well documented in a number of studies (Stoltzfus and de Bruijn 2000).

In the qualitative assay, all the sixteen rhizosphere diazotrophs were found to be positive where, *Serratia* sp. (CB2) and *S. marcescens* (CD1) exhibited maximum solubilization efficiency of 250 and 233 per cent respectively were observed in the present study (Table 3). However, the most efficient phosphate solubilizing bacteria were reported from genera *Bacillus* and *Pseudomonas* from the rhizosphere of legumes, cereals (rice and maize), arecanut palm, oat, jute and chilli (Kole *et al.* 1998).

Influence of phosphorus solubilizing organisms on the pH titrable acidity, available phosphorus and phosphatase enzyme production was studied and the results are given in Table 4. In general, pH of the medium was decreased with growth of all phosphorus solubilizing isolates. Among the sixteen rhizosphere isolates, not much variation pH reduction was observed but for the titrable acidity increased due to the growth of phosphorus solubilizing organisms. Maximum titrable acidity of 3.4 ±0.01 per cent was found with *S. marcescens* (CD1). The amount of available phosphorus was significantly higher in *Klebsiella* sp. (OR7) (0.96 ± 0.09 µg/ml) compared to the other isolates. The phosphatase activity was higher in *Staphylococcus saprophyticus* (OR5) (12.9 ±0.10 µg of PNP released/ml/day) followed by *Klebsiella* sp. (OR7) (10.90 ± 0.29 µg of PNP released/ml/day) (Table 4). These results confirm the known relation of phosphate solubilization with pH and the release of organic acids as one of the mechanism for the solubilization of $Ca_3(PO4)_2$, as was also reported by Vazquez *et al.* (2000). Solubilization can be accomplished by a range of mechanisms, which include excretion of metabolites such as organic acids, proton extrusion or production of chelating agents (Nahas 1996). The production of gluconic acid seems to be the most frequent agent of mineral phosphate solubilization. Several other mechanisms such as production of other inorganic acids such as sulphuric acid, nitric acid and carbonic acid have also been reported (Seshadre *et al.* 2002). In the present investigation, nitrogen fixing and mineral solubilizing activities were found in most of the diazotrophic strains. It is therefore probable that they can be used as bacterial inoculate to support growth and development of crop plants *in vitro* and in field experiment. These novel efficient isolates with plant growth promoting activity obtained from the weedy grass rhizosphere may be employed in nutrient deficient and problematic soils for stress mitigation and sustainable crop cultivation with fewer chemical inputs.

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Effects of different tillage systems and herbicide on soil microflora of *Lablab* bean rhizosphere

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ABSTRACT

A long term field study was conducted at the Agronomy Farm, Department of Agronomy, Dr. B.S. KKV, Dapoli (Maharashtra) in *Rabi* season *lablab* bean crop to evaluate the effect of different tillage systems *vis-à-vis* different weed control measures on the survival and growth of total bacteria, total fungi, total free living nitrogen fixers and total phosphate solubilizers in rhizosphere soil. Four types of tillage systems were evaluated, *viz.* (i) Conventional-conventional (ii) Conventional-zero (iii) Zero-conventional and (iv) Zero-zero tillage systems. Among weed control measures, comparative effects of hand weeding and recommended herbicides application (oxadiargyl as pre-emergence) were tested along with weedy check. The results of the investigation revealed that tillage systems didnot significantly influence microbial population. The marginal growth of different microorganisms was observed in conventional-conventional tillage system, whereas minimum was in zero-tillage system. There were no adverse effects of herbicide use on all the estimated microbial population at all the stages of the crop. In short use of recommended herbicide oxadiargyl at 0.12 kg/ha had no long term adverse effects on rhizosphere microflora of *lablab* bean crop.

Key words: Bacteria, Free living nitrogen fixers, Fungi, Herbicide, *Lablab* bean, Phosphate solubilzers, Tillage

The adoption of intensive cropping systems has resulted in a large-scale use of agro chemicals. Weeds as one of the groups of pest are the major biological constraints for many crop and cropping system. The lack of suitable ecofriendly weed control alternatives has led to increase in reliance on herbicides in many crops all over the world as they are less expensive, convenient than manual labour and very effective and easy to use. Generally herbicides are not harmful when applied at recommended rates (Selvamani and Sankaran 1993) but some herbicides may affect non-target organisms including microorganisms (Latha and Gopal 2010) such as bacterial population (Rajendran and Lourduraj 1999) and fungal population (Shukla 1997). These effects on non-target organisms may reduce the performance of important and critical soil functions such as organic matter decomposition, nitrogen fixation and phosphate solubilization which support the soil health, plant growth and in turn crop productivity. Nonetheless, some herbicide may even stimulate the growth and activities of the microflora (Wardle and Parkinson 1990). Most of the studies were focused on effects of single application of herbicides on soil microorganisms for a short period, which may not provide a realistic evaluation of such effects (Haney *et al.* 2000). Therefore, knowledge about effects of long term application of herbicides on soil microbes is highly essential. Hence, present investigation to study the long term effects of different tillage systems and application of weedicide such as oxidiargyl treatment for *Rabi Lablab* bean cropping system was carried out to find out the effects on survival and growth of total bacterial population, total fungal population, total free living nitrogen fixers and total phosphate solubilisers in the rhizosphere soil. The present paper deals with study related to rhizosphere soil of *Rabi Lablab* bean crop.

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MATERIALS AND METHODS

The field experiment was conducted under AICRP on Weed Control for eight years during 2003 to 2011 at the Agronomy Farm, College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India.

The experiment was conducted on *Kharif* rice (*Ratnagiri-1*) and *Rabi Lablab* bean (*Kelshi-Wal*) cropping system which included eight treatment combinations laid out in a split plot design with three replications. The main plot treatments included tillage system, *viz.* zero-zero tillage (Z-Z tillage), zero-conventional tillage (Z-C tillage), conventional-zero tillage (C-Z tillage), conventional-conventional tillage (C-C tillage) while the sub-plot treatments included weed control measures such as hand weeding at 20 and 40 DAS, oxidiargylat 0.12 kg/ha (pre-emergence), weedy check.

Rhizosphere soils were collected at 30, 50 days after sowing (DAS) and at harvesting stage of *Rabi Lablab* bean by uprooting four plants from each plot and keeping the soil around root system intact. After removing the bits of plant roots and other debris, the soil strongly adhered to the roots was immediately used without drying for determination of biological property of rhizosphere soil. The total bacterial population, total fungal population, free living nitrogen fixers and total phosphate solubilizers of rhizosphere soil were determined.

Enumeration of microorganisms

The colony forming units (CFU) of bacteria were enumerated on agar plates containing appropriate media following serial dilution technique and pour plate method. The media used were nutrient agar media for total bacterial population, Martin's rose Bengal agar media for total fungal population (Martins 1950), Noories N-free media for total free living nitrogen fixers (Noories 1959) and Pikovskaya's agar medium for total phosphate solubilizing microorganisms (Pikovskaya 1948).

RESULTS AND DISCUSSION

Effect of tillage system

The data regarding treatment effects on total population of bacteria, fungi, free living nitrogen fixers and phosphate solubilizers in the rhizosphere soil of *Rabi Lablab* observed at different growth stages of crop during *Rabi* hot weather season of 2011-12 are presented in (Table 1). Data revealed that various tillage system under the study did not significantly influence the total bacterial population, total fungal population, total free living nitrogen fixers and also total phosphate solubilizers at 30 DAS, 50 DAS and harvesting stage of *Lablab* bean crop during the *Rabi* season.

Effect of weed control measures

The total population of bacteria, fungi, free living nitrogen fixers and phosphate solubilizers due to use of pre-emergence application of herbicide oxadiargyl was at par with weedy check treatment at 30, 50 DAS and at harvesting stage which indicate indirect stimulation of microbial population in the rhizosphere due to the former treatment at all the stages. Such a stimulation in microbial population showed that major part of the microflora could tolerate the herbicide and possibly utilize the herbicide as a nutrient source, as reported by Wardle and Parkinson (1990). Lata and Gopal (2010) also reported that adverse effect of herbicide towards bacteria, fungi and phosphate solubilizing bacteria decreases due to microbial adaptation to these chemicals or due to their degradation. It can also be due to the microbial multiplication on increased supply of nutrients available in the form of microorganisam killed by the herbicides. This shows that herbicide oxidiargyl have no adverse effect on the estimated microflora of the soil.

The estimated microbial population such as bacterial free living nitrogen fixers and phosphate solubilisers in the rhizosphere of *Rabi Lablab* bean was significantly superior due to the treatment of hand weeding treatment twice at 20 and 40 DAS as compared to the application of herbicide oxadiargyl at 0.12kg/ha. These results are in conformity with those

Table 1. Effects of tillage systems and weed control measures on total population of bacteria, fungi, freeliving nitrogen fixers and phosphate solubilizers during *Rabi* season 2011 in *Lablab* bean

Treatment	Bacteria (CFU x10^6/g of soil)			Fungi (CFU x10^4/g of soil)			Free living nitrogen fixers (CFU x10^3/g of soil)			Phosphate solubilisers (CFU x10^3/g of soil)		
	30 DAS	50 DAS	At harvest	30 DAS	50 DAS	At harvest	30 DAS	50 DAS	At harvest	30 DAS	50 DAS	At harvest
Tillage system												
Z-Z	39.6	42.4	43.1	19.5	21.8	24.8	24.2	26.4	29.8	22.4	24.6	26.9
Z-C	40.2	42.1	46.2	21.5	25.7	27.1	25.4	26.8	30.9	22.7	25.8	28.2
C-Z	40.7	43.3	46.6	22.3	25.6	30.3	25.8	28.0	31.3	24.4	27.1	29.1
C-C	41.2	43.6	47.2	26.3	28.7	32.0	26.2	29.3	32.0	25.0	27.6	30.2
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed control measure												
HW at 20 and 40 DAS	43.4	45.9	48.9	23.8	28.5	30.5	27.9	31.2	33.7	26.1	28.5	31.1
Oxadiargyl at 0.12 kg/ha (PE)	37.9	41.0	42.8	20.7	22.4	26.6	22.9	24.3	28.8	21.2	24.1	27.1
Weedy check	39.9	41.7	45.7	22.7	25.4	28.6	25.3	27.5	30.5	23.5	26.1	27.6
LSD (P= 0.05)	2.97	3.58	3.16	NS	NS	NS	3.12	3.68	3.13	2.46	3.35	2.56
Interaction effect												
LSD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

of Singh and Tarafdar (2002) who reported that manual weeding helps to build up the microbial population. While Bhale *et al* (2012) reported that hand weeding allows pulverization of soil and better soil aeration which ultimately increase the microbial population in the soil.

On the basis of results of the present long term investigation for about eight years, it is concluded that various tillage system under study had no remarkable effects on microbiological properties of rhizosphere soil of *Rabi Lablab* bean crop and the use of oxadiargyl as a pre-emergence application at 0.12 kg/ha did not cause any long term adverse effect on rhizosphere microflora of *Lablab* bean crop at the given recommended dose even after its continuous application for eight years.

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Evaluation of pendimethalin residues in garlic

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ABSTRACT

A field experiment was conducted to study the persistence and accumulation of pendimethalin residues in garlic. Pendimethalin was applied as pre-emergence treatment at three different doses, *viz.* 0.75, 1.5 and 3.0 kg/ha. Mature garlic bulbs were collected at crop harvest and soil samples were collected at 0, 15, 30, 45, 60, 75, 90, 120 days after herbicide application and at crop harvest. These samples were analyzed for pendimethalin residues by a validated Gas Liquid Chromatography (GLC) method with an accepted recovery of 79.1–88.2%. The analysis showed that pendimethalin did not leave any residues in soil beyond harvest of the crop at any of the applied dose. On the other hand, garlic bulbs collected at harvest showed 0.004 µg/g pendimethalin residues at a dose of 3.0 kg/ha and below detectable limit (BDL) at 0.75 and 1.5 kg/ha.

Key words: Garlic, Pendimethalin, Persistence, Residues

Garlic (*Allium sativum)* is an important bulbous vegetable crop, cultivated commercially throughout tropical and subtropical belt of the world. It is very slow to germinate and grow in the initial stages. Weed infestation in garlic is one of the major factors for bulb yield loss to the tune of 79-89% (Ahmed 1991). Garlic is a long-duration crop and the aggravated labour problem in agriculture is a limitation. Therefore, it is necessary to rely on herbicides for an effective and timely weed control. The most important consideration in chemical weed control is persistence of herbicides in soil and their residues in crop produce. Pendimethalin [N-(1-ethylpropyl)-3, 4 dimethyl 2, 6 dinitrobenze-namine], a selective pre-emergence herbicide has wide spread use for control of a wide variety of grasses and broadleaf weeds (Sinha *et al.* 1996 and Bhowmick and Ghosh 2002) in crops like peas (*Pisum sativum* L.), rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), soybean (*Glycine max* L. *merr.*) and several other vegetable crops including garlic (*Allium sativum* L.). This herbicide is soil-applied, moderate in persistence and relatively immobile in nature (Tsiropoulos and Miliadis 1998 and Triantafyllidis *et al.* 2009). The most likely route of herbicide dissipation is soil binding. Field studies on persistence and accumulation of pendimethalin residues in garlic crop are meager. Thus, the present investigation was undertaken to study the persistence and accumulation of pendimethalin residues in garlic.

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MATERIALS AND METHODS

A field experiment was conducted at the Research Farm of Department of Agronomy, CSK HPKV, Palampur in a randomized block design with three replications. Residue analysis was conducted in the residue laboratory of Department of Agronomy, CSK HPKV, Palampur. Pendimethalin was sprayed at three different doses *i.e.* 0.75, 1.5 and 3.0 kg/ha in garlic crop as pre emergence herbicide. Five soil cores were randomly taken from each of the treated and untreated plot using auger upto the depth of 15cm at 0, 15, 30, 45, 60, 75, 90 and 120 days after herbicide application. These cores were bulked together, air dried, powdered and passed through a 2 mm sieve to achieve uniform mixing. Garlic bulbs were collected at the maturity of the crop from pendimethalin treated and untreated plots.

Pendimethalin residues were extracted as described by Sondhia and Dubey (2006). Pendimethalin reference analytical standard was obtained from Accu Standard Inc., USA. All the other chemicals and solvents used in the study were analytical grade reagents. The gas liquid chromatography (Clarus-500, Model Perkin Elmer) equipped with Ni^{63} electron capture detector (ECD) and fitted with a column RTx 5 (30 m x 0.25 mm i.d.) under oven isothermal conditions of 210 ^{o}C. The injector and detector were maintained at 240 ^{o}C and 350 ^{o}C respectively. Nitrogen was used as a carrier gas with a flow of 30 ml/min. The injection volume of standard solution and sample was 1 µl for analysis.

Garlic bulbs were cut into small pieces and homogenized with acetone. Homogenized garlic bulbs and soil samples were extracted with 50 ml acetone on a horizontal shaker for two hours. The contents were filtered and the collected filtrate was dried using vacuum rotary evaporator. The residues were dissolved in 50 ml dichloromethane and taken in a 500 ml separating funnel followed by the addition of 100 ml of 10% sodium chloride (hexane washed). The contents were shaken vigorously for 15-20 minutes and the layers were allowed to separate. The organic layer was collected and the aqueous layer was further extracted with 20 ml of dichloromethane 2-3 times. The dichloromethane fractions were pooled and passed through AR grade anhydrous sodium sulphate and was dried using rotary flash evaporator at 40^{o}C. The final volume was made upto 5 ml using distilled hexane in 10% acetone. However, clean up procedure was required for garlic bulbs. A glass column was packed with 6 g of activated florisil and in between two layers of anhydrous sodium sulphate and activated charcoal were added. Concentrated extracts of garlic samples were loaded on the top of column and eluted with 75 ml hexane. The eluted hexane was collected and concentrated using flash evaporator.

Validation of the method was performed in terms of recovery experiment before analysis of unknown samples. Different known concentrations of pendimethalin (0.01, 0.1, 0.5, 1.0, 5.0 and 10 ppm) were prepared in n-hexane by diluting the stock solution. One micro liter of standard solution was injected in gas liquid chromatography (GLC), the peak area measured and standard curve was prepared. The recovery study was conducted with soil and garlic bulbs. One ml of pendimethalin was added uniformly on the surface matrix and mixed well before adding extraction solvent. The extraction and cleanup process was performed as described in methodology. The results are presented in Table 1. Quantification of pendimethalin residues in soil and garlic was accomplished by comparing the peak response for samples with peak area of standards.

RESULTS AND DISCUSSION

Under described conditions of GC, pendimethalin was eluted as a single sharp peak at 7.6 minutes (Fig.1.) The standard curve for reference pendimethalin showed linearity and the detector showed good sensitivity for the pendimethalin residues up to 0.05 µg/ml. The recovery experiment conducted with soil and garlic bulbs showed that recovery percentage for soil varied from 79.3-83.8%; however, it varied between 79.1 and 88.2% in the case of garlic bulbs at fortification level of 0.5 and 1.0 µg/g of pendimethalin, respectively (Table 1). The recoveries of pendimethalin at different concentration levels were satisfactory within the range 79.1–88.2%, confirming a good repeatability of the method. The equation of analytical calibration graphs, obtained by plotting peak areas in the *y* -axis against concentrations of pendimethalin in the *x* -axis within the range of 0.05 to 10 µg/ml, was $y = 82723\ x + 316449$, which showed good linearity, and the value of correlation coefficient was 0.99. Pendimethalin residues and their per cent dissipation data in different matrices at different time intervals as detected by GLC are presented in Table 2. The initial deposits of pendimethalin in soil immediately after application of pendimethalin 0.75, 1.50 and 3.00 kg/ha were found to be 0.301, 0.668 and 1.439 mg/kg, respectively which after 120 days of herbicide application reached to below detectable levels, 0.001 and 0.08 mg/kg, respectively. Thus, the corresponding percent losses of pendimethalin were 100, 99.85 and 99.44%, respectively. The data on per cent dissipation revealed that dissipation rate was faster during first 15 days and thereafter dissipation occurred at constant rate. More than 80-90% of pendimethalin 0.75, 1.50 and 3.00 kg/ha dissipated within 75 days after application. The dissipation of pendimethalin on 75th day after application was 98.7, 95.6 and 87.9% for pendimethalin 0.75, 1.50 and 3.00 kg/ha, respectively indicating that only 1.30, 4.35 and 12.1% of applied pendimethalin remained in soil at 75th day. Pendimethalin residue data (Table 2) at three application rates *i.e.* 0.75, 1.50 and 3.00 kg/ha also revealed that herbicide in soil persisted upto 90 days at a dose of 0.75 kg/ha and 120 days at 1.50 and 3.00 kg/ha. This indicates that pendimethalin at higher doses per-

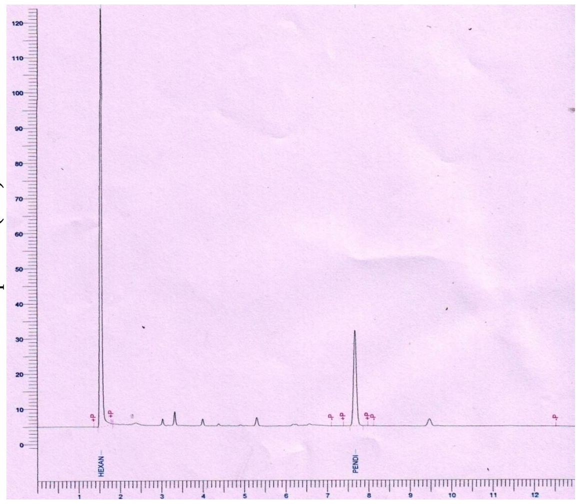

Fig. 1. Rt value of pendimethalin

Table 1. Recoveries of pendimethalin from soil and garlic fortified with known amount of herbicide

Herbicide	Amount added (µg/g)	*Amount recovered (µg/g)	Average recovery (%)
Soil	0.5	0.419 ± 0.05	83.8
	1.0	0.793 ± 0.026	79.3
Garlic	0.5	0.441 ± 0. 013	88.2
	1.0	0.791 ± 0.018	79.1

*Values are average of three replications

Table 2. Residues (mg/kg) of pendimethalin in soil (0-15 cm depth) treated at different doses

Days after herbicide application	Rates of pendimethalin application (kg/ha)		
	0.75	1.50	3.00
0	0.301 (0)	0.668 (0)	1.439(0)
15	0.119 (60.5)	0.389 (50.8)	1.048 (27.1)
30	0.052 (82.8)	0.245 (63.3)	0.864 (39.9)
45	0.018 (94.0)	0.160 (76.0)	0.587 (59.2)
60	0.011 (96.3)	0.068 (89.9)	0.336 (76.6)
75	0.004 (98.7)	0.029 (95.6)	0.174 (87.9)
90	0.001 (-)	0.009 (98.6)	0.133 (92.5)
120	BDL (-)	0.001 (99.8)	0.08 (94.4)
Harvest	BDL (-)	BDL (-)	BDL (-)

*The values given in the parentheses are % dissipation

Table 3. Slope of curve, rate constant and half life values of pendimethalin residues in soil

Pendimethalin (kg/ha)	Slope of curve (b)	Rate constant (K)	Half life (days)	Correlation coefficient	Regression equation
0.75	0.026	0.059	11. 9	0.99	Y= - 0.026 x + 2.494
1.50	0.020	0.046	15.0	0.99	Y= - 0.020 x + 2.938
3.0	0.14	0.032	21.5	0.96	Y= - 0.014 x + 1.318

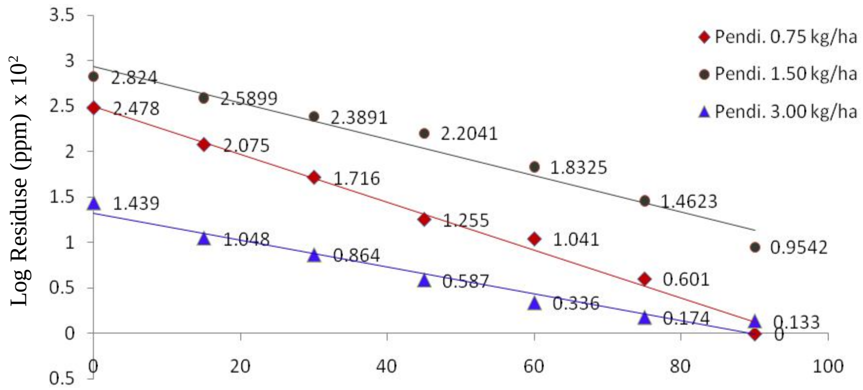

Fig. 2. First order dissipation curve of pendimethalin in soil

sisted in the soil for longer duration than lower doses. Pendimethalin did not leave residues in soil beyond harvest of the crop at any of the applied doses. Similar observations have been reported by Sinha *et al.* (1996) where pendimethalin persisted for over 75 days at the application rate of 2.0 kg/ha. The logarithmic plots of herbicides residue vs time are presented in Fig. 2. These plots indicated that dissipation of pendimethalin at all three levels of application, *viz.* 0.75, 1.50 and 3.00 kg/ha fitted first order kinetics decay curve and is in line with the findings of Tandon (2008). The slope of the curve, correlation coefficient, rate constant and half life of herbicide along with the regression equations are summarized in Table 3. Half life for pendimethalin at 0.75, 1.50 and 3.00 kg/ha were 11.9, 15 and 21.5 days, respectively. These findings are in agreement with that of Alister *et al.* (2009) who also reported the half life of pendimethalin varied from 10.5 to 31.5 days. This may be due to combined effect of soil physico-chemical properties including high organic carbon and comparatively low temperature (Raj *et al.* 1999). Pendimethalin residues in garlic bulbs were below the detectable level in case of pendimethalin 0.75 and 1.50 kg/ha and 0.004 mg/g in pendimethalin 3.00 kg/ha. From the data regarding residues of pendimethalin in garlic bulbs collected at the harvest of crop, it was evident that residues of pendimethalin were below maximum residue limit set by WHO/ FAO (0.5 mg/ kg). It indicates that the use of pendimethalin in garlic could be considered safe.

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Short communication

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Control of complex weed flora in transplanted rice with herbicide mixure

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Key words: Bispyribac-sodium, Ethoxysulfuron, Herbicide mixure, Transplanted rice, Weed, Yield

Rice (*Oryza sativa* L.) is one of the most important food crop of India, contributing to about 40% of total food grain production. It plays a vital role in food security and livelihood for almost every household. Out of the total 44 mha area under rice cultivation, puddled rice culture occupies 56% (Anonymous, 2005). Weeds pose a major problem in rice production as they not only compete with crop but also hinder the quality. Weed competition brings reduction in yield of transplanted rice by about 28-45% (Kumar *et al.* 2008, Yadav *et al.* 2009). Therefore, timely weed control is imperative for realizing desired level of productivity. Accordingly, an efficient and economic weed management program is necessary to control different types of weeds throughout the cropping period. Hand weeding is expensive, time consuming, difficult and often limited by scarcity of laborers in time. On the other hand, herbicides offer economic and efficient weed control if applied at proper dose and stage (Prakash *et al.* 2013).

The weed flora under transplanted condition is very much diverse and consists of grasses, sedges and broad-leaf weeds. The effective control of weeds at initial stages (0-40 DAT) can help in improving productivity of this crop. Therefore, presently there is a need to use high efficacy herbicides in combination coupled with broad spectrum nature to control the complex weed flora in transplanted rice (Gnanavel and Anbhazhagan 2010).

A field experiment was conducted during *Kharif* season of 2013 at Crop Research Centre (CRC) of G.B Pant University of Agriculture and Technology, Pantnagar, District, Udham Singh Nagar (Uttarakhand). The soil of experimental site was silty loam in texture having high organic carbon (0.89%), medium available P (21.7 kg/ha) and available K (144.8 kg/ha), low available N (228.9 kg/ha) and pH (7.4). The experiment was laid out in a randomized block design with three replications to evaluate twelve treatments, *viz*. post-emergence application of bispyribac-sodium at 25 g/ha, pre-emergence application of pretilachlor at 1000 g /ha, early post-emergence application of penoxsulam at 22.5 g /ha, pre-emergence application of pyrazosulfuron at 20 g/ha, post-emergence application of bispyribac-sodium at 25 g/ha + ethoxysulfuron at 18.75 g/ha, post-emergence application of bispyribac-sodium 20 g/ha + chlorimuron ethyl + metsulfuron-methyl 4 g/ha, pre-emergence application of pretilachlor at 750 g /ha *fb* post-emergence application of ethoxysulfuron at 18.75 g/ha, pre-emergence application of pretrilachlor at 750 g/ha *fb* post-emergence application of chlorimuron-ethyl + metsulfuron-methyl at 4 g/ha (RM), pre-emergence application of pyrazosulfuron at 20 g /ha *fb* manual weeding at 25 DAT, pre-emergence application of pretilacholor (6%) + bensulfuron (0.69%) (RM) at 660 g/ha, weed free and weedy check. The transplanted rice variety was "*Sarjoo 52*". Twenty four days old seedlings were transplanted in puddle field using two seedlings per hill at spacing of 20 x 15 cm on 27th June, 2013. The crop was raised by following recommended packages of practices for rice in Uttarakhand. The data on weed density and weed dry weigh were collected from each unit plot at 30, 60, 90 DAT and at harvest. A quadrate of 0.25 m^2 was placed randomly and weed species within the quadrate were identified and their number was counted. The average number of sample was multiplied by four to obtain the weed density/meter square. The weeds inside the quadrate were uprooted, cleaned and then oven dried. Dry matter of weeds was recorded and expressed in g/m^2. The data, the weed density and weed dry matter were analyzed after subjecting to square root transformation for comparison. The data on grain yield were recorded from the net plot and weed control efficiency was worked out.

In the experimental plots, the dominant weeds were *Echinochloa colona, E. crusgalli, Ischaemum rugosum, Caesulia axillaris, Ammania baccifera,*

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Alternanthera sessilis and *Cyperus iria*. All the herbicides showed effective control of all categories of weeds resulting in less weed dry matter and higher weed control efficiency as compared to weedy check. Combination of post-emergence application of bispyribac-sodium at 25 g/ha + ethoxysulfuron at 18.75 g/ha was most effective in minimizing the weed population and their dry matter accumulation as compared to other herbicidal treatments (Table 1). The reason behind the control of total weed density by the combination of post-emergence application of bispyribac-sodium at 25 g/ha + ethoxysulfuron at 18.75 g/ha might be due to the efficient broad spectrum control by bispyribac-sodium which resulted in elimination of both grassy and broad-leaf weeds and ethoxysulfuron being the broad-leaf killer and also reduces the population of sedges effectively. Post-emergence application of bispyribac-sodium alone and in combination at 20 and 25 g/ha was effective against mixed weed flora in transplanted rice. Similar results were reported by Walia *et al.* (2008) and Yadav *et al.* (2009). Ethoxysulfuron being an ALS inhibitor when applied at 18.75 g/ha was most effective against the population of *Caesulia axillaris, Ammania baccifera, Alternanthera sessilis*.The effectiveness of ethoxy-sulfuron against *Alternanthera* sp. was also reported by Shahbaz *et al.* (2007).

Weed control efficiency (WCE) with respect to grass, sedge and broad-leaved weeds (98.2%) was highest with post-emergence application of bispyribac-sodium at 25 g/ha + ethoxysulfuron at 18.75 g/ha followed by pre-emergence application of pretrilachlor at 750 g/ha *fb* post-emergence application of chlorimuron-ethyl + metsulfuron-methyl at 4 g/ha (93.4%). Highest dry matter accumulation was recorded in weedy check. The increase in dry weight of weeds in weedy check may be attributed to more nutrition available to the weeds. The results are in conformity with the findings of Ehsanullah *et al.* (2009) who observed numerically higher dry weight of weeds in weedy check over other treatments.

The highest rice grain yield (6.74 t/ha) was recorded in weed free plots which was statistically at par with post-emergence application of bispyribac-sodium at 25 g/ha + ethoxysulfuron at 18.75 g/ha fol-

Table 1. Effect of treatments on total weed density, weed dry weight, weed control efficiency and grain yield in transplanted rice

Treatment	Dose (g/ha)	Weed density (no./m^2)			*Weed dry weight (g/m^2)			WCE (%)	Grain yield (t/ha)
		Grasses	BLW	Sedges	Grasses	BLW	Sedges		
Bispyribac-sodium	25	3.1 (8.7)	5.6 (31.3)	1.0 (0.0)	3.8 (14.0)	2.4 (5.0)	1.0 (0.0)	77.7	6.05
Pretilachlor	1000	3.6 (12.0)	8.1 (65.3)	1.9 (2.7)	4.9 (23.2)	3.6 (12.3)	1.7 (2.0)	55.3	5.83
Penoxsulam	22.5	2.8 (6.7)	5.8 (32.7)	2.5 (5.5)	4.6 (19.9)	2.5 (5.2)	2.1 (3.7)	65.9	6.02
Pyrazosulfuron	20	4.1 (16.0)	8.1 (65.3)	2.6 (6.0)	6.0 (34.6)	3.4 (10.5)	2.5 (5.1)	40.0	5.55
Bispyribac-sodium + ethoxysulfuron	25 + 18.75	1.5 (1.3)	3.0 (8.0)	1.0 (0.0)	1.2 (0.5)	1.4 (1.0)	1.0 (0.0)	98.2	6.51
Bispyribac-sodium + chlorimuron-ethyl + metsulfuron-methyl (RM)	20 + 4	1.9 (2.7)	4.7 (20.7)	2.1 (3.3)	2.0 (3.1)	1.9 (2.7)	1.5 (1.3)	91.6	6.38
Pretilachlor *fb* ethoxysulfuron	750/ 18.75	2.2 (4.0)	5.3 (26.8)	1.0 (0.0)	3.1 (8.7)	1.9 (2.8)	1.0 (0.0)	86.6	6.22
Pretilachlor *fb* chlorimuron-ethyl + metsulfuron-methyl (RM)	750/4	1.5 (1.3)	4.5 (19.4)	1.9 (2.7)	1.6 (1.7)	1.9 (2.7)	1.5 (1.2)	93.4	6.39
Pyrazosulfuron *fb* manual weeding	20/25 DAT	2.5 (5.4)	6.2 (37.3)	1.0 (0.0)	4.1 (16.0)	2.3 (4.4)	1.0 (0.0)	76.0	6.05
Pretilacholor (6%) + bensulfuron (0.69%) 6.69% (RM)	660	3.2 (9.4)	6.9 (46.6)	3.4 (10.7)	4.6 (20.4)	2.7 (6.5)	3.3 (10.0)	56.3	5.96
Weed free	-	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	100.0	6.74
Weedy check	-	5.4 (28.0)	10.6 (111)	5.2 (26.0)	6.7 (44.3)	4.3 (17.2)	4.9 (22.7)	0.0	4.38
LSD (P=0.05)	-	0.5	0.4	0.2	0.6	0.3	0.3	-	0.59

Original value are given in parentheses

lowed by pre-emergence application of pretrilachlor at 750 g/ha *fb* post-emergence application of chlorimuron ethyl + metsulfuron methyl at 4 g/ha (RM) (Table 1)

The increase in grain yield under this treatment was due to less weed density and weed biomass as compared to all other treatments tried under this study. Application of post-emergence application of bispyribac-sodium at 25 g/ha caused significantly higher grain yield. Similar results were reported by Kumar *et al.* (2013). Ethoxysulfuron being an ALS inhibitor also significantly increased the grain yield when applied in combination with other herbicides. The results were in conformity with the findings of Dewangan (2011). Also, chlorimuron-ethyl + metsulfuron-methyl at 4 g/ha (RM) also proved to increased the grain yield when applied as post-emergence by suppressing weed population and reducing the weed biomass. Similar results were reported by Upasani *et al.* (2012).

No residual effect of tested herbicide in soil was observed after the harvest of rice crop. It is, therefore recommended that post-emergence application of bispyribac-sodium at 25 g/ha + ethoxysulfuron at 18.75 g/ha can safely be used for controlling the complex weed flora other combinations like. Pre-emergence application of pretrilachlor at 750 g/ha *fb* post-emergence application of chlorimuron-ethyl + metsulfuron methyl at 4 g/ha (RM); post-emergence application of bispyribac-sodium at 20g/ha *fb* post-emergence application of chlorimuron-ethyl + metsulfuron-methyl at 4 g/ha (RM); pre-emergence application of pretrilachlor at 750 g/ha *fb* post-emergence application of ethoxy-sulfuron at 18.75 g/ha in transplanted *Kharif* rice were at par with each other to improve the grain yield.

SUMMARY

Different herbicides alone and in combination were tested for the control of complex weed flora in transplanted rice during *Kharif* season 2013 at Crop Research Centre (CRC) of G.B Pant University of Agriculture and Technology, Pantnagar, District, Udham Singh Nagar (Uttarakhand). The experiment was laid out in randomized block design with three replications to evaluate twelve treatments. The major weeds were *Echinochloa colona, E. crusgalli, Ischaemum rugosum, Caesulia axillaris, Ammania baccifera, Alternanthera sessilis* and *Cyperus iria*. Combination of post-emergence application of bispyribac-sodium at 25 g/ha + ethoxysulfuron at 18.75 g /ha was most effective in controlling weed species and yielded maximum grain yield (6.51 t/ha) among the herbicidal treatments after weed free (6.74 t/ha).

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Short communication

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Efficacy of post-emergence herbicides for weed control in transplanted rice

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Transplanted rice is mainly infested by barnyard grass besides some sedges and broad-leaved weeds. Moreover, recommended herbicides are effective against grasses only when used as pre-emergence and if there is ponding of water at least for 48 hours after treatment. With the continuous use of these herbicides, particularly anilofos, problem of sedges and broad-leaf weeds is increasing every year. Due to increasing problem of sedges and lack of availability of water after transplanting, there is an urgent need to have an early post-emergence herbicide, which can provide effective control of complex weed flora. Additionally, continuous use of the same herbicide may lead to change in weed flora and their intensity with respect to time and may also result in evolution of resistance in some weed species. Some herbicides like bispyribac-sodium and azimsulfuron if applied at 15 and 25 DAT are effective for weed control in transplanted rice. Hence, a study was conducted to find out the efficacy of different post-emergence herbicides for weed control in transplanted rice.

The experiment was conducted at the Students' Farm of College of Agriculture, CCS Haryana Agricultural University, Kaul (Kaithal) during *Kharif* 2008. The soil of the experimental field was clay loam in texture and slightly alkaline in reaction. The soil was low in organic carbon, low in available N and medium in available P and high in available K. The experiment consisted of fifteen treatments, *viz.* two doses of post-emergence herbicides, bispyribac-sodium (25 and 30 g/ha) and azimsulfuron (30 and 40 g/ha) with two timings of their application (20 and 25 DAT) and one dose of fenoxaprop-p-ethyl 56.25 g/ha (25 DAT). Four pre-emergence herbicides pretilachlor 750 g/ha, butachlor 1500 g/ha, oxadiargyl 100 g/ha, pyrazosulfuron 20 g/ha along with weedy and weed free checks and were laid out in randomized block design with three replications. Thirty days old seedlings were transplanted on 3rd July, 2008 manually at a spacing of 20 x 15 cm with two seedlings per hill. The crop was raised with recommended fertilizer dose.

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The experimental field was dominated by grassy, broad-leaf weeds and sedges, *viz. Echinochloa colona, Echinochloa crusgalli, Ammania baccifera, Ludwigia parviflora, Lindernia* spp., *Marsilea quadrifolia, Cyperus iria* and *Cyperus difformis.*

Application of pretilachlor 750 g/ha (3 DAT), butachlor 1500 g/ha (3 DAT), bispyribac-sodium 25 and 30 g/ha (20 DAT) and pyrazosulfuron 20 g/ha (3 DAT) brought about similar significant reduction in number of grassy weeds. Yadav *et al.* (2008) also reported effectiveness of bispyribac to control grassy weds and sedges in transplanted rice. Azimsulfuron at all doses did not provide good control of grassy weeds than other herbicides but was significantly better than weedy check.

Pre-emergence herbicides pretilachlor 750 g/ha (3 DAT), butachlor 1500 g/ha (3 DAT) and pyrazosulfuron 20 g/ha (3 DAT) were statistically similar but better than oxadiargyl at 20 DAT in controlling broad-leaf weeds. Azimsulfuron 30 and 40 g/ha (20 DAT) and pyrazosulfuron 20 g/ha (3 DAT) were statistically similar to pretilachlor and butachlor to control the broad-leaved weeds. Azimsulfuron 30 and 40 g/ha (25 DAT), bispyribac-sodium (at all doses), fenoxaprop-p-ethyl, oxadiargyl and pyrazosulfuron were the next good herbicides and better than weedy check. Numbers of sedges were lowest in weed free treatment and highest in weedy check. Pretilachlor 750 g/ha (3 DAT), bispyribac sodium 25 and 30 g/ha (20 DAT), butachlor 1500 g/ha (3 DAT) and pyrazosulfuron 20 g/ha (3 DAT) were significantly at par to weed free to control sedges. Pal *et al.* (2012) also reported good efficacy of pyrozosulfuron at 20 and 25 g/ha applied at 3 DAT. Significantly lowest weed dry weight was recorded with use of pretilachlor at 750 g/ha and it remained statistically at par with butachlor 1500 g/ha, pyrazosulfuron 20 g/ha and also with post-emergence application (20 DAT) of bispyribac-sodium 25 and 30 g/ha. Walia *et al.* (2008) found significantly lower weed dry weight of grassy weeds with the pre-emergence application of pendimethalin 0.75 kg/ha *fb*

Table 1. Effect of weed control treatments on weed density, weed dry weight and weed control efficiency in transplanted rice

Treatment	Dose (g/ha)	Time of application (DAT)	Weed density (no./m^2)			Weed dry weight (g/m^2)	WCE (%)
			Grassy	Broad-leaf	Sedges		
Bispyribac-sodium	25	20	4.4 (19)	4.2 (27)	4.3(19)	7.7(59.3)	82.1
Bispyribac-sodium	25	25	5.1 (25)	5.8 (34)	5.4(29)	9.0(81.8)	75.3
Bispyribac-sodium	30	20	3.5 (12)	5.0 (25)	3.8(14)	6.5(42.4)	87.2
Bispyribac-sodium	30	25	4.8 (23)	4.4 (19)	5.2(27)	8.8(78.3)	76.3
Azimsulfuron	30	20	6.7 (45)	5.3 (28)	6.1(37)	10.3(105.8)	68.0
Azimsulfuron	30	25	8.1 (65)	4.0 (16)	6.4(40)	12.3 (150.7)	54.4
Azimsulfuron	40	20	6.6 (43)	5.0 (28)	6.0(36)	9.4 (88.7)	73.2
Azimsulfuron	40	25	7.4 (55)	5.0 (28)	6.3(39)	10.6(113.5)	65.7
Pretilachlor	750	3	3.5 (12)	3.9 (15)	3.4(11)	6.0(36.4)	89.0
Butachlor	1500	3	3.8 (14)	4.7 (22)	4.2(17)	6.9(48.5)	85.3
Oxadiargyl	100	3	7.4 (55)	6.3 (40)	5.5(30)	11.5(131.8)	60.0
Pyrazosulfuron	20	3	4.0 (16)	4.5 (20)	4.4(19)	7.6(57.5)	82.6
Fenoxaprop-p-ethyl	56.25	25	5.9 (35)	7.0 (49)	5.8(33)	11.2(125.0)	62.2
Weedy check			13.0 (170)	9.8 (95)	9.1(82)	18.2(330.5)	-
Weed free			0.7 (0)	0.7 (0)	0.7 (0)	0.7(0)	100
LSD (P=0.05)			1.0	1.1	1.0	1.7	-

Values are square root $\sqrt{x + 0.5}$ transformed and actual values are given in parentheses; DAT: Days after transplanting

Table 2. Effect of weed control treatments on yield attributes and yield in transplanted rice

Treatment	Dose (g/ha)	Time of application (DAT)	No. of panicles/m^2	No. of filled grains/ panicle	No. of unfilled grains/ panicle	1000-grain weight (g)	Grain yield (t/ha)
Bispyribac-sodium	25	20	310	157	14	24.8	6.40
Bispyribac-sodium	25	25	297	152	16	24.6	6.29
Bispyribac-sodium	30	20	324	162	12	24.9	6.55
Bispyribac-sodium	30	25	301	153	15	24.7	6.33
Azimsulfuron	30	20	283	146	18	24.7	6.15
Azimsulfuron	30	25	260	133	24	24.4	5.59
Azimsulfuron	40	20	288	149	17	24.7	6.20
Azimsulfuron	40	25	280	145	19	24.6	6.09
Pretilachlor	750	3	329	164	10	24.9	6.60
Butachlor	1500	3	322	162	13	24.9	6.54
Oxadiargyl	100	3	270	138	22	24.4	5.87
Pyrazosulfuron	20	3	315	160	13	24.8	6.38
Fenoxaprop-p-ethyl	56.2	25	275	142	21	24.5	6.02
Weedy check	-	-	220	120	30	23.8	4.04
Weed free	-	-	330	165	10	25.0	6.64
LSD (P=0.05)	-	-	28	8	4	0.5	0.27

DAT: Days after transplanting

post-emergence application of bispyribac 25 g/ha. Angiras and Kumar (2005) also found that broadcast application of pyrazosulfuron at 15 g/ha mixed with sand at 150 kg/ha resulted in significantly lower weed density and biomass without any phytotoxic effect on rice plants.

Post-emergence application of azimsulfuron was found to be less effective as grass weed population especially *E. crusgalli* and *E. colona* was higher. Yadav *et al.* (2008) reported lower dry weight of broad-leaf weeds under all the treatments of azimsulfuron.

Effective tillers/m^2, filled grains/panicle, 1000-grain weight and grain yield were influenced significantly by weed control treatments. Weed free treatment resulted in significantly highest yield attributes and yield, though at par with pretilachlor 750 g/ha (3 DAT), butachlor 1500 g/ha (3 DAT), bispyribac-sodium 25 and 30 g/ha (20 DAT) and pyrazosulfuron 20 g/ha (3 DAT) treatments. These treatments were also found equally effective in reducing unfilled grains per panicle. Similar results of bispyribac-sodium were registered by Yadav *et al.* (2009), Nalini *et al.* (2012), Veeraputhiran and Balasubramanian (2013).

Pre-emergence application of butachlor at 1500 g/ha, pretilachlor 750 g/ha, pyrazosulfuron at 20 g/ha or post-emergence herbicide bispyribac-sodium at the rate of 25 g/ha at 20 DAT could be suitable and economical herbicidal weed management option for transplanted rice to achive higher productivity.

SUMMARY

The experiment was conducted at the Students' Farm of College of Agriculture, CCS Haryana Agricultural University, Kaul (Kaithal) during *Kharif* 2008. The experiment consisted of fifteen treatments in block design with three replications. Thirty days old seedlings were transplanted on 3rd July, 2008 manually at a spacing of 20 x 15 cm with two seedlings per hill. The crop was raised with recommended fertilizer dose. Pre-emergence application of butachlor at 1500 g/ha, pretilachlor 750 g/ha, pyrazosulfuron at 20 g/ha or post-emergence herbicide bispyribac-sodium at the rate of 25 g/ha at 20 DAT could be suitable and economical herbicidal weed management option for transplanted rice to achive higher productivity.

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Short communication

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Effect of mechanical weeding in System of Rice Intensification and its adoption

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Rice is the staple food crop of India and the demand for rice is growing every year. To sustain the food self sufficiency and to meet the future demand, rice production should be increased. At present non-availability of labour, escalating input cost coupled with water shortage leads to non-economic of rice cultivation. System of Rice Intensification (SRI) is a modern and alternative method of rice cultivation for reduced usage of seed, water and labour and to realize higher productivity. The concept of SRI includes transplanting young seedlings, carefully, singly and widely spaced with soil kept well aerated by mechanical weeding. Adoption of rotary or cono weeder use in SRI plays a significant role in improving growth, yield and also economics of rice. It also decides the number of labour needed, cost of weeding and rate of increase in yield. SRI was recently introduced and successfully demonstrated in different sub basins of Tamil Nadu. Alternate wetting and drying in SRI may provide conducive to excess weed growth which if not controlled in time may cause immense loss of grain yield. Therefore, an attempt was made to study the performance of SRI with conventional method of rice cultivation and also to analyze the effect of rotary weeding in the Manimuthar sub basin area of Tamil Nadu State.

Eighteen on-farm demonstrations on System of Rice Intensification were carried out in ten hectares of farmers fields in Nagavayal, Kalllupatti, Karungalakudi, Vanjipatti, Kamboor, Alangampatti in Sivagangai and Madurai districts of Tamil Nadu from October 2010 to February 2011 under Tamil Nadu-Irrigated Agriculture Modernization and Water Bodies Restoration and Management Project (TN–IAMWARM) to study the effect and adoption level of rotary weeding on yield of rice under SRI. Two methods of rice cultivation, *viz.* SRI and conventional planting were compared. In SRI, the concepts, *viz.* lesser seed rate of 7.5 kg/ha raised in 100/m^2 mat nursery, transplanting of 14 days old seedlings at 25 x 25 cm spacing, irrigating 2.5 cm depth of water after hair line crack formation up to panicle initiation and after that one day after disappearance of ponded water with 5.0 cm water and weeding using rotary weeder at 10, 20, 30 and 40 days after transplanting (DAT) were followed. In conventional method of rice cultivation, use of a seed rate of 30-60 kg/ha in 800 m^2 nursery area, seedling age 21-30 days with a spacing of 15 x 10 to 20 x 10 cm, irrigation to 5 cm depth one day after disappearance of ponded water and manual weeding twice at 20 and 40 DAT were practiced. Fertilizer applications were followed as per the blanket recommendation of 150: 50:5 0 NPK kg/ha. The information on number of rotary weeding carried out by each farmers was collected and documented. The biometric observation on yield attributes and grain yield were recorded and economics were also worked out.

The grain yield of rice was substantially influenced by methods of rice cultivation (Table.1). System of Rice Intensification registered a mean grain yield of 6.063 t/ha, where as conventional method recorded only 5.42 t/ha. Thus, averaging over locations, SRI out yielded 11.06% than conventional method of rice cultivation. The average yield increment by four times, thrice and twice rotary weeding under SRI over conventional method were 24.1, 15.4 and 8.5%, respectively. The higher yield under SRI might be due to the rotary weeding which favoured better aeration, cut the older roots and formation of newer roots which might have absorbed more nutrients in turn leads to higher nutrient uptake. Veeraputhiran *et al.* (2008) also obtained 23.1% yield improvement under SRI than farmers practice in Tamirabarani Command areas in Thirunelveli district of Southern Tamil Nadu. At Mandya of Karnataka state, four time cono weeding recorded significantly higher grain yield than twice cono weeding (Ramachandra *et al.* 2012). Similarly, Kavitha and Raja (2012) also found significantly higher grain yield with thrice cono weeding than once cono weeding. Chaudhary *et al.* (2012) observed comparable grain yield with thrice and twice cono weed-

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ing of rice under SRI at PUSA, Bihar. The higher yield under rotary weeding was also due to improving the growth and functioning of root systems and enhanced diversity of soil biota that contributed to crop health and productivity as reported by Stoop *et al.* (2002).

The total cost of weeding by the SRI and conventional method of rice cultivation is given (Table 1). Increasing the number of rotary weeding increased the cost of weeding in SRI. Irrespective of the time of weeding, the cost of weeding under SRI was lesser than that of conventional method of rice cultivation. Adoption of SRI drastically reduced the cost of weeding by ` 2,534 /ha than that of conventional method of rice cultivation.

The adoption of rotary weeder by the individual farmer under SRI method of cultivation is furnished (Table 1). Of the total 18 farmers, 8 farmers practiced rotary weeding thrice, 6 twice and 2 once. The percentage of adoption of thrice and twice rotary weeding was 44.5 and 33.3% of farmers The lowest of only 2 farmers which is equal to 11.1% farmers carried out four times as per recommendation and once rotary weeding each. The differential pattern of using rotary weeder among the farmers was due to their attitude, education level, adoption behavior *etc*.

The economic feasibility of two methods of rice cultivation (Table 2) revealed that the cost of cultivation was comparatively lesser in SRI than that of farmers' practice. The mean cost of cultivation under SRI

Table 1. Adoption level, cost of weeding and grain yield under SRI and conventional rice cultivation

Number of rotary weeding	Number of farmers adopted	% of farmers adopted	Cost of weeding (x10^3 `/ha)		Grain yield (t /ha)	
			SRI	Conventional	SRI	Conventional
Four times (recommended)	2	11.1	4.30	5.95	7.05	5.68
Thrice	8	44.5	3.24	5.57	6.39	5.53
Twice	6	33.3	2.82	5.47	5.72	5.27
Once	2	11.1	1.60	5.10	5.09	5.35
Total /Mean	18	100	2.99	5.52	6.06	5.42

Table 2. Comparison of economics of SRI and times of rotary weeding with conventional method of rice cultivation

Particulars	Four times rotary weeding		Thrice rotary weeding		Twice rotary weeding		Once rotary weeding		Mean	
	SRI	Conv.	SRI	Conv.	SRI	Conv.	SRI	Conv.	SRI	Conv.
Cost of cultivation (x10^3 `/ha)	27.40	29.25	26.57	28.52	26.38	28.73	25.31	27.90	26.40	28.60
Gross income (x10^3 `/ha)	70.50	56.60	63.90	55.45	57.22	52.72	50.90	53.50	60.63	54.57
Net income (x10^3 `/ha)	43.10	27.35	37.39	26.92	30.83	23.98	25.59	25.60	34.23	25.96
Additional net income by SRI (x10^3 `/ha)	15.75	-	10.46	-	6.85	-	-	-	11.02	-
Benefit – cost ratio	2.56	1.93	2.32	1.93	2.10	1.83	2.01	1.91	2.25	1.90

was ` 26,398/ha as against ` 28,602 /ha under conventional method and thus adoption of SRI was found to reduce the cost of cultivation by ` 2,204 /ha. In addition, higher gross income and net income were also associated with SRI than conventional method of rice cultivation. Averaging over locations, SRI registered a mean net income of ` 34,230 /ha as compared to ` 25,964 /ha only under conventional method. Higher BC ratio was also associated with SRI (2.25) than conventional method (1.90). Lesser cost of cultivation coupled with higher gross and net income under SRI resulted additional economic benefit over farmers practice. Adoption of SRI gained an additional net profit of ` 11,021/ha as compared to conventional method of rice cultivation. The economic superiority of SRI as compared to farmers practice of rice cultivation was documented by Veeraputhiran *et al.* (2010).

The rate of increase in income benefits were higher with increasing the number of rotary weeding. The average increment of net income by four, thrice and twice times rotary weeding under SRI over conventional method of rice cultivation were ` 15,750/ha, 10,463/ha and 6,850/ha respectively. However, in one case rotary weeding was found uneconomical.

It can be concluded that adoption of SRI resulted 11.06 per cent higher yield, reduced weed management cost and better economic benefits which will pave way for sustainable rice production and higher standard of living of the farming community of the Manimuthar sub basin study area. In addition, weeding either by rotary or cono weeder by minimum three times is essential for getting higher rice productivity under SRI.

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SUMMARY

Eighteen on-farm demonstrations on System of Rice Intensification (SRI) were carried out in ten hectares of farmers fields in Sivagangai and Madurai districts of Tamil Nadu from October 2010 to February 2011 under Tamil Nadu-Irrigated Agriculture Modernization and Water Bodies Restoration and Management Project (TN–IAMWARM) to study the effect and adoption level of rotary weeding on yield of rice under SRI. The results revealed that SRI registered a mean grain yield of 6.06 t /ha against 54.2 t /ha under conventional method of rice cultivation. SRI yielded 11.06 per cent higher grain yield than conventional method. The number of rotary weeding also decides the rate of yield increase in SRI. The average yield increment by four, thrice and twice rotary weeding under SRI over conventional method were 24.1, 15.4 and 8.5 per cent, respectively. Among the total farmers, only 11.1 per cent farmers perfectly carried out four times rotary weeding as per recommendation. The percentage of farmers adopted thrice, twice and single rotary weeding were 44.5, 33.3 and 11.1 per cent, respectively. Adoption of SRI drastically reduced the cost of weeding as evident due to ` 2, 534 /ha lesser weed management cost under SRI (` 2989 /ha) than conventional method of rice cultivation (` 5, 523/ha). The cost of cultivation was comparatively lesser in SRI which resulted in gaining an additional net profit of ` 11, 021 /ha as compared to conventional method of rice cultivation.

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Short communication

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Effect of post-emergence herbicides on weeds and productivity of wheat

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Key words: Herbicides, Wheat, Yield, Yield attributes

Wheat (*Triticum aestivum* L.) is second most important staple crop after rice. It is predominant *Rabi* season crop of northern, central and upper peninsular region of the country. Among the various factors responsible for low productivity of wheat, weed infestation during early stages of growth is one of the major factors. Due to initial slow growth, it provides a congenial environment for weed growth. In wheat generally, first 30 to 40 days are highly critical from the point of crop weed competition. Mechanical weeding is costly, time consuming and sometimes not possible due to non-availability of labour. Under such a situation, chemical weed control offers a better alternative to manual weeding during early stage. Since, meagre information is available on the comparative efficiency of different herbicides for weed control, weeds before critical period of crop–weed competition.

An experiment was conducted during *Rabi* season of 2010-11 at Agronomy Farm, College of Agriculture, Pune. The experiment was laid out in randomized block design with three replications. The soil of the experimental field was clayey loam and low in total nitrogen, medium in available phosphorus and high in potassium. The ten treatments comprised different weed control methods, *viz*. T_1- One hand at 20 DAS and one hoeing at 40 DAS, T_2- Isoproturon 1000 g/ha at 30 DAS, T_3- Isoproturon at 750 g/ha + 2,4-D 563 g/ha at 30 DAS, T_4– Sulfosulfuron 22 g/ha at 30 DAS, T_5– Sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha at 30DAS, T_6– Metsulfuron methyl 6 g/ha at 30 DAS, T_7- Metsulfuron methyl 4.5 g/ha + 2,4-D 563 g/ha at 30 DAS and T_8- 2, 4-D 750 g/ha at 30 DAS T_9– Unweeded control, T_{10}- Weedy free check. The crop was fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha. A full dose of phosphorus and potassium were applied as a basal application. The nitrogen was applied in two splits, ½ at sowing and ½ at after first irrigation (22 DAS). As per the treatments, post-emergence herbicides were sprayed at 30 DAS through knapsack sprayer with flat fan nozzle using 500 litres of water per ha. The variety Triambak was sown at 22.5 cm apart by using seed rate of 125 kg/ha.

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The data with respect to weed population/m^2, dry matter of weed, weed control efficiency and weed index as affected by different treatments are represented in Table 1. The unweeded control registered significantly higher weed population (4.1/m^2) and dry matter of weeds *i.e.* 18.4 g/m^2 due to resulting from the luxuriant growth of the weeds in absence of any weed control treatments. Among the weed control treatments, application of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha registered significantly lower weed population (7.6/m^2) and dry matter of weeds (3.1 g/m^2) than rest of the treatments. It was closely followed by treatment T_7 *i.e.* metsulfuron-methyl 4.5 g/ha + 2,4-D 563 g/ha and T_4 *i.e.* application of sulfosulfuron 22 g/ha. The significantly lower weed population and dry matter of weed in application of sulfosulfuron at 16.5 g/ha + 2,4-D 563 g/ha might be due to excellent efficacy against all grassy and non-grassy type of weeds. Kumar *et al.* (2003) found that sulfosulfuron reduced total population and dry weight of various grass and broad leaved weeds and it might be due to reduced weed population, which resulted lower dry matter of weeds. Bharat and Kacharoo (2010) observed that tank mix application of sulfosulfuron + 2,4-D (25 + 500 g/ha) or alone sulfosulfuron (25 g/ha) reduced the weed population.

The data presented in Table 1, revealed that spraying of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha) observed significantly more weed control efficiency of 81.27% than rest of the treatments. The application of 2,4-D alone (T_8) showed statistically lower weed control efficiency (54.92%) than other herbicidal treatments. The statistically highest weed index was observed under unweeded control (34.90%) than rest of the treatments. Among weed control treatments, application of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha resulted into statistically lowest weed index (7.84%), however, it was at par with treatment T_7 (metsulfuron methyl 4.5 g/ha + 2,4-D 563 g/ha) and T_6 (sulfosulfuron 22 g/ha). The significantly highest weed index observed in unweeded control treatment (34.90%), indicating more yield reduction due to more weed competition and unchecked weed growth. Pandey *et al.* (2005) reported that sulfosulfuron (25 g/

Table 1. Mean weed population, dry matter weed control efficiency and weed index as influenced by different treatments

Treatment	Weed population/m^2	Weed dry matter (g/m^2)	WCE (%)	Weed index (%)
T_1- One hand weeding at 20 DAS and one hoeing at 40 DAS	3.2* (10.0)**	4.7	60.2 (75.35)	16.4
T_2- Isoproturon 1000 g/ha at 30 DAS	3.8 (14.6)	6.4	53.1 (64.03)	18.6
T_3- Isoproturon 750 g + 2,4-D 563 g/ha at 30 DAS	3.9 (15.0)	6.8	52.6 (63.04)	18.4
T_4- Sulfosulfuron 22 g/ha at 30 DAS	3.3 (10.6)	4.7	59.3 (73.89)	12.3
T_5- Sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha at 30 DAS	2.8 (7.6)	3.1	64.4 (81.27)	7.8
T_6- Metsulfuron-methyl 6 g/ha at 30 DAS	3.4 (11.0)	5.1	58.6 (72.88)	14.3
T_7- Metsulfuron-methyl 4.5 g + 2,4-D 563 g/ha at 30 DAS	3.2 (9.6)	3.5	60.9 (76.34)	11.9
T_8- 2,4-D 750 g/ha at 30 DAS	4.3 (18.3)	6.4	47.8 (54.92)	20.0
T_9- Unweeded control	6.4 (40.6)	18.4	0	34.9
T_{10}- Weed free check	0.7 (0.0)	0.0	90.0 (100)	0.0
LSD (P=0.05)	0.1	0.4	1.36	5.57

*Transformed values ($\sqrt{x+0.5}$); **Original values

Table 2. Mean length of spike, number of spikelets/spike, number of grains/spike, grain weight/plant and thousand grain weight, grain and straw yield as influenced by different treatments

Treatment	Length of spike (cm)	No. of spikelets /spike	No. of grains /spike	Grain weight /plant (g)	1000 - seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
T_1- One hand weeding at 20 DAS and one hoeing at 40 DAS	8.4	15.7	40.2	7.2	39.1	4.0	5.6
T_2- Isoproturon 1000 g/ha at 30 DAS	7.8	14.7	38.9	6.3	37.8	3.9	5.0
T_3- Isoproturon 750 g + 2,4-D 563 g/ha at 30 DAS	8.1	15.2	39.9	7.1	38.5	3.9	5.1
T_4- Sulfosulfuron 22 g/ha at 30 DAS	8.4	15.5	42.0	7.5	38.7	4.2	5.7
T_5- Sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha at 30 DAS	8.6	16.4	44.9	7.7	39.8	4.4	5.9
T_6- Metsulfuron-methyl 6 g/ha at 30 DAS	8.1	15.5	41.6	6.5	38.7	4.1	5.7
T_7- Metsulfuron-methyl 4.5 g + 2,4-D 563 g/ha at 30 DAS	8.4	15.8	42.1	7.5	39.3	4.3	5.8
T_8- 2,4-D 750 g/ha at 30 DAS	7.3	14.8	37.9	6.5	37.1	3.8	5.2
T_9- Unweeded control	6.3	13.5	34.3	5.2	35.5	3.1	4.5
T_{10}- Weed free check	9.2	17.5	46.8	8.3	41.5	4.8	6.5
LSD (P=0.05)	0.4	1.1	2.4	0.5	1.5	0.28	0.46

ha) was reduced significant weed count compared with hand weeding and mixture of 2,4-D + isoproturon (0.4 + 0.6 kg/ha) and also recorded highest weed control efficiency, which may be due to broad spectrum control of both narrow and broad leaved weeds.

The yield attributes presented in Table 2 were differed significantly by various weed control treatments. The statistically higher yield attributes, *viz.* length of spike, number of spikelets/spike, number of grains/spike, grain weight/plant and thousand seed weight were recorded in weed free check than rest of the weed control treatments except treatment T_7, where, it was found at par for number of grains/spike. The application of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha statistically outyielded the length of spike and grain weight/plant than T_3, T_2 and T_8 however, it was at par with treatments T_1, T_4 and T_7. The same treatment (T_5) also registered statistically higher number of spikelets/spike (16.4) than T_3, T_8, T_2 and T_9, however, it was at par with treatments T_7, T_1, T_4 and T_6. The number of grains/spike was statistically higher with T_{10} and it showed significant superiority over all other treatments except T_7 where it was at par. The application of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha (T_5) showed its significant superiority over rest of the treatments and it was found at par with treatments T_1, T_7, T_6, T_4, and T_3 for thousand seed weight. The statistically minimum values of yield attributes were obtained in unweeded control (T_9). It could be seen from the data in Table 2 that weeds free check (T_{10}) produced maximum grain yield (4.8 t/ha) and straw yield (6.5 t/ha), which were significantly superior over rest of the treatments. Among the weed control treatments, the best treatment was T_5 *i.e.* spraying of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha, which recorded maximum grain and straw yield. Whereas, unweeded control (T_9) observed significantly the lowest grain and straw yield than rest of the treatments.

The increase in yield attributes might be because of less weed competition, significant reduction in weed population and weed biomass which may be enhanced N, P and K uptake by crop besides efficient use of moisture, space and light thereby resulting in significant increase in yield attributes over unweeded control plots. It has been observed that sulfosulfuron is a broad spectrum herbicide, which controlled both grassy and broadleaved weeds, while, 2,4-D also controlled dicot weeds effectively. Bharat and Kachroo (2010) studied the bioefficacy of herbicides in wheat and revealed that application of sulfosulfuron + 2,4-D produced significantly higher effective tillers/m^2 (66.25), grains/ear (61.67), grain yield (4.78 t/ha) and straw yield (8.45 t/ha) than application of metsulfuron methyl (4 g/ha) and 2,4-D alone (750 g/ha) and unweeded control. The results are conformity with the findings of Bisen *et al.* (2006), Kumar *et al.* 2001, Saini and Angiras (2005), Singh *et al.* 2002, Singh *et al.* (2010) and Yadav *et al.* (2008).

SUMMARY

A field experiment was conducted during *Rabi* season of 2010-11 at College of Agriculture, Pune to study the effect post-emergence herbicides on weeds and productivity of wheat. Among the weed control treatments, application of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha registered significantly lower weed population (7.6/m^2), dry matter of weeds (3.1 g/m^2) and significantly more weed control efficiency of 81.27% than rest of the treatments. The same treatment recorded lowest value of weed index. The values of yield attributes were higher in magnitude in weed free check treatment. Among the herbicide treatments, post-emergence application of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha recorded higher values of yield attributes, *viz.* length of spike, number of spikelets/spike, number of grains/spike, grain weight/plant and thousand seed weight. Amongst the weed control treatments, application of sulfosulfuron 16.5 g/ha + 2,4-D 563 g/ha recorded maximum grain and straw yield of 4.4 and 5.9 t/ha, respectively as compared to other treatments.

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Short communication

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Comparative efficacy of quizalofop-ethyl against weeds in groundnut

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Groundnut production is as high as 35,367 MT in world, the production in India is about 5,500 MT which is traceable to weed infestation (www.cnagri.com). Unmanaged weeds from groundnut crop results in yield loss as high as 60% to 80% Ikisan (2000). In groundnut, less crop canopy during the first 6 weeks of crop growth favours strong competition with weeds causing significant reduction in yield. Therefore, timely and effective weed control during this critical period of crop weed competition become necessary for attaining maximum yield (Etejere *et al.* 2013).

Manual weeding which is the age long practice for weed control in this crop is very laborious, time consuming and expensive most importantly when there is dearth of manpower. Use of chemical herbicides is the best possible alternative over the manual weeding and inter culture operations. It has also been recommended that there should be no intercultural operations applied at pegging stage of the crop (45 days after sowing). Chemical herbicide and cultural methods are effective to control the weeds in groundnut crop (Patel *et al.* 1997). Hence, the application of post-emergence herbicides shall be more useful in controlling the weeds. The present study aimed to find out the effective and economic use of post emergence herbicides to control the grassy weeds in groundnut crop.

A field experiment was conducted during *Kharif* season of 2012 at Norman E. Borlaug, Crop Research Center of GBPUA&T, Pantnagar to evaluate the efficacy of quizalofop-ethyl at various doses as sponsor sample (SS) over the available market sample (MS) against the complex weed flora in groundnut under foothill of Uttarakhand state. Sowing of groundnut variety "*Chandra*" was done manually on June 28, 2012 with a row spacing of 30 cm apart. The experiment was laid out in randomized block design with three replication. The seven weed control treatments consisted of two different doses of (quizalofop-ethyl) sponsor sample (SS) as well as market sample (MS) 5% EC applied at 37.5 and 50 g/ha, imazethapyr 10% SL at 150 g/ha as standard check, weed free and weedy check were maintained till harvest. Post-emergence application of herbicides (imazethapyr and quizalofop-ethyl) were applied uniformly at 20 DAS (days after sowing) by using a spray volume of 500 L/ha with the help knapsack sprayer fitted with flat fan boom nozzle. The crop was fertilized with 20:30:45 kg NPK, respectively. Total weed density and dry matter accumulation of weeds were recorded at 45 DAS. Weed control efficiency, weed persistence index and herbicide efficiency index were determined as per Walia (2003). Regression analysis was also carried out between grain yield weed control efficiency at 45 DAS. The data were analyzed following analysis of variance (ANOVA) technique and mean separation were adjusted by the multiple comparison test (Gomez and Gomez 1984).

The most dominant grassy weed species found in the weedy plots were *Echinochloa colona*, *Eleusine indica*, *Panicum maximum*, *Digitaria sanguinalis* and *D. aegyptium*. Among broad-leaf weeds, *Parthenium hysterophorus*, *Mollugo stricta*, *Digera arvensis*, *Phyllanthus niruri* and *Commelina benghalensis* were more rampant.

Result revealed that all the weed management practices significantly reduced the density of weeds over the weedy check. Application of quizalofop-ethyl applied sponsor sample (SS) and market sample (MS) at 50 g/ha were at par with each other and showed its superiority in suppressing the density of weeds, which was lesser than rest of the weed mangement practices (Table 1). Quizalofop-ethyl (MS and SS) at 50 g/ha resulted into significantly less population of grassy weeds over rest of the herbicidal treatments. These results were in conformity with Dixit *et al.* (2012). The application of quizalofop-ethyl at either level of its application did not have any effective control on broad-leaved weeds (BLWs). However, application of imazethapyer at 150 g/ha were found significant in reducing the density of broad-leaved weeds compared to weedy check. Imazethapyr was found less effective

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Table 1. Effect of quizalofop-ethyl on density, biomass and impact indices of groundnut at 45 DAS

Treatment	Dose (g/ha)	Weed density no./m^2		Total weed dry weight (g/m^2)	WCE (%)	Weed persistence index	Herbicide efficiency index
		Grassy weeds	Broad-leaved weeds				
Quizalofop-ethyl	37.5	(2.6) 1.8	(50.8) 7.2	(86.0) 9.3	77.7	0.59	13.5
Quizalofop-ethyl	50.0	(0.0) 1.0	(49.4) 7.1	(54.1) 7.4	86.0	0.39	24.6
Quizalofop-ethyl	37.5	(2.6) 1.8	(49.3) 7.1	(88.7) 9.5	77.1	0.59	15.7
Quizalofop-ethyl	50.0	(0.0) 1.0	(45.3) 6.8	(62.5) 7.9	83.8	0.46	20.0
Imazethapyr	150	(82.7) 9.1	(8.0) 3.0	(197.6) 14.1	48.8	1.05	6.7
Weed free check	-	(0.0) 1.0	(0.0) 1.0	(0.0) 1.0	100.0	0.0	0.0
Weedy check	-	(113) 10.2	(57.5) 7.6	(386) 19.6	0.0	1.0	0.0
LSD (P=0.05)	-	0.9	0.8	1.8	-	-	-

towards the density of grassy weeds due to the higher population of *E. indica* which was not controlled by the application of imazethapyr.

Better response of quizalofop-ethyl in controlling grassy weeds might be due to the fact that aryloxyphen-oxpropionates (AOPP) class to which the herbicide belongs is readily absorbed translocated to meristemaitic region and excert herbicide activity. It acts by inhibiting the enzyme Acetyl Coenzyme carboxylase (ACCase) in susceptible species (Burton 1997). Acetyl coenzyme catalyzes, the first commited step of biosynthesis, is adenosine triphosphate depented carboxylation od acetyl CoA to malonyl CoA. Narrow leaved weeds have a eukaryotic type ACCase in the chloroplast which is sensitive to ACCase inhibitors. Whereas most broad-leaved weed species have a prokaryotic type ASsase which is not sensitive to ACCase inhibitor (Incledon and Hall 1997). Among the tested herbicides, quizalofop-ethyl (MS and SS) at 50 g/ha was found most effective to check all the types of grassy weeds and their growth resulting in lowest biomass in these treatments compared to standard check, imazethapyr 150 g/ha. The efficiency of various treatments with respect to weed control efficiency fluctuated to a greater extent under the influence of various weed control treatments being highest with application of quizalofop-ethyl (SS) at 50 g/ha.

Weed control measures brought about measurable improvement in yield and yield attributes of groundnut over the weedy check. Higher number of pods/plant (no. per plant) and kernel/pod were recorded with application quizalofop-ethyl 5% EC (SS) at 50 g/ha and remained at par with its lower dose applied at 37.5 g/ha. Weed free treatment recorded significantly highest kernel yield in groundnut followed by quizalofop-ethyl 5% EC (SS) at 50 g/ha. The results generated gains support from the other reports (Solanki *et al*. 2005). Among all the herbicide treated plot, the maximum kernel yield of groundnut was obtained with application of quizalofop-ethyl 5% EC (SS) at 50 g/ha which was at par with its market sample applied at same dose and minimum value was associated with weedy plot and post-emergence application of imazethapyr at 150 g/ha. Imazethapyr failed to performed better towards the grain yield because of higher population of *E. indica*. Among all the tested herbicides, lowest weed index (32.7%) was recorded with the application of quizalofop-ethyl 5% EC (SS) at 50 g/ha resulting in 77% increase in kernel yield of groundnut over weedy check.

The effective control of weeds starting from the early crop growth and development stage might have resulted in better kernel yield of groundnut. The variation in kernel yield under different treatments was the results of variation in weed density and weed biomass. Kernel yield and weed control efficiency were positively

Table 2. Effect of quizalofop-ethyl on yield and economics of groundnut

Treatment	Dose g/ha	Pods (no./plant)	Kernel/pod	Kernel yield (t/ha)	Weed index (%)	Net profit ($x10^3$ `/ha)	B:C ratio
Quizalofop-ethyl	37.5	10.6	1.55	0.88	39.4	11.07	0.33
Quizalofop-ethyl	50.0	10.7	1.53	0.98	32.7	15.55	0.46
Quizalofop-ethyl	37.5	10.4	1.52	0.86	41.3	9.72	0.29
Quizalofop-ethyl	50.0	10.5	1.51	0.92	36.7	12.70	0.38
Imazethapyr	150	9.0	1.47	0.78	46.3	5.48	0.16
Weed free check	-	13.5	1.60	1.46	0.0	36.95	1.03
Weedy check	-	6.4	1.32	0.22	84.9	-21.00	-0.66

SS:sponsor sample, MS :market sample

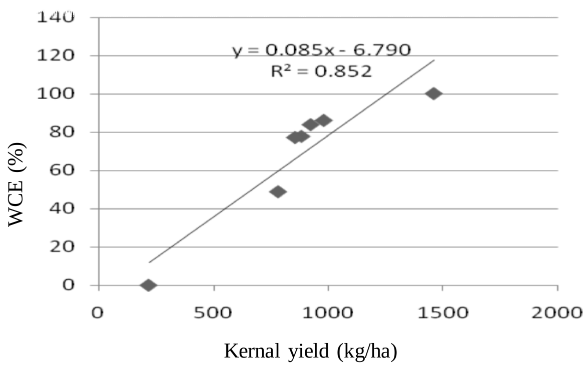

Fig. 1. Relationship between grain yield and weed control efficiency

correlated (Fig. 1). Kernel yield of groundnut increased linearly with increase in weed control efficiency. Grain yield increased from 1000 to 1500 kg/ha as weed control efficiency increased from 60 to 100%. Among the herbicidal treatments, the highest net return and BCR (benefit : cost ratio) were recorded with application of quizalofop-ethyl 5% EC (SS) at 50 g/ha, which was comparable with its market sample applied at 50 g/ha and both of them were higher with rest of the weed control treatments (Table 2) might be due to achieving higher yield. Weedy check had a negative value for the net returns and B:C ratio which depicted groundnut to be unprofitable without effective weed control.

Therefore, application of quizalofop-ethyl 5% EC (sponsor sample) at 50 g/ha proved to be effective and a profitable alternative to the existing recommendation for groundnut under the subtropical region of Uttarakhand.

SUMMARY

A field experiment was conducted at Norman E. Borlaug, Crop Research Center GBPUA&T, Pantnagar to evaluate the efficacy of quizalofop-ethyl market sample (MS) and sponsor sample (SS) in managing grassy weed flora in groundnut. Result revealed that that application of quizalofop-ethyl 5% EC (SS) at 50 g/ha resulted in significantly higher kernel yield (0.98 t/ha) which was at par with its market sample applied at the same dose. Density and dry matter accumulation of weeds was also minimum by the application of these herbicides. However the highest kernel yield was obtained under the weed free situation. Lower weed density, weed dry weight, weed persistence index and weed index in the plots where quizalofop-ethyl (SS) at 50 g/ha was applied. Higher weed control efficiency and herbicidal efficiency index, economic return were recorded under quizalofop-ethyl 5% EC (SS) at 50 g/ha as compared to standard check imazethapyr 150 g/ha. Thus, the post-emergence application of quizalofop-ethyl 5% EC (SS) at 50g/ha seemed to be more beneficial with high productivity and economic return owing to effective weed control.

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Pre- and post-emergence herbicides for weed management in mungbean

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Key words: Herbicides, Microbial population, Phytotoxicity, Post-emergence, Pre-emergence

Mungbean is recommended for cultivation mainly in *Kharif* season under Vidarbha condition in Maharastra, India. Weed management is an important factor for enhancing the productivity of mungbean as weeds compete for nutrients, water, light and space with crop during early growth period. Yield losses in mungbean due to weeds have been estimated to range between 30-50% (Kumar *et al.* 2004). Mechanical practices such as hand weeding and inter -culturing are effective but unavailability of labour and incessant rains during the early crop season normally limit the weeding operations. Therefore, chemical weeding under such circumstances become indispensible and can be the excellent alternate. Pendimethalin is only recommended pre-emergence herbicides in mungbean, however, peasants could not find time to apply it during the same day or next day due to busy shedule in sowing operation. This warrants the use of pre- and post-emergence herbicides for weed control. The present study was, therefore, conducted to evaluate the effect of different herbicides for mungbean, which can be cost effective and acceptable to the growers of this crop.

A field experiment was carried out at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the *Kharif* season to see the effect of post-emergence herbicides *viz*. imazethapyr 10 EC, quizalofop-ethyl 10 EC, fenoxoprop-ethyl 10 EC, imazethapy 35 EC + imazamox 35 EC and pre-emergence pendimethalin 30 EC and pendimethalin 2 EC + imazethapyr 30 EC on growth and yield of mungbean cultivar *'PKV Green Gold* (*AKM-9911*)'. The soil of experimental site was clayey with pH 7.8, having available N 235 kg/ha, available P 20.9 kg/ha, available K 323 kg/ha and OC 0.41 %. The experiment was laid out in randomized block design having three replications. All the herbicides alone or in combination were applied 20 days after sowing (DAS) with knapsack sprayer fitted with flat-fan nozzle using 500 litre water/ha. Mungbean seed was treated with carrier based *Rhizobium* and PSB, each at the rate of 2.5 g per kg seed and mixed well to ensure the inoculums to stick on to the surface of the seeds. The N and P through urea and diammonium phosphate were applied as basal at sowing. Serial dilution plate technique was used for isolation and enumeration of soil fungi, actinomycetes and bacteria as described by Pahwa *et al.* (1996).The crop was sown on 20 June 2010 and was harvested on 3 September 2010. The total rainfall received during the crop growth was 552.3 mm in 28 rainy days during 2010. The required plant population (30 cm row to row and 10 cm plant to plant) was maintained by thinning plants after three weeks of sowing.

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Weed flora

The weed flora emerge during the period of experimentation were grasses like, *Dactylectinum aegyptium*, *Echinochloa colona* and *Bracharia* sp., sedges like *Cyperus rotundus* and broad-leaved weeds like *Commelina diffusa*, *Amaranthus viridis*, *Digeria arvensis*, *Parthenium hysterophorus* and *Phyllanthus niruri*.

Among herbicides and cultural methods of weed control, application of imazethapyr at 1.0 kg/ha and 0.075 kg/ha at 20-25 DAS followed by HW twice recorded lowest dry weight of weeds at all the growth stages. However, imazethapyr was effective against annual broad-leaf weeds like *Commelina diffusa*, *Amaranthus viridis*, *Digeria arvensis*, *Parthenium hysterophorus* and grassy weeds like *Bracharia* sp. *Echinochloa colona*, perennial sedge like *Cyperus rotundus*. The highest total weed dry matter production (25.18 g/m^2) at 30 DAS was recorded in weedy check plots; whereas, the lowest total weed biomass was recorded with the HW twice (1.34 g/m^2) which was closely followed by application of imazethapyr at 1.0 kg/ha at 20-25 DAS (5.64 g/m^2), imazethapyr at 0.075 kg/ha (7.16 g/m^2) (Table 2). Higher weed control efficacy and long lasting effects of imazethapyr in reducing weed dry matter might be due to broad-spectrum activity of herbicides particularly on established plants of both narrow and broad-leaf weeds and its greater efficiency to retard cell division of meristems as a result of which weeds died rapidly.

Table 1. Grain yield, yield attributing characters and economics of mungbean as influenced by different weed management practices

Treatment	Grain yield (t/ha)	Plant height (cm)	Leaf area at 30 DAS (cm^2)	Root nodule /plant at 30 DAS	Pods/ plant	Test weight (g)	Cost of cultivation ($x10^3$ `/ha)	Net returns ($x10^3$ `/ha)	B:C ratio
Pendimethalin 1.0 kg/ha as PE	1.06	74.7	6.67	26.4	20.3	34.7	13.27	23.95	1.80
Pendimethalin + imazethapyr 0.75 kg/ha as PE	1.00	76.7	6.58	21.7	18.6	33.4	11.78	23.53	2.00
Pendimethalin + imazethapyr 1.0 kg/ha as PE	0.91	77.9	6.65	30.4	17.2	33.3	12.52	19.45	1.55
Quizalofop-ethyl 0.075 kg/ha at 20-25 DAS	1.01	75.4	7.48	27.0	18.7	33.2	14.02	21.29	1.52
Fenoxoprop-ethyl 0.075 kg/ha at 20-25 DAS	0.97	76.2	7.52	26.2	17.9	34.1	13.50	20.51	1.52
Imazethapyr + imazamox 0.075 kg/ha at 20-25 DAS	0.90	59.3	5.04	17.2	16.4	35.7	14.11	18.26	1.35
Imazethapyr + imazamox 1.0 kg/ha at 20-25 DAS	0.85	53.6	5.10	16.8	18.5	34.2	12.86	15.71	1.11
Imazethapyr 0.075 kg/ha at 20-25 DAS	1.19	74.7	7.82	17.9	24.0	37.5	13.27	28.78	2.24
Imazethapyr 1.0 kg/ha at 20-25 DAS	1.24	73.3	7.84	16.3	25.5	37.2	14.74	30.37	2.29
HW twice at 20 and 40 DAS	1.15	66.0	8.41	40.5	22.2	38.5	14.74	26.25	1.78
Weed free	1.27	75.9	7.71	35.4	21.2	38.8	11.14	29.73	2.02
Weedy check	0.53	78.9	6.21	35.4	12.8	31.2	11.14	18.08	1.62
LSD (P=0.05)	0.14	3.5	0.6	4.9	4.0	2.6	-	5.16	--

Effect on crop

The highest yield attributes, *viz.* branches/plant, pods/plant, grain weight/plant and test weight were recorded with the application of imazethapyr at 1.0 and 0.075 kg/ha at 20-25 DAS, respectively due to safer behaviour of herbicides against crop plants and phytotoxic effect on weeds. The data pertaining to test weight revealed that the HW twice and herbicides (pre- and post-emergence) had significant effect on test weight. The as highest test weight was recorded in plots maintained weed free and HW twice which was statistically at par with imazethapyr at 0.075 and 1.0 kg/ha. However, application of imazethapyr + imazamox at both the levels reduced the plant height, leaf area, branches/plant, pods/plant, pod length and grain weight/plant over remaining herbicides.

Application of pre- and post-emergence herbicides significantly reduce the nodulation, the degree of reduction was more with imazethapyr + imazamox at both the levels followed by pre-emergence application of pendimethlain and pemdimethalin + imazethapyr. The weed free treatment produced significantly maximum mungbean yield (1.27 t/ha) over remaining treatments except imazethapyr at 1.0 kg/ha at 20-25 DAS (1.24 t/ha) and hand weeding twice (1.15 t/ha). Higher seed yield of soybean was recorded due to effective control of weeds by imazethapyr at 1.0 kg/ha (Meena *et al.* 2011). However, pre-emergence application of pendimethalin at 1.0 kg/ha and pendimethalin + imazethapyr 0.75 kg/ha and 1.0 kg/ha, respectively, did not influenced grain yield. Higher weed control efficiency was observed with post-emergence application of imazethapyr at 1.0 kg (70.77%) followed by 0.075 kg/ha (67.74%) at 20-25 DAS, respectively. Weed index was computed as the yield reduction comparative to highest yielding treatment *i.e.* weed free. In case of weed management practices, hand weeding showed minimum weed index (9.21) followed by post-emergence application of imazethapyr at 1.0 kg/ha (1.89) and imazethapyr at 0.075 kg/ha (6.37). Post-emergence application of imazethapyr + imazamox at 1.0 kg/ha and 0.075 kg/ha recorded maximum weed index *i.e.* 32.97 and 28.64% respectively, indicating the reduction in mungbean grain yield due to presence of weeds throughout crop growth period.

Microbial population

Initially, after the herbicides treatment (15, 30 and at harvest) microbial counts was slightly less in pre-emergence application of pendimethalin and pemdimethalin + imazethapyr, reaching a maximum between 30 DAS and at harvest (Table 3). The toxic effect of herbicides normally appears immediately after the application when their concentration in the soil is highest. Later on, microorganism take part in degradation process and herbicide concentration and its toxic effect decreases (Radivojevic *et al.* 2004). The

Table 2. Effect of different weed management treatment on dry weight of weeds, weed control efficiency and weed index in mungbean

Treatment	Dry weight of weeds (g/m^2)		Weed control efficiency (%)	Weed index (%)
	30 DAS	At harvest		
Pendimethalin 1.0 kg/ha as PE	8.15	14.6	57.7	16.2
Pendimethalin + imazethapyr 0.75 kg/ha as PE	9.11	15.4	55.2	20.6
Pendimethalin + imazethapyr 1.0 kg/ha as PE	8.64	15.2	56.0	28.0
Quizalofop-ethyl 0.075 kg/ha at 20-25 DAS	16.1	14.0	59.2	19.9
Fenoxoprop-ethyl 0.075 kg/ha at 20-25 DAS	16.2	14.1	58.9	23.5
Imazethapyr + imazamox 0.075 kg/ha at 20-25 DAS	6.11	12.5	63.8	28.6
Imazethapyr + imazamox 1.0 kg/ha at 20-25 DAS	5.64	13.9	67.6	33.0
Imazethapyr 0.075 kg/ha at 20-25 DAS	7.16	11.1	67.7	6.37
Imazethapyr 1.0 kg/ha at 20-25 DAS	4.38	10.1	70.7	1.89
HW twice at 20 and 40 DAS	1.34	4.12	88.0	9.21
Weed free	1.13	3.13	90.9	0.0
Weedy check	25.1	34.5	0.0	57.9
LSD (P=0.05)				

Table 3. Microbial population at periodical growth stages as influenced by different weed management practices

Treatment	Bacteria (cfu ×10^7/g soil)			Fungi (cfu ×10^4/g soil)			Actinomycetes (cfu ×10^6/g soil)		
	Before sowing	30 DAS	At harvest	Before sowing	30 DAS	At harvest	Before sowing	30 DAS	At harvest
Pendimethalin 1.0 kg/ha as PE	15.1	22.3	38.8	14.8	20.8	31.1	10.2	17.7	26.7
Pendimethalin + imazethapyr 0.75 kg/ha as PE	15.2	22.2	38.7	14.6	20.8	31.9	10.3	17.3	26.7
Pendimethalin + imazethapyr 1.0 kg/ha as PE	15.5	22.1	38.7	14.6	20.8	31.2	10.3	17.1	26.5
Quizalofop-ethyl 0.075 kg/ha at 20-25 DAS	15.4	20.8	38.7	14.4	20.1	32.8	10.2	15.5	24.5
Fenoxoprop-ethyl 0.075 kg/ha at 20-25 DAS	15.5	20.9	38.6	14.6	20.2	32.9	10.2	15.7	24.7
Imazethapyr + imazamox 0.075 kg/ha at 20-25 DAS	15.5	20.7	38.5	14.5	20.1	32.9	10.1	15.8	24.8
Imazethapyr + imazamox 1.0 kg/ha at 20-25 DAS	15.4	20.6	38.4	14.6	20.1	31.7	10.1	15.3	24.3
Imazethapyr 0.075 kg/ha at 20-25 DAS	15.4	20.8	38.5	14.6	20.1	33.6	10.2	15.6	24.6
Imazethapyr 1.0 kg/ha at 20-25 DAS	15.5	20.7	38.4	14.7	20.1	33.0	10.3	15.3	24.3
HW twice at 20 and 40 DAS	15.4	24.7	39.9	14.5	24.1	35.2	10.3	20.1	28.2
Weed free	14.5	24.8	40.0	14.4	24.2	36.5	10.3	20.1	28.3
Weedy check	15.6	24.2	39.0	0.06	23.3	34.1	10.2	19.2	26.1
LSD (P=0.05)	15.4	0.08	0.13	14.4	0.06	2.22	0.10	0.09	0.07

total microbial population was highest with cultural operations and lower with herbicides. The application of herbicides in recommended dose did not affect the microbial population significantly. Among herbicides results showed that application of herbicide in combinations resulted in reduced microbial populations compare to soils treated with single herbicide. Balasubramanian and Sankaran (2004) also reported initial suppression of soil micro flora but the herbicides application in different soils which recovered later on.

Economics

Among the herbicides, application in alone or with combinations has recorded higher monetary returns over weedy check. Among the weed-control treatments, imazethapyr at 1.0 kg/ha (` 30,370/ha) and imazethapyr at 0.075 kg/ha (` 28,776/ha) gave the maximum monetary returns, due to excellent control of grassy and broad-leaf weeds without any adverse effect on crop growth. Lower monetary returns which is at par with each other was recorded with imazethapyr + imazamox at 1.0 kg/ha (` 15,710/ha), imazethapyr

+ imazamox at 0.075 kg/ha (` 18,260/ha) due to inability of this herbicides to control weeds. Weed free treatment recorded lower monetary returns and benefit cost ratio than imazethapyr at 1.0 kg/ha, mainly due to the high cost involved in repeated manual weeding to keep these crop weed free in spite of higher grain yield. Among the weed-control treatments, highest benefit ratio (2.29) was recorded with imazethapyr at 1.0kg/ha followed by imazethapyr at 0.075 kg/ha (2.24) and least with imazethapyr + imazamox at 1.0 kg/ha (1.11).

It was concluded that imazethapyr at 0.075 kg/ha applied 20-25 days after sowing was the most remunerative and effective herbicide for controlling the complex weed flora in mungbean under Eastern Maharashtra conditions.

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Short communication

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Chemical weed management in *Chrysanthemum*

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Key words: Chemical control, *Chrysanthemum*, Weed management

Chrysanthemum (*Chrysanthemum morifolium* Ramat.) is one of the most widely cultivated herbaceous perennial flowering plant belonging to family Asteraceae and commonly known as 'Autumn Queen' or 'Queen of East'. *Chrysanthemum* produces showy flowers with different flower colour, flower shape and plant height that can be used as pot plants for beautifying indoors and outdoors, as cut flowers for making bouquets and base decoration, as loose flower for making garlands, worshipping purpose and for garden decoration. It contributes largely to the floriculture industry by virtue of its yield potential, colour variation and long life (Mukherjee 2008).

The growth of the plants and flower yield depends on the cultivation practices adopted and weed free environment right from the early stage. Weeds are unwanted and undesirable plants which interfere with the utilization of land and water resources, thus adversely affect plant growth, human welfare and also harbor insect and disease pests (Rao 2000). Timely hand weedings are not practiced on a large scale, as labour is scarce, costly and time consuming. Incessant rains during initial periods often render the hand-weeding impossible. Hence, an alternative method would be to use herbicides which are practically effective and economical in reducing weed competition at right time so that it is possible to obtain higher flower yield. Thus, the use of herbicides in controlling weeds is comparatively economical, convenient and efficient by one or two applications (Yadav and Bose 1987).

A number of herbicides have become available in the market for control of weeds in flower crops. However, detailed information on this choice of herbicides, their appropriate dosage and time of application is not fully standardized to the farmers usage. In the present study, an attempt was made to find out an effective weed management practice in chrysanthemum.

An experiment was carried out during 2013-14 at the research farm of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana. Soil of the experimental site was sandy loam in texture. Eleven treatments comprising of different pre-emergence herbicides, *viz.* butachlor 1.0 kg/ha, butachlor 1.0 kg/ha + 2 hand weedings, butachlor 1.5 kg/ha, pendimethalin 0.75 kg/ha, pendimethalin 0.75 kg/ha + 2 hand weedings, pendimethalin 1.0 kg/ha and atrazine 1.0 kg/ha, atrazine 1.0 kg/ha + 2 hand weedings, atrazine 1.5 kg/ha besides weed-free (where plots were kept weed free with regular hand weeding) and weedy check (where no cultural practices were followed to control weeds) as control were laid out in randomized block design.

The healthy terminal rooted cuttings (5-7 cm) of *Chrysanthemum* cv. "*Garden Beauty*", free from symptoms of any disease or insect pest were prepared during mid of June and then planted in propagating plug trays having burnt rice husk as rooting media. Plug trays were kept moist by sprinkling water to ensure satisfactory rooting of cuttings. New roots developed after 15-20 days. After the application of herbicides the plots were kept undisturbed till transplanting of rooted cuttings. Terminal rooted cuttings were transplanted in field in the first week of August for further evaluation. Planting of *Chrysanthemum* was done at a spacing of 30 x 30 cm having plot size of 1.2 m x 1.2 m. All the recommended package of practices such as hoeing, irrigation, application of fertilizers and adequate crop protection measures against pests and diseases were followed to get good plant growth and quality flower production. Pinching operation was practiced at two stages *i.e.* first at four weeks after transplanting and second at seven weeks after transplanting to encourage the emergence of lateral shoots.

To record observations on weed count, weeds removed from 50 x 50 cm quadrat, thrown randomly in each plot at 30 and 60 days after application of herbicides, was considered. After counting, the weeds they were oven dried for 48 h at 50°C and dry weight was recorded. Weed species like *Poa annua, Digitaria sanguinalis, Eragrostis tanella, Cyperus rotundus, Phyllanthus niruri* and *Parthenium hysterophorus*

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were found in experimental plot. Weed control efficiency (WCE) was calculated on dry weight basis.

Results revealed that all the herbicides showed significant effect on controlling weed population. Butachlor 1.0 kg/ha + 2 HW registered minimum weed population (8.31/m²), (9.77 /m²) at 30 and 60 days after transplanting (DAT), respectively. Reduction in weed population in these treatments can be attributed to relatively better management practices which shifted the competition in favour of *Chrysanthemum*. Similar results confirming the findings of the present study were obtained in gladiolus (Kumar *et al.* 2012). The number of weeds per unit area (m²) in weed free treatment both at 30 and 60 days after transplanting was nil, where plots were kept weed free with regular hand weeding. The less number of weeds in weed free treatment were due to better availability of nutrients, moisture, sunlight and space for crop growth. This is in conformity with the findings of Basavaraju *et al.* (1992) in China aster, Pal and Das (1990) in tube rose and Koutepas (1982) in gladiolus. The minimum weed fresh matter (11.83 g/m²) and (13.51 g/m²) was recorded from butachlor treatment of 1.0 kg/ha + 2 HW suggesting that the best weed control was given by this treatment at 30 and 60 days after transplanting. It was quite closely followed by pendimethalin 0.75 kg/ha + 2 HW and atrazine 1.0 kg/ha + 2 HW. All the treatment differed significantly with each other with regard to weed parameters (Table 1.)

At 30 DAT, lowest weed dry matter (4.87g/m²) was recorded from butachlor 1.0 kg/ ha + 2 HW followed by atrazine 1.0 kg/ha + 2 HW (4.54g/m²) and pendimethalin 0.75 kg/ha + 2 HW with (5.27g/m²). Similar trend was followed for dry matter at 60 DAT with the values of 5.04 g/m², 5.66 g/m² and 6.34 g/m², respectively. Reduction in weed population and weed dry weight in herbicidal treatments with hand weedings can be attributed to relatively better management practices and proved to be economical weed management practice which shifted the competition. There was significant enhancement in weed control efficiency (100%) with weed free treatment (plot that was kept weed free throughout the crop growth period through manual weeding) followed by application of butachlor 1.0 kg/ha + 2 hand weeding (84.47%), which was significantly superior to weedy check (0.0%). The crop plants in the former treatments experienced good vegetative growth right from the early stages up to the end of cropping period because of less competition of weeds for nutrients, water, space and sunlight (Kumar *et al.* 2012). Similar were the findings of Singh and Bijimol (1999) and Patil and Shalini (2006).

The crop plants in the former treatments experienced good vegetative growth right from the early stages up to the end of cropping period because of less competition of weeds for nutrients, water, space and sunlight. Application of butachlor 1.0 kg/ha + 2 hand weeding proved to be economical weed management practice. Similar findings were obtained by Singh and Bijimol

Table 1. Effect of different pre-emergence herbicides on weed dynamics of *Chrysanthemum*

Treatment	Weed count (per m²)		Fresh weight (g/m²)		Dry weight (g/m²)		Weed control efficiency (%) 60 DAT
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
Butachlor 1 kg/ha	13.2 (175)	14.3 (205)	18.5 (347)	19.6 (386)	8.5 (73)	8.7 (75)	53.4
Butachlor 1 kg/ha + 2 hand weedings (at monthly interval)	8.3 (69)	9.8 (95)	11.8 (141)	13.5 (182)	4.9 (24)	5.0 (25)	84.5
Butachlor 1.5 kg/ha	10.9 (119)	10.3 (105)	15.3 (233)	14.1 (198)	6.4 (41)	6.5 (41)	74.5
Pendimethalin 0.75 kg/ha	13.7 (189)	15.6 (244)	19.3 (373)	21.4 (458)	8.9 (80)	9.7 (95)	41.0
Pendimethalin 0.75 kg/ha + 2 hand weedings (at monthly interval)	8.5 (72)	10.1 (101)	11.8 (141)	13.8 (190)	5.3 (27)	6.3 (39)	75.8
Pendimethalin 1.00 kg/ha	10.6 (112)	12.0 (144)	14.8 (219)	16.5 (270)	6.5 (42)	7.5 (56)	65.2
Atrazine 1.0 kg/ha	13.4 (181)	14.2 (201)	18.9 (359)	19.5 (378)	8.9 (79)	8.6 (74)	54.0
Atrazine 1.0 kg/ha + 2 hand weedings (at monthly interval)	8.4 (71)	10.2 (104)	12.0 (145)	14.0 (195)	4.5 (20)	5.7 (32)	80.1
Atrazine 1.5 kg/ha	10.8 (117)	11.6 (135)	15.1 (230)	15.9 (253)	6.6 (43)	7.3 (52)	67.7
Weed free	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	100.
Weedy (control)	17.6 (309)	19.6 (384)	24.5 (602)	26.8 (720)	12.0 (143)	12.7 (161)	0.00
LSD (P=0.05)	2.02	1.40	2.80	1.91	1.78	1.15	

Original values are given in parentheses; DAT=Days after transplanting; HW= Hand weeding

(1999) and Patil and Shalini (2006). Herbicides also showed better control of weeds was due to their effectiveness in controlling and weeds and recorded comparatively higher weed control efficiency due to lower dry weight of weeds as compared to weedy control.

SUMMARY

A field experiment was laid out in randomized block design with eleven treatments comprising of ifferent pre-emergence herbicides, *viz.* butachlor 1.0 kg/ha, butachlor 1.0 kg/ha + 2 hand weedings, butachlor 1.5 kg/ha, pendimethalin 0.75 kg/ha, pendimethalin 0.75 kg/ha + 2 hand weedings, pendimethalin 1.0 kg/ha and atrazine 1.0 kg/ha, atrazine 1.0 kg/ha + 2 hand weedings, atrazine 1.5 kg/ha besides weed-free (where plots were kept weed free with regular hand weeding) and weedy check (where no cultural practices were followed to control weeds) as control. Results revealed a significant enhancement in flower yield with weed free and butachlor 1.0 kg/ha + 2 hand weedings which were superior over weedy check. The highest weed control efficiency (100%) was also observed in weed free treatment, followed by butachlor 1.0 kg/ha + 2 hand weedings (84.5%) and atrazine 1.0 kg/ha + 2 hand weedings (80.1%). Application of butachlor 1.0 kg/ha along with hand weedings proved to be economical.

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Short communication

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Weed management and dynamics of weed seed bank in fennel

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Fennel, *Foeniculum vulgare* Mill. (family Apiaceae), a native of Southern Europe and Mediterranean area, is an important seed spice. Area under *Rabi* direct-seeded fennel is increasing day by day, because of its more profitabbility than other *Rabi* crops like wheat, gram, cumin, mustard *etc.* In spite of this fact, the productivity of *Rabi* fennel is low as compared to its potential yield. The reason for low productivity is lack of ideal agronomic practices and knowledge regarding use and economic importance of fennel besides unavailability of appropriate production technologies. Farmers pay reasonable attention to cultivation, especially in respect of seedbed preparation, manuring and irrigation, however not careful about weed control aspect which remains one of the constraints in boosting up the production.

Therefore, it is essential to find out an appropriate and economical method of weed control to keep fennel fields weed free at the critical stages of crop-weed competition. Initial slow growth of fennel leads to severe weed crop competition and reduces growth, as well as yield as high as 91.4% (Mali and Suwalka 1987).

A field experiment was conducted at Instructional Farm, Junagadh Agricultural University, Junagadh (Gujarat) during *Rabi* season of 2011-12. The experiment was laid ant in RBD with three replications. The soil of experimental field was clayey in texture, slightly alkaline in reaction (pH 8.0 and EC 0.56 dS/m), low in available N (238 kg/ha), medium in available P (36.8 kg/ha) and K (221 kg/ha). The experiment comprised ten treatments, namely, pendimethalin 0.90 kg/ha as pre-emergence (PRE) + hand weeding (HW) at 45 DAS, oxadiargyl 75 g/ha as early post-emergence (POE) at 7 DAS + HW at 45 DAS, glyphosate 1.0 kg/ha as early POE at 7 DAS + HW at 45 DAS, pendimethalin 0.90 kg/ha as PRE + quizalofop-ethyl 40 g/ha POE at 45 DAS, pendimethalin 0.90 kg/ha as PRE + fenoxaprop-ethyl 75 g/ha POE at 45 DAS, pendimethalin 0.90 kg/ha as PRE + propaquizafop 75 g/ha as POE at 45 DAS, pendimethalin0.90 kg/ha as PRE + oxadiargyl 75 g/ha as POE at 45 DAS, HW twice at 15 and 45 DAS, weed free and unweeded check. The fennel variety '*GF-11*' was sown in second week of November at a spacing of 60 × 20 cm using seed rate of 8 kg/ha and fertilized with 90-30-00 kg N-P_2O_5-K_2O/ha.

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Herbicides were uniformly applied with a spray volume 500 L/ha. Weed index (WI), weed control efficiency (WCE) and herbicidal efficiency index (HEI) were also worked out as per formulae to assess the efficiency of different weed management practices. For the study of weed seed bank, five soil samples were taken from the soil before sowing of the crop and one composite sample was prepared, while plot-wise samples were taken after harvest of the crop. The soil samples were drawn by core sampler of 2 cm in diameter from 15 cm depth as per the FAO protocol (Forcella *et al.* 2011). Each soil core was individually bagged and numbered. Seed extraction was done by sieving of the samples through copper sieves of 5 mm in diameter. This followed by their rinsing by water and sieving of the samples through a descending series of sieves up to sieve of 0.5 mm in diameter. Seeds were then dried at the room temperature and separated manually. Determination of the separated seeds was performed visually and sample-wise seed count was recorded.The experimental data recorded for growth parameters, yield attributes and yield parameters and economics were statistically analyzed for level of significance..

The experimental field was infested with monocot weeds, *viz. Brachiaria* sp. (7.67%), *Indigoflora glandulosa* (7.00%), *Asphodelus tenuifolius* (5.00%) and *Dactyloctenium aegyptium* (1.33%), dicot weeds, *viz. Digera arvensis* (18.67%), *Chenopodium album* L. (16.3%), *Physalis minima* (7.67%), *Portulaca oleracea* L. (5.67%), *Euphorbia hirta* (4.00%) and *Leucas aspera* (1.33%), and sedge *Cyperus rotundus* (25.3%).

Besides, in weed free treatment, the lowest weed population (Table 2) and the highest WCE (93.63) was recorded in HW twice at 15 and 45 DAS, which remain at par with pendimethalin as PRE + HW at 45 DAS and pendimethalin as PRE + fenoxaprop-ethyl POE at 45 DAS. These treatments attributed to the effective control of early as well as late flushes of weeds resulted lower weed biomass. Next to weed free, minimum WI (0.52%) was obtained with pendimethalin PRE + fenoxaprop-ethyl POE at 45 DAS, closely followed by pendimethalin PRE + HW at 45 DAS (0.91%). The result confirms the findings of Thakral *et al.* (1995), Meena and Mehta (2009) and Nagar *et al.* (2009).

The dynamics of weed seed bank in soil drastically influenced by different weed management treatments (Table 1). The lowest weed seed bank was recorded with pendimethalin as PRE + HW. Pendimethalin as PRE controlled weeds right from the start and weeds those escaped and emerged later were controlled by hand weeding at 45 DAS. The treatments, *viz.* pendimethalin as PRE+ quizalofop-ethyl as POE, pendimethalin as PRE + fenoxaprop-ethyl as POE and pendimethalin as PRE + propaquizafop as POE were found to increase weed seed bank. This might be ascribed to the post-emergent herbicides, *viz.* quizalofop-ethyl, fenoxaprop-ethyl and propaquizafop which are grassy weed killers, leaving dicot weeds to produce seeds. The unweeded check recorded the highest size of weed seed bank due to production of large number of weed seeds under uncontrolled condition leading to 978 % increase in the initial weed seed bank.

Among the weed management, the highest plant height, and seed and stover yields (1.83 and 4.50 t/ha) were recorded with pendimethalin PRE + fenoxaprop-ethyl POE at 45 DAS, which was statistically at par with pendimethalin PRE + HW at 45 DAS and HW twice at 15 and 45 DAS (Table 1). The improved growth and yield under these treatments might be due to effective weed control resulting in lesser competition of weeds which might have resulted in the better utilization of nutrients and moisture available in the soil by crop leading to increased rate of photosynthesis and supply of photosynthates to various metabolic sinks. Similar findings have been reported by Bhati (1994), Chaudhary (2000), Meena and Mehta (2009) and Nagar *et al.* (2009). It was evident that pendimethalin as PRE + fenoxaprop as POE gave the highest net return (` 81,993/ha) and B:C ratio (3.22), followed by pendimethalin as PRE + HW, HW twice and weed free treatment (Table 1). The lower net returns and B:C ratio in weed free might be due to more cost required to create weed free condition for entire period in the crop season.

It was concluded that effective management of weeds along with profitable seed yield and net returns of direct seeded *Rabi* fennel can be obtained with pendimethalin PRE + fenoxaprop-ethyl POE at 45 DAS and reduction in seed bank obtained with pendimethalin PRE + HW at 45 DAS or HW twice at 15 and 45 DAS or keeping the crop weed free throughout crop period according to availability of labour.

Table 1. Effect of treatments on plant height, yield, dry weight of weeds, weed index and weed control efficiency, weed seed bank and economics of fennel

Treatment	Plant height at harvest (cm)	Seed yield (t/ha)	Stover yield (t/ha)	Dry weight of weeds at harvest (t/ha)	WI (%)	WCI (%)	Weed seed bank/core			Cost of cultivation (x10^3 `/ha)	Net returns (x10^3 `/ha)	B : C ratio
							Initial	Final	Addition (+)/ Depletion (-)			
Pendimethalin + HW	146.3	1.82	4.44	0.08	0.91	93.3	210	74	-136 (-65)	36.88	81.44	3.21
Oxadiargyl + HW	130.9	1.04	2.94	0.24	43.2	81.0	210	147	-63 (-30)	36.98	31.62	1.86
Glyphosate + HW	127.7	1.08	2.99	0.28	41.0	77.4	210	161	-49 (-23)	36.40	34.72	1.95
Pendimethalin + quizalofop	137.1	1.32	3.66	0.49	28.2	60.4	210	278	+68 (+32)	36.74	49.84	2.36
Pendimethalin + fenoxaprop	149.9	1.83	4.50	0.20	0.52	84.3	210	242	+32 (+15)	36.88	81.99	3.22
Pendimethalin + propaquizafop	136.5	1.32	3.64	0.30	28.0	75.7	210	221	+11 (+5)	36.71	50.05	2.36
Pendimethalin + oxadiargyl	137.4	1.31	3.55	0.10	28.5	91.6	210	99	-111 (-53)	36.84	49.19	2.34
HW twice	146.6	1.79	4.49	0.08	2.28	93.6	210	125	-85 (-40)	36.61	80.30	3.19
Weed free	153.1	1.84	4.51	0.00	0.00	100	210	76	-134 (-64)	39.75	79.70	3.01
Unweeded check	126.6	0.92	2.66	1.25	49.9	0.00	210	2264	+2054 (+978)	33.60	26.98	1.80
LSD (P=0.05)	14.7	0.36	0.82	0.08	-	-	-	73	-	-	-	-

Table 2. Effect of integrated weed management on weed population in fennel

Treatment	Monocot weeds/m^2 at			Dicot weeds/m^2 at			Sedge weeds/m^2 at			Total weeds/m^2 at		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
Pendimethalin + HW	1.22 (1.00)	1.17 (1.00)	1.05 (0.67)	2.27 (4.67)	1.34 (1.33)	1.44 (1.67)	2.60 (6.33)	1.56 (2.00)	1.66 (2.33)	3.53 (12.0)	2.18 (4.33)	2.22 (4.67)
Oxadiargyl + HW	1.34 (1.33)	1.68 (2.33)	1.77 (2.67)	2.38 (5.33)	2.54 (6.00)	2.40 (5.33)	3.27 (10.3)	2.67 (6.67)	2.68 (6.67)	4.14 (17.0)	3.94 (15.0)	3.89 (14.6)
Glyphosate + HW	1.86 (3.00)	1.84 (3.00)	1.56 (2.00)	4.22 (17.3)	2.57 (6.67)	2.59 (6.33)	2.53 (6.33)	2.18 (4.33)	2.78 (7.33)	5.21 (26.6)	3.79 (14.0)	4.02 (15.6)
Pendimethalin + quizalofop-ethyl	1.46 (1.67)	2.60 (6.33)	2.61 (6.33)	2.66 (6.67)	3.67 (13.0)	3.39 (11.0)	3.36 (11.0)	3.76 (13.7)	3.52 (12.00)	4.44 (19.3)	5.78 (33.0)	5.45 (29.3)
Pendimethalin + fenoxaprop-ethyl	1.34 (1.33)	1.22 (1.00)	1.17 (1.00)	2.65 (6.67)	3.58 (12.3)	3.13 (9.33)	2.67 (6.67)	1.58 (2.00)	1.72 (2.67)	3.89 (14.6)	3.98 (15.3)	3.67 (13.0)
Pendimethalin + propaquizafop	1.46 (1.67)	2.04 (3.67)	1.74 (2.67)	2.54 (6.00)	3.76 (13.6)	3.52 (12.0)	3.22 (10.0)	2.95 (8.33)	2.72 (7.00)	4.26 (17.7)	5.10 (25.6)	4.69 (21.6)
Pendimethalin + oxadiargyl	1.34 (1.33)	2.08 (4.00)	1.68 (2.33)	2.81 (7.67)	0.88 (0.33)	1.05 (0.67)	3.13 (9.33)	2.85 (7.67)	2.80 (7.33)	4.33 (18.3)	3.53 (12.0)	3.29 (10.3)
HW twice	1.05 (0.67)	1.22 (1.00)	1.17 (1.00)	1.34 (1.33)	1.34 (1.33)	1.44 (1.67)	1.34 (1.33)	1.34 (1.33)	1.68 (2.33)	1.95 (3.33)	2.04 (3.67)	2.33 (5.00)
Weed free	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.88 (0.33)	0.71 (0)	0.88 (0.33)	1.17 (1.00)	0.71 (0)	0.88 (0.33)	1.34 (1.33)
Unweeded check	2.78 (7.33)	4.41 (19.0)	4.63 (21.0)	5.95 (35.3)	7.26 (52.3)	7.33 (53.7)	4.03 (16.0)	4.93 (24.6)	5.04 (25.3)	7.67 (58.6)	9.82 (96.0)	10.02 (100)
LSD (P=0.05)	0.41	0.52	0.51	0.73	0.71	0.67	0.77	0.71	0.72	0.69	0.50	0.45

Figures in parentheses are original values of weed count $\sqrt{x+0.5}$ transformation

SUMMARY

A field experiment was conducted during *Rabi* season of 2011-12 at Junagadh (Gujarat) to find out most effective and economical method of weed control in *Rabi* fennel (*Foeniculum vulgare*). Results revealed that besides weed free treatment, significantly higher plant height, seed and stover yields of fennel were recorded with pre-emergence application of pendimethalin at 0.90 kg/ha + post-emergence application of fenoxaprop-ethyl at 75 g/ha at 45 DAS, which was at par with pendimethalin at 0.90 kg/ha PRE + hand weeding (HW) at 45 DAS and HW twice at 15 and 45 DAS. These treatments also recorded lower weed density and dry weight of weeds along with higher net returns and B:C ratio owing to lower weed index and higher weed control efficiency. The highest depletion of weed seed bank was observed with pendimethalin at 0.90 kg/ha PRE + HW at 45 DAS.

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Short communication

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Herbicidal activity of surfactant formulation of karanj

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Natural plant products are catching attention of scientist for their use as pesticide/herbicides to control pests/weeds. The main advantage of these products is that they may be easily and cheaply produced by farmers and small-scale industries as crude, or partially purified extracts (Copping and Duke 2007). In the last two decades, considerable efforts have been made for screening the plants in order to develop new botanical pesticides as alternatives to the existing chemicals. Surfactants are adjuvants that facilitate and accentuate the emulsifying, dispersing, spreading, or other surface modifying properties of liquids. They are biodegradable in the soil environment. The foliar uptake of pesticide in the presence of adjuvants has been investigated extensively and some prediction on the ease of foliar uptake can be realized in relation to the formulation technology (Hess and Foy 2000).

Non edible oil seeds are the potential source of biochemicals which can be converted into surfactants having secondary metabolites as lipid associates. A work was therefore initiated to explore herbicidal activity of surface active formulation against broad-leaved weeds *Checorium intybus* and *Medicago =denticulate* commonly found in field.

Seeds of *Pongamia pinnata* commonly known as karanj were extracted with petroleum ether (60-80 ^{0}C) for 6 hours. Solvent was evaporated with the help of vacuum evaporator under reduced pressure and was separated. Surfactant formulation was prepared with *P. pinnata* seeds oil and additives. Following properties of surfactant formulation were done:

Wetting power: The Draves- Clarkson method was used as reported in Bureau of Indian Standard. Strips of 1x1 inch were cut from cotton fibre cloths. Sinking times were determined for different concentrations of product.

Emulsifying power: Forty ml of liquid paraffin and 40 ml of aqueous phase containing different concentration of test sample in a 500 ml stoppered conical flasks were shaken vigorously up to ten times then the mixture was transferred to a measuring cylinder and the time taken for 10 ml of the aqueous phase to separate was recorded.

Surface tension: Surface tension of modified oil of different concentration was determined with the help of stalegmometer.

Viscosity: Viscosity of different concentration were determined with the help of viscometer.

Testing of surfactant formulation on seed germination: The seeds of *Checorium intybus* and *Medicago denticulata* were collected locally from wild stands and seeds germination, seedling development were tested by filter paper method. Surfactant dilutions were prepared by dissolving in water to reach the final concentration of 7.5, 5.0, 2.5 and 1% w/v. Five ml of each tested solution was then added to 9 cm diameter Petridish that contained paper filter. Ten uniform size seeds were put on the filter paper and covered with a lid. The tested Petridishes were kept under room temperature (25 ± 5 ^{0}C). The experiment was done with 5 replications. The treatment with distilled water served as control. Data on germination, shoot length and root length were recorded at 14 days after inoculation.

The surface tension of different dilutions varied 0.04 – 0.052 dyns/cm while pH ranged 7.2 – 8.9 (Table 1). The treatment with 7.5% dilution of formulation showed complete retardation of growth of *M. denticulata* while no shoot formation of *Checorium intybus* was observed (Table 2). The per cent shoot growth inhibition of weeds *M. denticulata* and *Checorium intybus* varied 51.1 – 100% and 71.7 – 100%, respectively (Fig. 1 and 2). The incorporation of lowest dilution *i.e.* 1% concentration of formulation also reduced growth significantly. The herbicidal efficacy of formulation is a reflection that it penetrates into the seed cuticle and affects germination as well as growth of seedling. Surface tension of different dilution was low in comparison to water without surfactant.

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Table 1. Properties of surfactant formulation at different dilutions

Surfactant formulation dilution (%)	pH	Wetting power (min.)	Emulsifying power (min.)	Surface tension (dyns/cm)	Viscosity (mPa.s)
1.0	7.2	1.00	1.24	0.052	0.60
2.5	7.3	1.12	3.11	0.046	0.75
5.0	7.9	1.26	9.14	0.044	0.80
7.5	8.9	1.44	10.34	0.040	0.98

Table 2. Effect of surfactant formulation on growth of two weed species at 14 days after incubation

Concentration of surfactant formulation (%)	*Medicago denticulata*		*Checoriumintybus*	
	Shoot length (cm)	Root length (cm)	Shoot length (cm)	Root length (cm)
1.0	1.82	0.95	0.85	0.72
2.5	0.53	0.12	0.20	0.31
5.0	0.12	0.00	0.00	0.19
7.5	0.00	0.00	0.00	0.10
Control	3.72	1.25	3.00	4.30
LSD (0.5)	0.56	0.13	0.23	0.42

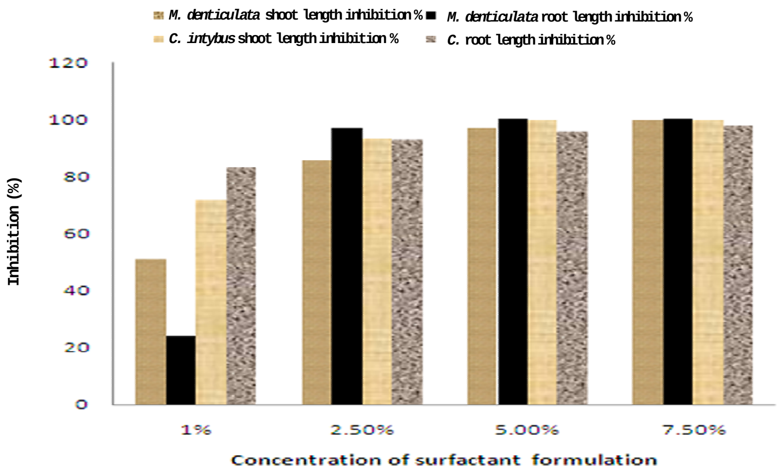

Fig. 1. Effect of surfactant formulation on shoot and root inhibition at diffrent concentration

The role of polyethylene glycols in herbicidal formulations is well documented. Bioefficacy of glyphosate was enhanced with the addition of surfactant (Triton x 100) which reduces surface tension, enhance spreading of drop and fine drop deposition as reflected by biomass reduction bioassay to glyphosate alone (Kudsk *et al.* 1989). Manthey *et al.* (1989) explained that refined or esterified vegetable oil may be as effective or more effective than petroleum oils in enhancing the phytotoxicity of herbicides. Robert and John (1999) showed that sethoxydin was most phytotoxic when applied with vegetable oils. This study indicates that surfactants from non edible oil seeds can be potentially utilized as herbicide or as adjuvant in herbicides to reduce doses of synthetic chemicals significantly.

SUMMARY

Surface active formulation from non edible oil was evaluated for herbicidal activity against weeds, *Checorium intybus* and *Medicago denticulata* under *in vitro* conditions. Different dilutions of formulation exhibited markedly variable herbicidal activities against germination and seedling growth of the target weed species. Different concentrations (1.0 – 7.5%) inhibited the growth of shoot and root of *C. intybus* and *M.denticulata* by 71.7 – 100, 83.3 – 97.7% and 51.17 – 100, 24 – 100%, respectively. No shoot formation was recorded in 5.0 and 7.5% dilution against *C. intybus* and *M. denticulate*. The present study concluded that the surfactant formulations from non edible oil of *Pongamia pinnata* possess potential herbicidal activities against weeds. Pollution of the environment is now a major concern. Therefore, utilization of plant product based surfactant as herbicide will pave a way for possible exploitation of surfactants in weed management.

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