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Evaluation of cultivars and herbicides for control of barnyard grass and nutsedge in *boro* rice

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ABSTRACT

A field experiment was conducted to test the efficacy of different herbicides and cultivars during *boro* seasons of 2009 and 2010 on clay loam soils at BHU, Varanasi. The herbicides used were butachlor 1500 g/ha (pre-emergence) *fb* 2,4–D 500 g/ha + NIS (0.25%) at 20-25 DAT, pretilachlor 750 g/ha (pre-emergence) *fb* azimsulfuron 35 g/ha + NIS (0.2%) at 15 DAT, penoxsulam 22.5 g/ha + NIS (0.25%) at 15 DAT, ethoxysulfuron 18 g/ha + fenoxaprop + safner 56 g/ha + (NIS 0.25%) at 15 DAT, propanil 3000 g/ha + trichlorpyr 500 g/ha + NIS (0.25%) at 20-25 DAT and pyrazosulfuron 20 g/ha (pre-emergence) *fb* bispyribac 25 g/ha + NIS (0.25%) at 25 DAT under *'Gautam'*, *'Prabhat'* and *'Krishna Hamsa'* cultivars. Weed count and its dry matter under *'Prabhat'* cultivar were lower than that with other two cultivars for both *Echinochola* and *Cyperus* spp. resulting in higher weed control efficiency with *Prabhat* as compared to other two cultivars where as, significantly highest grain yield of 4.15 t/ha was obtained in *Gautam* cultivar due to higher growth and yield attributes. The application of ethoxysulfuron + fenoxaprop was most effective in minimizing population of *Cyperus* spp. and its dry matter with highest WCE. *'Gautam'* cultivar with highest net return of ₹ 24,898/ha and benefit cost ratio of 1.19 and pretilachlor *fb* azimsulfuron with net return of ₹ 27,461/ha and benefit: cost ratio of 1.32 were found most profitable among the cultivars and herbicidal treatments, respectively.

Key words: *Boro* rice, Cultivars, Herbicides, Unweeded control, Weed free

In India, rice occupies an area of 45.5 million hectares with production of 99.2 million tonnes and occupies second position, after China among the rice growing countries of the world. contributing about 41.8% of total food grain production and accounting 20-25% of the agricultural GDP (Rai 2006). Uttar Pradesh is the second largest rice growing state in the country, with an area of 6.03 million ha and production of 13.1 million tonnes (Anonymous 2010). Productivity of *boro* rice in eastern Uttar Pradesh is only two-third (2.0 t/ha) as against the average productivity of 3.0 t/ha of eastern India. Weed competition is one of the prime yield limiting biotic constraints resulting into yield reduction to the tune of 28 to 45% (Raju and Reddy 1995, Singh *et al*. 2003). *Echinochloa* spp. and *Cyperus* spp. are major weeds responsible for yield reduction in rice. Varieties with their characters such as growth, vigor and smothering effects affect the weed growth in boro rice cultivation. The present study was carried out to evaluate the performance of different rice cultivars along with promising herbicides for appropriate weed management programme.

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MATERIALS AND METHODS

Field experiment was conducted during *boro* seasons of 2009 and 2010 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The soil of the experimental field was Gangetic alluvial having clay loam in texture with pH 7.49. It was moderately fertile, being medium in available organic carbon (0.51%), low in available nitrogen (196 kg/ha), and medium in available phosphorus (24.05 kg P_2O_5 ha) and potassium (230.05 kg/ha). The experiment was laid out in split-plot design with three cultivars (*'Gautam'*, *'Prabhat'* and *'Krishna Hamsa'*) in main plots and nine weed control treatments (unweeded control, weed free, and weeding twice at 30 and 50 DAT, butachlor 1500 g/ha (pre-emergence) *fb* 2,4-D 500 g/ha + NIS (0.25%) at 20-25 DAT, pretilachlor 1.0 kg *fb* azimsulfuron (pre-emergence) 35 g/ha + NIS (0.25%) at 15 DAT, penoxsulam 22.5 g/ha + NIS (0.25%) at 15 DAT, ethoxysulfuron 18 g/ha + fenoxaprop + safner 56 g/ha + (NIS 0.25%) at 15 DAT, propanil 3000 g/ha + trichlorpyr 500 g/ha + NIS (0.25%) at 20-25 DAT and pyrazosulfuron 20 g/ha (pre-emergence) *fb* bispyribac 25 g/ha + NIS (0.25%) at 25 DAT) in sub-plots. All the herbicides were applied in saturated soil moisture as per protocol of application time. Two to three seedlings per hill were transplanted at spacing of 20 x 10 cm on 27th January, 2009 and 2nd February, 2010. Crop was supplied with nutrients *i.e.* 120, 60, 60 kg N, P_2O_5 and K_2O as well as 5 kg Zn/ha. Full quantity of P_2O_5, K_2O and Zn through diammonium phosphate, muriate of potash and zinc sulphate and one half of N was applied as basal dose at the time of puddling. Remaining N in form of urea was top dressed in two equal splits, at active tillering and panicle initiation stage. The data on weed count and their dry matter (at 20, 40, 60, 80 DAT and harvest) were recorded with the help of a quadrate (0.5 x 0.5 m) at two places per plot and then converted into per square metre. Weed control efficiency (WCE) was calculated based on weed dry weight. The data on weed count and dry weight were analysed using square root ($\sqrt{x+0.5}$) transformation.

RESULTS AND DISCUSSION

The most dominant weed species found in the experimental field throughout the crop growth in rice were; *Cynodon dactylon* and *Echinochloa* spp. among grasses: *Cyperus* spp. among sedges and *Ipomoea aquatica*, *Marsilea minuta*, *Nymphaea nouchali*, *Pistia stratiotes*, *Veronica anagallis-aquatica*, *Ranunculus sceleratus* among broad-leaved. *Echinochola* spp. constituted 28.3% and *Cyperus* spp. 24.9% of total weed population at maximum weed flush (80 DAT).

Effect on weeds

The pooled data of two years indicated that '*Prabhat*' cultivar registered significantly lower number of *Echinochloa* spp. (Table 1) and *Cyperus* spp. (Table 2), as well as its dry matter at almost all the stages of crop growth. Vigorous crop growth and droopy lower leaves

Table 1. Effect of cultivars and herbicides on weed count and weed dry matter of *Echinochola* spp. and weed control efficiency (pooled data of two years)

Treatment	Weed count (no./m²) at different DAT					Weed dry matter (g/m²) at different DAT				
	20	40	60	80	Harvest	20	40	60	80	Harvest
Cultivars										
'Gautam'	1.01	2.83	2.37	2.60	2.86	0.93	1.38	3.23	3.76	5.13
	(0.96)	(13.74)	(8.00)	(10.59)	(12.59)	(0.66)	(2.39)	(15.27)	(23.54)	(40.23)
'Prabhat'	0.93	2.63	2.21	2.38	2.66	0.91	1.58	2.97	3.28	4.80
	(0.59)	(11.04)	(7.07)	(8.85)	(11.04)	(0.71)	(3.41)	(14.13)	(17.67)	(33.93)
'Krishna Hamsa'	1.11	2.80	2.67	3.08	3.28	0.94	1.88	3.30	4.47	5.34
	(1.15)	(12.89)	(13.56)	(18.22)	(17.44)	(0.59)	(5.23)	(18.65)	(30.54)	(44.45)
LSD (P=0.05)	N.S.	N.S.	0.42	0.12	0.26	N.S.	0.26	0.44	0.25	0.23
Herbicides										
Hand weeding twice	1.16	3.23	1.22	2.00	2.17	1.10	1.60	1.80	3.36	4.96
	(1.44)	(12.11)	(1.33)	(4.56)	(4.56)	(1.33)	(2.55)	(3.74)	(14.28)	(27.23)
Butachlor *fb* 2,4-D	0.98	1.73	2.67	1.89	2.92	0.84	1.48	4.84	3.21	5.68
	(0.78)	(3.00)	(7.67)	(3.67)	(10.44)	(0.31)	(2.30)	(25.09)	(11.13)	(35.58)
Pretilachlor *fb* azimsulfuron	1.20	1.17	1.51	1.48	1.48	1.04	0.91	1.22	1.76	2.17
	(1.44)	(1.44)	(2.78)	(2.44)	(2.33)	(1.11)	(0.52)	(1.43)	(3.92)	(5.74)
Penoxsulam	0.90	1.79	1.77	1.53	1.77	0.80	1.15	1.92	2.30	3.07
	(0.44)	(3.67)	(3.89)	(3.56)	(3.67)	(0.19)	(1.23)	(4.96)	(8.04)	(11.08)
Ethoxysufuron + fenoxaprop	0.96	2.16	1.92	2.27	2.83	0.90	1.17	3.19	3.65	4.64
	(0.67)	(7.22)	(4.11)	(5.78)	(8.67)	(0.49)	(1.29)	(10.72)	(14.76)	(22.91)
Propanil + trichlopyr	0.91	4.22	4.02	4.61	4.73	0.92	2.20	5.03	6.49	8.47
	(0.56)	(19.11)	(18.44)	(23.67)	(24.67)	(0.59)	(5.16)	(27.26)	(43.27)	(77.53)
Pyrazosulfuron *fb* bispyribac	0.95	2.05	1.44	1.99	2.27	0.78	1.08	1.58	2.79	4.02
	(0.67)	(5.78)	(2.11)	(4.56)	(6.44)	(0.14)	(0.94)	(2.63)	(9.98)	(17.38)
Unweeded	1.40	7.71	6.49	7.68	7.55	1.27	4.20	8.21	10.22	12.06
	(2.11)	(60.67)	(45.56)	(64.78)	(62.44)	(1.69)	(19.08)	(68.32)	(109.88)	(158.38)
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
LSD (P=0.05)	0.32	0.56	0.54	0.54	0.49	0.30	0.45	0.56	0.76	0.64

Values within parentheses are original. Data are subjected to square root transformation ($\sqrt{x+0.5}$). *fb* : followed by; DAT: Day after transplanting of '*Prabhat*' cultivar might be responsible for intercepting the sunlight to restrict the profused weed growth, ultimately reduced weed infestation. These observations were in conformity with reports of Pillai (1977), Thakur *et al.* (1995) and Singh *et al.* (2004). The higher weed control efficiencies of 67.9 and 60.2 for *Echinochloa* spp. as well as 67.7 and 52.7 for *Cyperus* spp. at 80 DAT and harvest respectively in *'Prabhat'* cultivar were might be due to lower weed dry matter accumulation as compared to other two cultivars (Table 3).

Application of pretilachlor (pre-emergence) *fb* azimsulfuron 15 DAT was most effective in controlling *Echinochloa* spp. with significantly lower weed count and dry matter and highest weed control efficiencies (82.78 and 82.01% at 80 DAT and harvest) which might be due to higher efficacy of these herbicides. Other herbicidal treatments except propanil + trichlopyr were also effective in controlling *Echinochloa* spp.

The application of ethoxysulfuron + fenoxaprop at 15 DAT had the best performance in reducing the population of *Cyperus* spp. recording significantly lower weed count and its dry matter. The herbicidal treatment butachlor *fb 2,4-D* as well as pyrazosulfuron *fb* bispyribac was also very effective for control of *Cyperus* spp. The highest weed control efficiencies were achieved with ethoxysulfuron + fenoxaprop recording a WCE of 84.02 and 70.61% at 80 DAT and harvest.

Effect on crop

Among all the three cultivars, *'Gautam'* recorded significantly higher grain yield (4.14 t/ha) than *'Prabhat'* (3.78 t/ha) and *'Krishna Hamsa'* (3.65 t/ha) despite of higher weed count and dry matter than *'Prabhat'* cultivar due to higher growth and yield attributes which might have resulted in higher yield (Table 3). Similar results have also been reported by Singh *et al.* (2004).

Table 2. Effect of cultivars and herbicides on weed count and weed dry matter of *Cyperus* spp. and weed control efficiency (pooled data of two years)

Treatment	Weed count (no./m^2) at different DAT					Weed dry matter (g/m^2) at different DAT				
	20	40	60	80	Harvest	20	40	60	80	Harvest
Cultivars										
'Gautam'	0.85 (0.63)	1.09 (1.78)	2.33 (12.52)	2.30 (10.00)	1.42 (3.48)	0.73 (0.06)	0.79 (0.19)	1.43 (3.63)	2.00 (6.46)	1.24 (2.22)
'Prabhat'	0.76 (0.15)	0.72 (0.04)	1.68 (6.04)	2.10 (7.52)	1.40 (3.69)	0.73 (0.06)	0.71 (0.01)	1.20 (2.13)	1.72 (4.66)	1.24 (2.34)
'Krishna Hamsa'	0.84 (0.44)	0.74 (0.11)	2.74 (13.33)	2.83 (15.22)	1.84 (5.96)	0.78 (0.21)	0.72 (0.03)	1.44 (2.81)	2.22 (8.98)	1.43 (3.66)
LSD (P=0.05)	N.S.	0.20	0.40	0.35	N.S.	N.S.	0.04	0.12	0.26	N.S.
Herbicides										
Hand weeding twice	0.86 (0.44)	0.93 (1.22)	1.62 (5.33)	2.27 (6.67)	1.92 (5.56)	0.77 (0.17)	0.75 (0.09)	0.90 (0.44)	1.62 (2.94)	1.78 (4.46)
Butachlor *fb* 2,4-D	0.71 (0.00)	0.71 (0.00)	1.23 (2.67)	1.24 (2.22)	1.15 (1.56)	0.71 (0.00)	0.71 (0.00)	1.44 (3.47)	0.99 (0.68)	0.94 (0.69)
Pretilachlor *fb* azimsulfuron	1.13 (1.89)	1.16 (1.94)	3.00 (17.33)	2.73 (12.89)	1.63 (4.17)	0.77 (0.17)	0.81 (0.23)	0.92 (0.58)	1.84 (4.10)	1.09 (1.03)
Penoxsulam	0.71 (0.00)	0.71 (0.00)	1.41 (2.89)	1.73 (6.89)	1.12 (1.67)	0.71 (0.00)	0.71 (0.00)	0.86 (0.38)	1.55 (4.92)	0.82 (0.39)
Ethoxysufuron + fenoxaprop	0.76 (0.11)	0.71 (0.00)	0.71 (0.00)	0.93 (0.78)	0.97 (1.00)	0.75 (0.09)	0.71 (0.00)	0.71 (0.00)	0.85 (0.40)	0.77 (0.14)
Propanil + trichlopyr	0.94 (0.89)	0.96 (0.78)	4.26 (23.67)	4.28 (23.33)	2.58 (10.44)	0.83 (0.44)	0.76 (0.10)	1.94 (4.58)	3.63 (16.26)	2.29 (7.97)
Pyrazosulfuron *fb* bispyribac	0.71 (0.00)	0.71 (0.00)	1.33 (3.11)	1.38 (2.33)	0.85 (0.56)	0.71 (0.00)	0.71 (0.00)	1.25 (2.63)	1.31 (1.78)	0.78 (0.19)
Unweeded	0.81 (0.33)	1.07 (1.83)	5.98 (40.67)	6.44 (43.11)	3.06 (14.44)	0.76 (0.11)	0.81 (0.24)	3.51 (13.63)	5.32 (29.24)	2.62 (9.78)
Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
LSD (P=0.05)	0.22	0.34	0.66	0.73	0.51	N.S.	0.08	0.34	0.44	0.41

Values within parentheses are original. Data are subjected to square root transformation ($\sqrt{x+0.5}$). *fb* : followed by; DAT: Day after transplanting

Table 3. Effect of cultivars and herbicides on weed control efficiency, 1000-grain weight, tillers/hill, yield and economics in *boro* rice (pooled data of two years)

Treatment	WCE (%) in *Echinochloa*		WCE (%) in *Cyperus*		1000-grains weight (g)	Tillers /hill at 80 DAT	Grain yield (t/ha)	Net returns (x10^3 ₹/ha)	Benefit : cost ratio
	80 DAT	Harvest	80 DAT	Harvest					
Cultivars									
'Gautam'	63.2	57.5	62.4	52.7	22.76	17.48	4.15	24.89	1.19
'Prabhat'	67.9	60.2	67.7	52.7	22.29	16.70	3.78	21.35	1.01
'Krishna Hamsa'	56.3	55.7	58.3	45.4	21.83	14.90	3.65	19.85	0.94
LSD (P=0.05)	-	-	-	-	0.48	1.25	0.09	0.10	0.05
Herbicides									
Hand weeding twice	67.1	58.9	69.5	32.1	22.89	18.78	4.41	26.80	1.21
Butachlor *fb* 2,4 – D	68.6	52.9	81.4	64.1	21.80	14.54	3.59	20.57	1.05
Pretilachlor *fb* azimsulfuron	82.8	82.0	65.4	58.4	22.61	17.76	4.35	27.46	1.32
Penoxsulam	77.5	74.5	70.9	68.7	22.06	15.61	3.84	23.08	1.17
Ethoxysufuron + fenoxaprop	64.3	61.5	84.0	70.6	22.46	16.99	4.12	25.78	1.30
Propanil + trichlopyr	36.5	29.8	31.8	12.6	21.58	13.78	3.38	17.85	0.89
Pyrazosulfuron *fb* bispyribac	72.7	66.7	75.4	70.2	22.44	16.24	3.95	21.74	0.98
Unweeded	0.0	0.0	0.0	0.0	21.36	12.34	2.41	9.20	0.50
Weed free	-	-	-	-	23.43	21.21	4.65	25.79	1.00
LSD (P=0.05)	-	-	-	-	0.63	0.95	0.10	1.14	0.06

Maximum grain yield was recorded in the treatment hand weeding twice at 30 and 50 DAT with an increase of 82.7% in yield over unweeded control. Pretilachlor *fb* azimsulfuron was the most effective among herbicidal treatments realizing 80.2% higher grain yield over unweeded control which was also statistically similar to hand weeding twice.

On the basis of two years mean, the maximum net returns and benefit : cost ratio were obtained by *'Gautam'* followed by *'Prabhat'* cultivar. The corresponding values for net returns and benefit : cost ratio were ₹ 24.898/ha and 1.19 and ₹ 21,352/ha and 1.01, respectively. Among herbicides, pretilachlor *fb* azimsulfuron recorded highest net returns (₹ 27,461/ha) and benefit: cost ratio (1.32) which was followed by ethoxysulfuron + fenoxaprop with net return of ₹ 25,783/ha and benefit : cost ratio as 1.30. Though, weed free condition gave the highest yield but net returns and benefit : cost ratio were not highest due to involvement of more labour, resulting in higher cost.

It was concluded that *'Prabhat'* followed by *'Gautam'* was found to be the most effective boro rice cultivar in respect of minimizing weed count of *Echinochola* and *Cyperus* spp., The cultivar *'Gautam'* showed its superiority over *'Prabhat'* and *'Krishna Hamsa'* in respect of yield attributes and yield. The herbicidal treatment pretilachlor 750 g/ha (pre-emergence) *fb* azimsulfuron 35 g/ha + NIS (0.25%) at 15 DAT was most effective in reducing the population and dry matter of *Echinochloa* spp. where as ethoxysulfuron 18 g/ha + fenoxaprop + safner 56 g/ha + (NIS 0.25%) at 15 DAT was most effective in reducing population of *Cyperus* spp. *'Gautam'* cultivar gave significantly higher net return (₹ 24,898/ha) and benefi:cost ratio (1.19) over *'Prabhat'* and *'Krishna Hamsa'*. Pretilachlor 750 g/ha (pre-emergence) *fb* azimsulfuron 35 g/ha + NIS (0.25%) at 15 DAT recorded significantly higher yield attributes and yield fetching significantly higher net return (₹ 27,461/ha) and benefit : cost ratio (1.32).

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Saline tolerant plant growth promoting diazotrophs from rhizosphere of bermuda grass and their effect on rice

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ABSTRACT

In this study, beneficial effects of multifaceted growth promoting isolates for rice were investigated under two different salt concentrations in pot culture conditions. Two most salt tolerant isolates (TRY2) *Serratia* sp. and *Bacillus* sp. (TRY4) were selected and their growth promoting characters were studied under slight and moderate NaCl concentration. Isolates *Serratia* sp. and *Bacillus* sp. were able to fix the nitrogen and solubilise phosphate, synthesise IAA, acc deaminase regardless of NaCl concentration in most cases, under conditions of salinity. In pot experiments, plant growth (plant height, dry weight, and chlorophyll content) was promoted by bacterial inoculation with 2.9 and 5.8 g NaCl/kg soil. In this study, uptake nutrients (N^+, P^+, and K^+) were increased regardless of NaCl concentration with inoculation of *Serratia* sp. and *Bacillus* sp. and uptake of Na^+ was reduced with treatments receiving 5.8 NaCl/kg soil with *Serratia* sp. and *Bacillus* sp. isolates used as inoculants as compared to control. The present observations showed that strains *Serratia* sp. and *Bacillus* sp. partially alleviated the saline stress in rice, likely through the integration of several mechanisms that improve the plant response.

Key words: *Bacillus* sp, Plant growth promoting diazotrophs, Rice, Salinity stress, *Serratia* sp.

Salinity is one of the most serious environmental problems influencing crop growth throughout the world. In India, out of an estimated area of 187.7 million ha of total degraded lands, 8.1 million ha are salt affected in which 3.1 million ha are in the coastal regions (Sziderics *et al.* 2007). In most saline soils, sodium chloride is the predominant salt species, and its effect can be observed by decreased productivity or plant death (Munns 2005). Most of the plants possess several mechanisms to decrease the negative effects of salinity including regulation and compartmentalization of ions, synthesis of compatible solutes, induction of antioxidative enzymes, induction of plant hormones, and changes in photosynthetic pathways (Parida and Das 2005).

Cynodon dactylon Pers. (Poaceae), a hardy perennial grass, is one of the most commonly occurring weeds in India. It is widely accepted that the rhizosphere of any plant species is a unique niche harboring diversified bacterial communities, which serve as potential resource for bioprospecting. The rhizosphere of plant species growing profusely under stress-conditions harbors novel diazotrophs to meet their nitrogen requirement as observed in salt marsh grasses such as Sp. artina alterniflora, *Juncus roemerianus* (Bagwell and Lovell 2000), ligotrophic habitant *Drosera villosa* (Albino *et al.* 2006) and desert growing *Lasiurus* grass (Chowdhury *et al.* 2009).

The beneficial roles of diazotrophs to plants include nitrogen-fixation, mineral solubilization, production of phyto hormones such as indole acetic acid (IAA) and cytokinins. By virtue of such attributes, pre-treatment of seeds with a suspension of *Azotobacter* was shown to improve seed germination and plant growth (Ravikumar *et al.* 2004). An increasing supply of N through dinitrogen fixation may increase crop production in saline habitats (Yao *et al.* 2010). Diazotrophic bacteria are also PGPR, because of their competitive advantage in C-rich and N-poor environments (Kennedy *et al.* 2004). Several reports revealed that inoculation with free living diazotrophs like *Azotobacter*, *Pseudomonas* and *Azosp. irillum* increased the yield of rice by 20–55% (Mirza *et al.* 2006) and a strain of diazotrophic *Burkholderia* increased the rice plant biomass by 69% (Kennedy *et al.* 2004). Some isolations including genus *Pseudomonas* and *Bacillus* have been shown to have capacity to promote the wheat growth in salinated soils of Uzbekistan (Nautiyal *et al.* 2008). In other work, Palomino *et al.* (2009) reported that *Bacillus subtilis* is a Gram-positive sporulating bacterium able to adapt to wide variations in osmotic and saline strength. Studies

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showed that inoculation with *Azosp.irillum* spp. increased plant growth and the K^+/Na^+ ratio of two maize cultivars (Hamdia *et al*. 2004). Moreover, Yao *et al* (2010) reported that inoculation with *Pseudomonas putida* promoted cotton growth and germination under conditions of salt stress. Considering the efficacy, input cost and environmental safety, use of chemical fertilizers for crop production in saline soil is not a sound proposition.

The objective of this study was to identify the multi-faceted growth promoting salt tolerant diazotrophs from the rhizosphere of *Cynodon dactylon* and their effect on rice seedling in the presence and absence of salt stress under pot culture conditions.

MATERIALS AND METHODS

Isolation and screening of growth promoting diazotrophs

The soil samples were collected from the rhizosphere of *C. dactylon* at salinity affected agricultural fields of Trichy district, Tamilnadu on March, 2012. Diazotrophic microorganisms isolated using serial dilution technique (10^{-6} dilution) on selective N-free malate medium (NFM) (Piao *et al*. 2005) with 1% (w/v) NaCl concentration. 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 -20º C. The salt tolerances of diazotrophic bacterial isolates were determined on free nitrogen media supplemented with different NaCl concentrations of 0-10%.

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 PGMT vector supplied with TA cloning kit (Promega, 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).

Plant growth promoting features of isolates

Plant growth-promoting capabilities of the selected strains were studied in the presence and absence of NaCl (nitrogen fixation, phosphate solubilization, indole acetic acid, acc d synthesis and siderophore production).The nitrogen fixing capacity of the diazotrophic isolates was evaluated by estimating the acetylene reduction activity (ARA) (Bergersen 1980) using gas chromatograph (Chemito-7610) equipped with FID detector and Porapak N column (2m x 1/8"). Temperatures such as injector, detector, and column were maintained at 110°C, 120°C and 73°C, respectively. Nitrogen gas was used as carrier gas at the flow rate of 30 ml/min. After completion of ARA, the bacterial cells in the medium were evenly mixed and the protein concentration was measured (Lowry *et al*.1951). ARA results were expressed as n mole ethylene /mg/protein/h. An aliquot was taken from each pure culture for evaluation of plant growth promoting characteristics indole acetic acid (IAA) production was done using the method of Chandramohan and Mahadevan (1968). Solubilization of insoluble phosphates (Bunt and Rovira 1955) were also assayed. Siderophore production was checked using the Chrome Azurol S (CAS) agar plates (Dubey and Maheshwari 2004). ACC deaminase activity was measured by measuring the production of á-Ketobutyrate as described by Honma and Shimomura (1978).

Effects of NaCl and bacterial inoculation on rice growth

Pot experiments were conducted in order to evaluate the effect of NaCl and bacterial inoculation on growth of rice. Pots containing 400 g of dry-sterilized soil were supplemented to reach 0, 2.9 and 5.8 g NaCl/kg soil, which was prepared by adding 0, 1.08 and 2.25 g NaCl dissolved in 100 mL water. The treatment without exogenous addition of NaCl was considered as 0 g NaCl/kg soil concentration. Characteristics of the soil without added salt were pH (1:5 water)- 6.5, EC- 1.50 dS /m, organic matter -15 g /kg, available N-289 kg/ha, P-18.92 kg/ha, potassium - 134.34 kg/ha. Dehulled rice seeds var. *ADT43* were disinfected by soaking in 30% hydrogen peroxide and 70% ethanol for 10 min, and followed by rinsing several times in sterilized distilled water. The seeds were then pre-germinated in sterilized plain agar at room conditions for five days. For inoculum preparation, bacteria were grown in nutrient broth for 24 h at 37^0C, rinsed twice, and finally resuspended to the same initial volume using phosphate buffer pH7.0. Roots of seedlings, with the same size, were submerged three times in bacterial suspension adjusted to OD_{600} = 1 and planted in each pot supplemented or not with NaCl. Seedlings submerged in sterilized water were used as a control. Biometric observations such as plant height and dry matter production were taken at 4 weeks after the inoculation. In addition, chlorophyll content of rice leaves was estimated by the method of Hiscox and Israelstam (1979).

Inorganic elements

Leaf tissues were separated after harvesting and air-dried at 70°C for 5 days. Dried materials were ground and then digested in H_2SO_4 for the determination of total nitrogen (Kjeldahl method) or in a ternary solution (HNO_3: H_2SO_4 : $HClO_4$ = 10:1:4 with volume) for the determination of P, K and Na (Mani *et al.* 2007).

RESULTS AND DISCUSSION

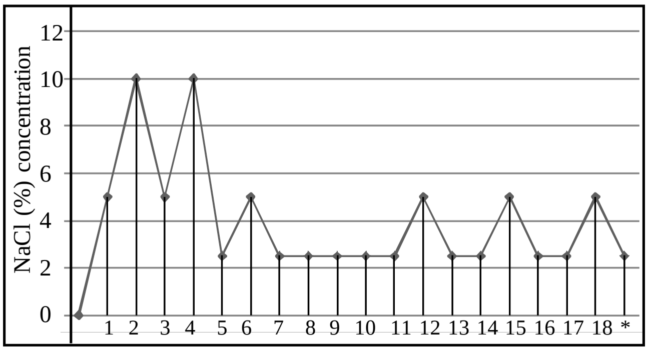
In the present study 18 pure cultures of diazotrophic organisms were isolated from saline soils and tested for tolerance of NaCl. Among the isolates tested, isolates C2 and C4 tolerated a higher content of NaCl (10%) than other isolates (Fig. 1). Due to their high tolerances, TRY2 and TRY4 were selected for further studies. Identification of isolates based on phenotypical and physiological criteria however was difficult, if the features displayed by a particular isolate are not fully identical with a described species. Utilization of PGPB has become a promising alternative to alleviate plant stress caused by salinity (Fu *et al.* 2010). Thus the molecular based method, 16S rDNA sequence analysis, was therefore chosen to identify the selected isolates. The isolates were identified as *Serratia* sp. (TRY2) and *Bacillus* sp. (TRY4) within the order Enterobateriales and Firmicutes, respectively (Table 1).

Table 1. Molecular characteristics of selected isolates

Code of the isolate	Length of 16sr DNA sequence (bp)	Most closely related organism	Similarity (%)
TRY2	1540	*Serratia* sp.	99
TRY4	1469	*Bacillus* sp.	99

Plant growth-promoting features

The isolates *Serratia* sp. and *Bacillus* sp. were able to reduce acetylene in both the presence and absence of NaCl. In the present study, the nitrogenase enzyme activity of the isolates ranged from 114 ± 4.63 to 136 ± 7.92 n moles of ethylene/mg of protein/h. The highest nitrogenase activity was exhibited by isolate *Bacillus* sp. with 2.9g NaCl concentration (136±7.92 n moles of ethylene/ mg of protein/ h) (Table 2).



TRY- 1 to 18; *Az 2 04

Fig. 1. Maximum salt tolerance level of diazotrophic isolates

The microbial synthesis of plant growth regulators is an important factor in soil fertility. Salt-tolerant IAA-producing bacterial strains *P. aureantiaca* and *P. extremorientalis* alleviated quite successfully the reductive effect of salt stress on percentage of germination (up to 79%), probably through their ability to produce IAA (Egamberdieva *et al.* 2008). They were able to produce indole-3-acetic acid (IAA) in saline conditions. In the present study, the maximum amount of IAA was produced by *Bacillus* sp. (18.8 ±1.0 µg/ml of sample) followed by *Serratia* sp. (14.8±0.8 µg/ml of sample) with 2.9 g/l NaCl concentration (Table 2).

Diazotrophic microorganisms showing phosphate solubilizing activity have beenreported. (Mayak *et al.* 2004). Phosphate solubilization activity was exhibited by both strains *Serratia* sp and *Bacillus* sp (Table 2). In the present study, the maximum amount of siderophore was produced by isolate *Bacillus* sp and *Serratia* sp with 2.9 NaCl concentration which produced 16.5±0.9 and 15.5±0.8 µg/ml of sample respectively. In other work, direct use of *P. putida* siderophores by plants has been demonstrated in many species, including dicot legumes such as peanut or monocots such as sorghum (Albino *et al.* 2006).

The results obtained demonstrated that the selected salt-tolerant bacterium containing ACC deaminase. *Pseudomonas fluorescens* strain TDK1 containing ACC deaminase activity enhanced the saline resistance in groundnut plants and increased yield as compared to plants inoculated with *Pseudomonas* strains lacking ACC deaminase activity (Saravanakumar and Samiyappan 2007). In the present study, maximum amount of ACC observed in *Bacillus* sp. (89.8 ± 1.1 nmoles of á-ketobutyrate /mg/h) followed by *Serratia* sp. (76.6 ± 2.3 nmoles of á - ketobutyrate/mg/h) with 5.8g/l NaCl concentration (Table

Table 2. Plant growth promoting rhizobacteria (PGPR) features of strains

Strain	NaCl (g/l)	[1]ARA	[2]IAA	[2]Phosphate solubilzation	[2]Siderophore production	[3]acc deaminase activity
Serratia sp.	0	117(±9.2)^{c}	11.7(±1.2)^{ab}	12.0(±0.9)^{ab}	11.0(±1.0)^{b}	13.9 (±1.0)^{d}
	2.9	122(±8.1)^{ab}	14.8(±0.8) ^{ab}	11.8(±0.7)^{ab}	15.5(±0.8)^{a}	34.8 (±1.4)^{c}
	5.8	118(±7.1)^{c}	10.3(±0.9)^{b}	14.8 (±1.2)^{a}	11.0(±0.6)^{b}	76.6 (±1.3)^{b}
Bacillus sp.	0	114(±4.6)^{ab}	11.8(±0.8) ^{b}	11.7 (±0.9)^{ab}	12.5(±0.8)^{b}	14.9 (±1.2)^{d}
	2.9	136 (±7.9)^{a}	18.8(±1.0)^{a}	12.8 (±0.7)^{ab}	16.5 (±0.9)^{a}	45.8 (±1.1)^{c}
	5.8	123 (±5.2)^{ab}	10.8(±1.0)^{b}	10.8 (±1.0)^{b}	10.5 (±1.0)^{b}	109.8(±1.2)^{a}

ARA: Acetylene reduction activity; IAA: Indole acetic acid; Values are mean (± standard error) (n=3) and values followed by the same letter in each column are not significantly different from each other as determined by DMRT ($p \leq 0.05$). [1]n moles of ethylene/ mg of protein/h, [2]µg/ml of sample, [3]n moles of a-ketobutyrate/mg/h

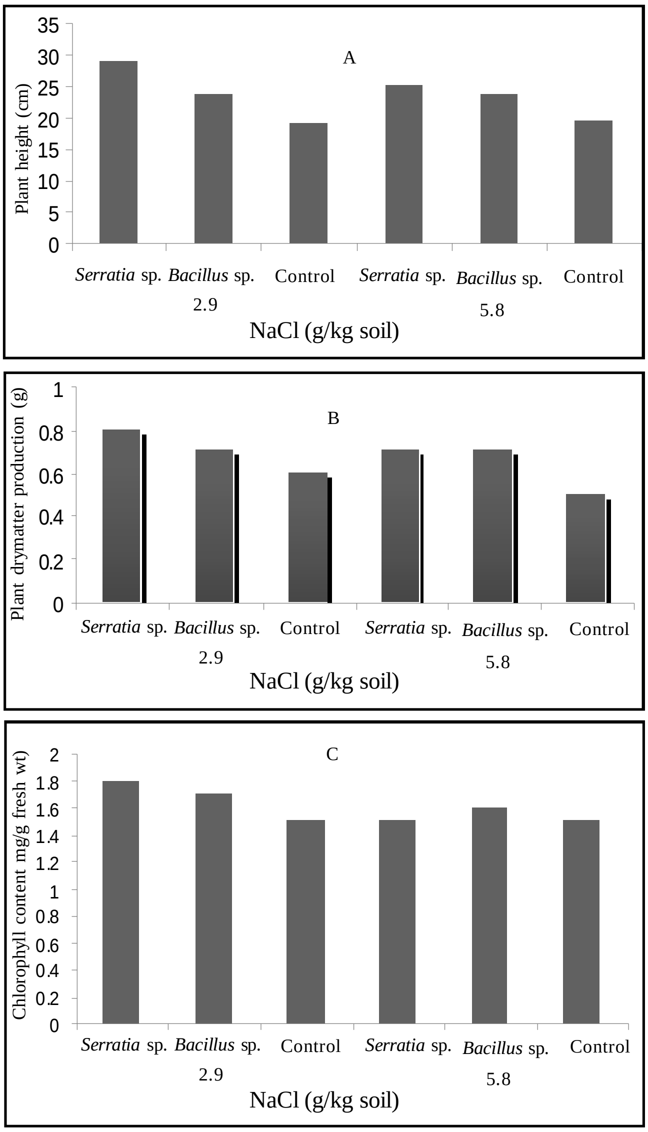


Fig 2. Effect of NaCl and diazotrophic PGPR on a) plant height, b) plant dry matter production and C) chlorophyll content of rice seedlings

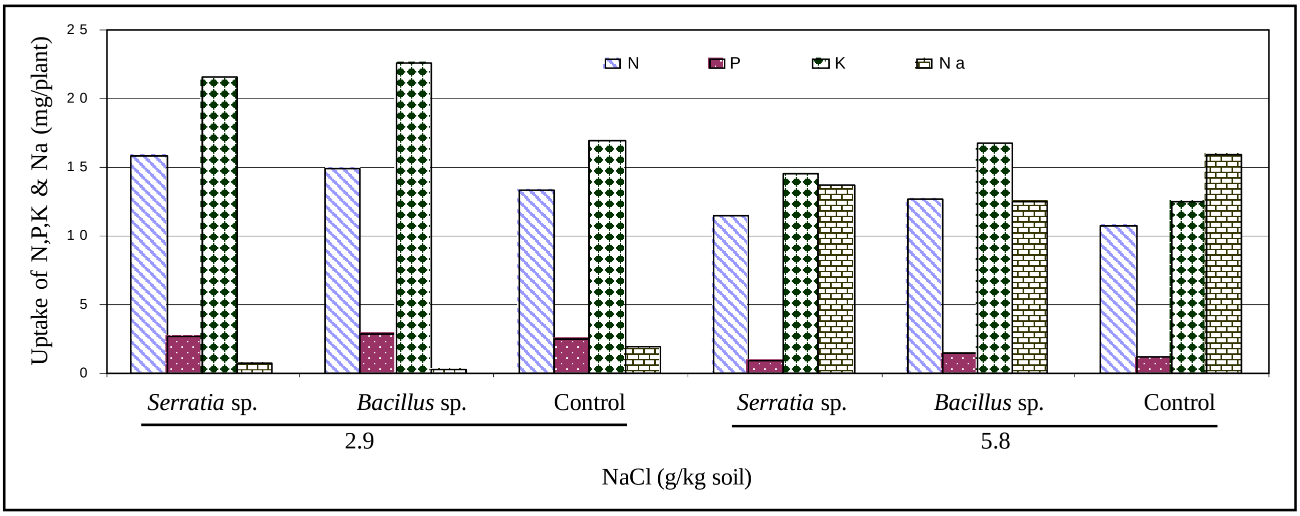
2). In other work, *Pseudomonas putida* UW4, which produces IAA and ACC deaminase, protected canola seedling from growth inhibition by high levels of salt (Mayak *et al.* 2004).

Rice growth and nutrient uptake

Electrical conductivities were 3.05 and 6.00 dS/m for 2.9 and 5.8 g NaCl/kg soil, respectively. Inoculation with strains *Serratia* sp. and *Bacillus* sp. increased plant growth, both normal and under saline stress. Similar work conducted by Mayak *et al.* (2004) that *Achromobacter piechaudii* having ACC deaminase activity significantly increased the fresh and dry weights of tomato seedlings grown in the presence of NaCl salt (up to 172 mM). In the present study, the treatment inoculation with strain *Bacillus* sp. in 1.5 g NaCl/kg soil, the increase in plant height (28.9± 1.3cm) and dry matter production (0.8 g) (Fig. 2). Salinity decreases carbon uptake by limiting photosynthesis, causing an over-reduction of photosynthetic electron chain, and redirecting the photon energy into processes that favour the production of reactive oxygen species (ROS) (Hichem *et al.* 2009). In our study, the maximum total chlorophyll (1.8± 0.3 mg) was observed in *Serratia* sp. with 2.9 NaCl g/kg. Diazotrophs may become selectively enriched to promote plant growth because of their competitive advantage in C-rich and N poor environments (Kennedy *et al.* 2004). Hence inoculation with diazotrophic bacteria might improve crop growth and productivity in such soils.

The PGPR strains varied greatly in their effect on the concentration of major mineral nutrients in rice leaves under soil salinity conditions. The N, P, K, and Na uptake per plant in the soil salinity treatment were significantly decreased compared to the non-salinity treatment (Fig. 3). The concentration of major cations in the non-salinity treatment was increased more with the PGPR treatment (*Serratia* sp. and *Bacillus* sp.) than the control, but Na^{+}

Fig. 3 Effect of NaCl and diazotrophic PGPR on uptake N, P, K and Na



uptake under soil salinity were decreased in the treatment inoculated with (*Serratia* sp.) and (*Bacillus* sp.) strains. Among the isolates, *Bacillus* sp. caused a lower uptake of Na (22.5 ± 0.6 mg) compared to *Serratia* sp. (Fig. 3). Our findings clearly showed that two isolates of *Serratia* sp. and *Bacillus* sp. were capable of exerting multifaceted beneficial plant-growth promoting activities under moderate saline conditions. These isolates could serve as potential bioinoculants for meeting the nutritional requirement of the crop plants in an eco-friendly and cost effective manner in saline soil conditions.

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Efficacy of clodinafop, isoproturon and their sequential application on *durum* wheat as influenced by fertilizer application

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ABSTRACT

Field experiments were conducted in Safsaf area in Libya during growing season of 2009-10 and 2010-11. The field infested with many weeds of mixed flora was used to investigate the efficacy of clodinafop, isoproturon and their sequential application in '*Zorda'* cultivar of *durum* wheat during different crop growth stages that is seedling, tillering and elongation in the presence or absence of diammonium phosphate (DAP) at 2.5 t/ha. Results revealed that all weed control treatments reduced weed density and dry weight recorded at 60 days of sowing. The least weed density was recorded from sequential application of clodinafop and isoproturon compared to weedy check. Herbicide application at seedling stage of crop growth in the absence of DAP was more effective in reducing weeds density and their dry weight. Crop height, effective tillers, biological yield, grain and straw yield, seed and harvest index increased due to sequential application of clodinafop and isoproturon during seedling stage in the presence of DAP compared to weedy check and elongation stage in the absence of DAP.

Key words: Clodinafop, Chemical control, *Durum* wheat, Isoproturon, Sequential application

Durum wheat (*Triticum durum* L.) occupies prime position among the food crops of Libya which is grown in the Jabal El-Akhdar in an area of 42,000 ha with an average production of 1.2 t/ha (Tayyeb 2003). It is usually grown in areas where irrigation facilities are comparatively less (rainfed farming). The better grain yield realization is not possible without proper weed management in this crop, because weeds compete with the crop for nutrient, water, space and sunlight. The yield reduction in *durum* wheat depends upon the type and density of associated weed flora (Singh *et al*. 1997, Singh and Yadav 1998, Bhat *et al*. 2006). Among the grass weeds, wild oat (*Avena fatua*) can cause yield reduction from 15-50% (Singh *et al*. 1995a, Walia and Brar 2001, Anon. 2009).

There are several weed species infesting wheat (Singh *et al*. 1995b) with large potential to lower crop yields due to severe competition. Weed stage, herbicide rates and fertilizers application impact weed control and crop-weed competition (Singh *et al*. 1995a, Singh *et al*. 1997, Balyan *et al*. 2000, Bhat *et al.* 2006). Herbicide efficacy can be increased by tank mixing, if compatible (Sharma *et al*. 2002, Singh *et al*. 2011) or their sequential application (bromoxynil and diclofop-methyl) for effective control of weed flora in wheat (Tayyeb 2012). Compatibility of herbicides depends on mixture partners (Yadav *et al*. 2009), but isoprouron has been found compatible with both grassy and broad-leaved herbicides (Singh *et al*. 1993) and can be used as tank mix or in sequence. Clodinafop which is effective against wild oat and isoproturon for grasses and broad-leaved weeds have recently been introduced in Libya. The present experiment was conducted to study the effect of sequential application of clodinafop and isoproturon in managing weeds of rain-fed *durum* wheat when applied at different crop stages in the presence or absence of fertilizer.

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MATERIALS AND METHODS

The experiments were conducted at the research farm of Agriculture Research Center in Safsaf (22° 46´ N, 32° 39´ E, 490 MSL), Libya during 2009-10 and 2010-11. The soil of the experimental field was deep silty loam, typic lithic xerochrepts, low in organic carbon and slightly alkaline (pH 7.8). The region has a cold winter suited for wheat. Average annual rainfall was 521 to 561 mm. The experiment field was infested with mixed population of *Avena fatua*, *Bromus tectorum*, *Lolium multiflorum*, *Medicago* sp., *Brassica tournefortii*, *Chenopodium album*, *Anagallis arvensis* and *Convolvulus arvensis*. The weed control treatments were clodinafop at 280 g/ha, isoproturon at 1.2 kg/ha and their sequential application at the above rates along with weedy check treatment. Spraying was done at the 2-3 leaf stage of crop (S1), tillering stage (S2) and elongation stage (S3) in the presence of diamonium phosphate (DAP) fertilizer at 250 kg/ha (F1) or without fertilization (F0).

The experiment was conducted in a split plot design with four replications. The durum wheat cultivar '*Zorda*' [Gerardo V Z 469 – AA "S" – CM 363 – 5M - 4Y – 3M – 0Y] was sown using 90 kg/ha seed on 11 and 15 November in 2009 and 2010, respectively. The herbicides were in the main plots, time of herbicidal application in the subplots and fertilizer in the sub-sub-plot in a plot size of 5.2 x 2.4 m. The data on weed density were recorded 60 days after sowing (DAS) using 50 x 50 cm quadrant. The plant height, effective tillers/m, biological yield, grain and straw yield (t/ha), harvest index, weed dry matter of both grass and broad-leaved weeds were recorded at the time of harvest. Data were submitted to analysis of variance with least significant differences test ($P < 0.05$).

RESULTS AND DISCUSSION

Weed density

All weed control treatments reduced weed density significantly at 60 DAS than the weedy check (Table 1). The minimum grass weed density was recorded in sequential application during both the seasons compared to the control. Effect of time of application during different crop growth stages was not significantly different on the grassy weed density during the first season, however, during the second season, highly significant differences were apparent due to sequential application when applied at the seedling stage. Moreover, grassy weed density was significantly reduced by herbicides in the presence of DAP fertilizer. The interaction of herbicides and crop growth stages was highly significant during both the years. There was a highly significant difference in grassy weed density due to interaction of stage of crop growth and fertilizer for grassy weeds density during 2009-10 and 2010-11, and a highly significant effect of interaction of herbicide x stage of crop growth x fertilizer on grassy weed density in the season 2010-11.

The broad-leaved weeds density recorded significant variations due to herbicidal treatment. Sequential application gave the least density in the first season, but there was no significant effect in the broad-leaved weeds density due to different crop growth stages in both the seasons (Table 1). The fertilizer (DAP) significantly increased broad-leaved weeds density compared to no fertilization during both the seasons. The interaction of herbicide and fertilizer in the first season was highly significant. Good broad-leaved weeds control was also reported by Sharma *et al.* (2002) by tank mix applications of isoproturon with chlorsulfuron.

Weeds dry weight

Total weeds (grassy + broad-leaved) dry weight was significantly decreased due to weed control treatments. The least dry weight of 0.54, 0.01 kg/m^2 was recorded from sequential application of clodinafop and isoproturon compared to the weedy check (1.63, 2.33 kg/m^2) for both the seasons (Table 2). Minimum weed dry weight 0.51 kg/m^2 was statistically significant due to weed control at seedling stage in 2nd season. However, weedy dry wet was statistically on par with all stages of crop growth in the first season (Table 2). Total weed dry weight was not affected by the application of fertilizer during both the seasons, which might be due to poor control of broad-leaved weeds in the herbicide treated plots. Meanwhile, the interaction (herbicides x time of application) effect in weed dry wet was independent because of significant differences and only herbicide x stage of application was significant during the first season.

Effect on crop

Crop plant height was significantly more in the first year of study due to application of herbicides over weedy check, but the differences were non-significant during second year (Table 2). Similarly, application of herbicides at the seedling stage resulted in taller plants, but only dur-

Table 1. Weeds density as affected by herbicidal treatments at different wheat crop growth stages in the presence or absence of DAP fertilizer

Treatment	Grass weeds (no./m^2)		Broad-leaved weeds (no./m^2)	
	2009-10	2010-11	2009-10	2010-11
Herbicides (H)				
Clodinafop	3.5	3.0	9.2	8.4
Isoproturon	7.0	6.8	3.2	8.2
Clodinafsop *fb* isoproturon	2.2	2.9	2.5	8.5
Weedy check	11.2	12.8	9.7	8.9
LSD (P=005)	0.9	0.6	2.3	NS
Time of application (stage of growth) (S)				
Seedling	6.8	6.2	8.5	8.8
Tillering	7.3	5.8	8.3	8.4
Elongation	6.9	5.4	7.9	8.3
LSD (P=0.05)	NS	0.54	NS	NS
Fertilization by DAP (F)				
Unfertilized	8.1	6.4	7.5	9.5
Fertilized	5.9	5.3	4.8	7.5
LSD (P=0.05)	1.4	0.1	0.4	0.2
Interactions				
H X S	*	**	NS	NS
H X F	**	**	**	NS
S X F	*	NS	NS	**
H X S X F	NS	**	NS	NS

Table 2. Effect of herbicides, stage of spraying and DAP fertilization on crop and weeds

Treatment	Plant height (cm)		Total weed dry weight (t/ha)		Effective tillers (no./ m^2)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Herbicides						
Clodinafop	44.5	59.0	8	3	73	66
Isoproturon	44.9	62.8	6	1	81	76
Clodinafop *fb* isoprooturon	40.6	63.5	5	0	96	88
Weedy check	31.8	61.6	16	23	66	51
LSD (P=0.05)	7.93	NS	2	2	9	9
Crop growth stage at spraying						
Seedling (S1)	48.5	57.1	8	5	1.1	80
Tillering (S2)	37.3	63.5	8	6	68	73
Elongation (S3)	35.5	58.6	10	10	68	51
LSD (P=0.05)	6.6	NS	1	1	9	6
Fertilization						
Unfertilized	42.9	62.2	7	6	75	58
Fertilized	38.0	61.1	7	7	83	77
LSD (P=0.05)	NS	NS	NS	NS	5	5

fb = followed by, NS=Not Significant; * =Significant (P<0.05); ** = Highly significant (P<0.01).

ing the first season. Effect of DAP fertilization was non-significant on plant height in both the seasons (Table 2). Two or three way interactions were non-significant except herbicide x stage during the first season.

Effective tillers are the main yield attributing characters which were significantly influenced by the weed control treatments. Maximum tillers density of 96 and 88 was recorded in the sequential application of clodinafop followed by isoproturon compared to 66 and 51 in the check (Table 2). Among herbicides, lowest tillers were recorded with alone application of clodinafop which may be due to no control of broad-leaved weeds. Time of herbicidal application significantly effected the effective tillers in both the years of study, highest being at seedling stage. DAP fertilizer increased tillers significantly compared to no fertilizer application. All the interactions were significant except fertilizer and stage of application.

The biological yield was highly significant due to herbicided treatments and time of application in the two seasons of the study (Table 3). Maximum bio-yield 1.84, 3.3 t/ha were recorded due to sequential application compared to the check treatments 1.5 and 0.9 t/ha during 2010 and 2011, respectively. Herbicide application at seedling stage produced 1.8 and 3.2 t/ha biological yield compared to spraying at elongation stage (1.5 and 0.9 t/ha during 2010 and 2011, respectively). The DAP fertilization was not effective in the biological yield during both the years of study. All the treatments of clodinafop, isoproturon and their sequential application and the check were statistically at par with each other in respect of grain yield during the second year which was observed during first year. The same response regarding to the effect of the time of herbicides application in the presence or absent of DAP and the trial factors interaction was recorded in both the seasons. Whereas, straw yield under herbicidal treatments and time of application was significantly more than the check treatment when applied at 2-3 leaves stage of crop stage. The higher straw yield in sequential herbicidal application might be due to better weed control which ultimately increased the yield attributes without no effect of DAP application on the straw yield in 1st and 2nd year of the study.

Harvest index was significantly affected due to varying herbicides treatment and time of application in 2nd season. Harvest index was higest by sequential application of clodinafop and isoproturon at the S1 stage of crop growth without effect of DAP application in both the seasons. Sequential application of clodinafop 280 g in 500 l water/ha and isoproturon 1.2 l in 500 l water/ha was compatible and there was no adverse effect on efficacy of both the herbicides against complex weed flora and grain yields of wheat, however, these herbicides alone or sequential will not be effective where resistance weeds are prevalent.

Table 3. Effect of herbicides, stage of spraying and DAP fertilization on wheat yield

Treatment	Biological yield (t/ha)		Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Herbicides								
Clodinafop	1.6	2.8	0.50	0.62	1.1	2.1	29	22
Isoproturon	1.9	2.9	0.41	0.66	1.5	2.2	21	23
Clodinafop *fb* isoproturon	1.8	3.3	0.42	0.74	1.4	2.9	23	22
Weedy check	1.5	1.9	0.43	0.21	1.1	0.6	27	11
LSD (P=0.05)	0.1	0.4	NS	0.20	NS	0.6	0.0	0.1
Crop growth stage at spraying								
Seedling	1.8	3.2	0.45	0.74	1.4	2.5	24	23
Tillering	1.8	2.9	0.43	0.58	1.4	2.4	23	19
Elongation	1.5	0.9	0.39	0.30	1.1	0.6	25	32
LSD (P=0.05)	0.0	0.3	NS	NS	0.0	0.8	NS	8
Fertilization								
Unfertilized	1.7	2.4	0.43	0.83	1.3	1.6	25	33
Fertilized	1.7	2.7	2.76	0.84	1.3	1.9	26	30
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

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Bioefficacy of pinoxaden in combination with other herbicides against complex weed flora in wheat

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ABSTRACT

An experiment to evaluate the bioefficacy of pinoxaden in combination with broad-leaved herbicides 2,4-D, metsulfuron and carfentrazone in wheat was conducted at Hisar during 2006-07 and 2007-08. Dominant weed flora of the experimental fields were *Phalaris minor* among grassy weeds and *Chenopodium album, Melilotus indicia* and *Rumex dentatus* among broad-leaved weeds. The tank mix application of pinoxaden with broad-leaved herbicides proved significantly effective in reducing density and dry weight of weeds and gave 85-100 % control of broad-leaved and 100% control of *P. minor*. Tank mixing of carfentrazone with pinoxaden although caused injury in terms of yellowing of tips but injury symptoms disappeared within 15 days after spray and did not result in any detrimental effect on grain yield of wheat. Application of broad-leaved herbicides 7 days earlier than pinoxaden or 7 days after application of pinoxaden also proved effective in controlling *P. minor* and broad-leaved weeds. Tank mixture of 2,4-D with pinoxaden did not result any antagonistic effect as anticipated as is evident by number of spikes, plant height, and number of grains per panicle and grain yield with use of 2,4-D were at par with weed free check.

Key words: Antagonism, Carfentrazone, Metsulfuron, Pinoxaden, Tank mixture, 2,4-D

Little seed canary grass (*Phalaris minor*), a problematic weed of wheat in rice-wheat cropping system in north-west India has developed resistance against isoproturon (Malik and Malik 1994, Malik and Singh 1995). To tackle the resistance problem, clodinafop, fenoxaprop and sulfosulfuron have been recommended for control of grassy weeds in wheat (Walia *et.al.*1998, Chhokar and Malik 2002). Continuous use of same herbicide for many years resulted in development of resistance against some weeds which happened in case of isoproturon. Therefore, alternate herbicides were needed to evaluate to tackle the resistance problem. Earlier studies conducted on cross resistance in Punjab and Haryana of isoproturon and alternate herbicides (clodinafop, fenoxaprop and sulfosulfuron) revealed that efficacy of clodinafop has decreased from 100% during 2004-05 to 78.1% during 2006-07 (Walia *et al.* 2007). In Haryana, GR_{50} values of fenoxaprop and sulfosulfuron in 2002-03 have increased 6.2 and 2.3 times as compared to 1996-97 (Yadav and Malik 2007). The herbicide pinoxaden 5 EC at 40 - 50 g/ha was found very effective and recommended for the control of grassy weeds in wheat especially against clodinafop resistant *P. minor* biotypes without any residual toxicity to succeeding rice and sorghum crops (Walia *et al.* 2007, Punia *et al.* 2008, Punia and Yadav 2010).

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Several broad-leaved weeds are becoming a serious problem along with grassy weeds in wheat. There is need for tank mix or sequential application of herbicides like 2,4-D, carfentrazone and metsulfuron for the control of complex weed flora. Tank mix application of 2,4-D with clodinafop and fenoxaprop gave reduced control of grassy weeds because of antagonism between 2,4-D and these grass weed killers (Banga and Yadav 2004, Punia *et al.* 2004, Yadav *et al.* 2010). Keeping this in view, efforts were made to explore the possibility of using pinoxaden in tank mixture with 2,4-D, metsulfuron and carfentrazone for satisfactory control of complex weed flora in wheat.

MATERIALS AND METHODS

An experiment to evaluate the bioefficacy of pinoxaden 5 EC in combination with broad-leaved weeds in wheat was conducted during *Kharif* and *Rabi* seasons of 2006-07 and 2007-08, at Agronomy Research Area of CCS Haryana Agricultural University, Hisar. The experimental soil was sandy loam (Typic Ustochrepts) with 61% sand, 22.1% silt and 19.1% clay, medium in fertility with 0.29% organic carbon and pH of 8.2. Wheat variety '*PBW-343*' was drilled on November 14, 2006 and November 5, 2007 during first and second year respectively, by FIRBS method, in a plot size of 6.0 x 2.1 m^2, by using seed rate of 87.5 kg/ha. The study was arranged in randomized block design and was replicated thrice. Recommended dose of fertilizers and irrigations were applied uniformly. The treatments comprising of pinoxaden 5 EC at 45 g/ha alone and in combination with metsulfuron, carfentrazone or 2,4-D as tank mixture, sequential application of these broad-leaved herbicides before or after pinoxaden use at recommended rates were applied at 40 DAS by flat fan nozzle delivering 375 l/ha volume. Observations for weed population and their dry matter accumulation were recorded at 30 DAT with the help of random quadrate (0.5 x 0.5 m) at four places in a plot and then converted into per m^2. This data was subjected to square root ($\sqrt{x+1}$) transformation to normalize their distribution before analysis. Data on per cent visual control by herbicides on 0-100 scale, yield attributes and grain yield was recorded at harvest which was statistically analyzed using analysis of variance.

RESULTS AND DISCUSSION

Experimental field was infested with natural population of grassy (69%) and broad-leaved weeds (31 %) during both the years. The dominant weeds were little seed canary grass (*P. minor*) among grassy weeds and common lambs quarters (*Chenopodium album*), yellow sweet clover (*Melilotus indica*) and golden dock (*Rumex dentatus*) were present as broad-leaved weeds.

Effect on weeds

The density and dry mater of weeds decreased significantly due to different herbicide treatments as compared to untreated check at 30 days after treatment (Table 1). Although pinoxaden at 45 g/ha provided excellent control (95-100%) of grassy weeds but did not show any efficacy against broad-leaved weeds as shown by density and biomass of weeds. The tank mix application of pinoxaden with broad-leaved herbicides proved significantly effective in reducing density and dry weight of weeds and gave 85-100 % control of broad-leaved and 100% control of *P. minor*. This is in conformity with the findings of Yadav *et al.* (2009). Tank mixture of 2,4-D with pinoxaden did not result any antagonistic effect as anticipated. Hence pinoxaden can safely be used as tank mix with 2,4-D, metsulfuron or carfentrazone with no loss of herbicide efficacy.

Effect on crop

Tank mixing of carfentrazone with pinoxaden although caused injury in terms of yellowing of tips but injury symptoms disappeared within 15 days after spray and did not result in any detrimental effect on grain yield of wheat. Number of spikes, plant height, and number of grains per panicle and grain yield were significantly affected due to various herbicide treatments. Maximum Number of spikes per m.r.l. with tank mixture of pinoxaden + metsulfuron were 151 and 188, during 2006-07 and 2007-08, respectively and were statistically at par with all combinations of pinoxaden + 2,4-D, pinoxaden+ carfentrazone, or their sequential applications with pinoxaden and weed free treatment. Number of grains per panicle was maximum (49) in weed free, which were sta-

Table 1. Effect of herbicidal treatments on density and per cent control of weeds in wheat

Treatment	Dose (g/ha)	Density of *P. minor* (no./m^2) at 30 DAT		Dry wt. of weeds (g/m^2) at 30 DAT		Visual control (%) Grassy weeds		Visual control (%) BLWs		Crop injury at 10 DAT	
		2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Pinoxaden	45	1.4 (1)	1 (0)	12.9	17.6	95	100	0	0	0	0
Pinoxaden + carfentrazone-ethyl	45 + 20	1(0)	1(0)	3.5	3.2	100	100	85	87	5	3
Pinoxaden + metsulfuron-methyl	45 + 4	1(0)	1(0)	2.1	0	100	100	98	100	0	0
Pinoxaden + 2,4-D	45 +500	1(0))	1(0)	2.9	3.1	100	100	90	93	0	0
Carfentrazone-ethyl *fb* pinoxaden	20 and 45	1(0)	2(3)	4.5	4.8	100	89	87	90	0	0
Metsulfuron-methyl *fb* pinoxaden	4 and 45	1(0)	1(0)	0	0	91	100	92	100	0	0
2,4-D *fb* pinoxaden	500 and 45	1 (0)	1.4(1)	2.8	3.5	100	93	94	90	0	0
Pinoxaden *fb* Carfentrazone-ethyl	45 and 20	1.7(2)	1(0)	3.3	2.9	91	100	90	90	0	0
Pinoxaden *fb* metsulfuron-methyl	45 and 4	1(0)	1(0)	0	1.7	100	100	100	98	0	0
Pinoxaden *fb* 2,4-D	45 and 500	1(0)	1(0)	3.3	2.6	100	100	91	94	0	0
Carfentrazone-ethyl	20	5.1(25)	5.4(28)	19.6	24.6	0	0	92	90	0	0
Metsulfuron-methyl	4	6.4(40)	6.6(43)	27.7	32.8	0	0	95	100	0	0
2,4-D	500	5.7(32)	6.1(36)	24.5	29.4	0	0	94	93	0	0
Weedy	-	5.9(34)	6.5(41)	47.8	52.6	0	0	0	0	0	0
Weed-free	-	0(1)	0(1)	0	0	100	100	100	100	0	0
LSD (P=0.05)		0.42	0.61	1.8	1.6	2.1	1.4	2.5	5.3	-	-

Table 2. Effect of herbicidal treatments on yield attributes of wheat

Treatment	Dose (g/ha)	Number of spikes per meter row length		Grains/spike		1000-grain weight (g)		Grain yield (t/ha)	
		2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Pinoxaden	45	146	180.3	49.7	51.0	43.1	42.7	4.26	4.55
Pinoxaden + carfentrazone-ethyl	45 + 20	150.0	186.0	50.0	50.0	43.2	43.3	4.65	4.82
Pinoxaden + metsulfuron-methyl	45 + 4	151.3	188.2	50.0	52.0	43.5	44.3	4.69	4.86
Pinoxaden + 2,4-D	45 + 500	149.7	186.6	49.3	50.0	43.3	44.0	4.64	4.80
Carfentrazone-ethyl *fb* pinoxaden	20 and 45	153.7	187.6	49.7	502	43.2	43.5	4.51	4.64
Metsulfuron-methyl *fb* pinoxaden	4 and 45	153.3	188.0	50.3	51.0	43.2	43.6	4.59	4.78
2,4-D *fb* pinoxaden	500 and 45	149.0	185.7	51.0	50.0	43.2	42.9	4.56	4.82
Pinoxaden *fb* Carfentrazone-ethyl	45 and 20	152.0	185.0	50.0	50.3	43.1	42.7	4.59	4.72
Pinoxaden *fb* metsulfuron-methyl	45 and 4	150.0	186.0	50.7	50.7	43.1	43.3	4.66	4.86
Pinoxaden *fb* 2,4-D	45 and 500	149.0	184.0	49.0	49.0	43.4	43.9	4.60	4.79
Carfentrazone-ethyl	20	122.0	170.0	47.0	50.0	43.0	43.7	3.70	3.82
Metsulfuron-methyl	4	123.7	169.7	47.2	50.0	43.5	43.6	3.83	3.95
2,4-D	500	121.0	168.7	48.0	48.7	42.4	42.9	3.65	3.84
Weedy	-	121.7	167.7	48.3	47.7	43.0	43.0	2.93	3.26
Weed free	-	150.1	188.0	51.0	52.7	43.7	43.8	4.67	4.88
LSD(P=0.05)		7.4	7.9	2.4	2.1	NS	0.9	0.48	0.24

tistically at par with all combinations of pinoxaden + metsulfuron and pinoxaden alone at both the application rates.

In 2006-07, maximum grain yield (4.69 t/ha) was recorded with use of pinoxaden + metsulfuron at 45+ 4 g/ha which was at par with weed free (4.67 t/ha) and all combinations of pinoxaden and broad-leaved herbicides (Table 2). Similarly in 2007-08, maximum grain yield (4.88 t/ha) was recorded in weed free followed by pinoxaden +metsulfuron (4.86 t/ha), pinoxaden + carfentrazone (4.82 t/kg) and pinoxaden+ 2,4-D (4.80 t/ha). Presence of weeds throughout the growing season brought about 37.2 and 33.1 % reduction in grain yield as compared to weed-free check during 2006-07 and 2007-08, respectively.

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Resource conservation techniques and pendimethalin for control of weeds in *durum* wheat cultivars

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ABSTRACT

A field experiment was conducted on *durum* wheat during 2005-06 and 2006-07 to study the effect of resource conservation techniques (RCTs), cultivars and pendimethalin herbicide on weeds and yield of *durum* wheat. Zero tillage (ZT) significantly reduced the population of *Phalaris minor* and dry matter of grassy weeds as compared to conventional tillage (CT) and furrow irrigated raised bed system (FIRBS), however, density and dry matter of broad-leaved weeds was higher under ZT that under CT and FIRBS. Grasses were predominant under FIRBS as compared to CT. Cultivar *'PDW 291'* had less density and dry weight of weeds having superior yield attributes and produced significantly higher grain yield over *'WH 896'* and *'WH 912'*. Pre-emergence application of pendimethalin (1.5 kg/ha) reduced the density and dry matter accumulation by grassy as well as broad-leaved weeds effectively and increased the wheat grain yield by 25% over weedy check.

Key words: *Durum* wheat, Pendimethalin, Resource conservation techniques, Weeds, Yield

Durum wheat (*Triticum durum*) is the second most important species, after *Triticum aestivum*, occupying nearly 10% of the wheat area in India. Earlier its cultivation primarily confined to the rainfed conditions of central and southern India, with very small area in Punjab and West Bengal mainly due to high susceptibility to rusts and foliar diseases. However, with the development of high yielding semi-dwarf type, a large area has come up in Punjab under irrigated conditions, where it was popularized to contain Karnal bunt disease. Now efforts are on to export it to earn foreign exchange (Anonymous 2009). The profitability, productivity and sustainability of rice-wheat cropping systems are at stake. Now, farmers need technologies which are more favorable for lowering their cost and improving their returns. They need environment friendly technologies those have less deleterious effect on natural resources. Under such situations, conservation agriculture based resource conservation techniques (RCTs) *i.e.* zero tillage (ZT) and furrow irrigated raised bed system (FIRBS) could be a valid option to reduce the turn-around time, water, cultivation cost and to ensure establishment of good crop stand of wheat without loss in productivity and sustainability of natural resources.

Since variation in planting system modifies macro- and micro-environment to which plants are exposed, there is a need to identify most appropriate variety best suited for each of the planting system. It has been reported that both *T. aestivum* and *T. durum* wheat varieties differ in physio-morphological traits, thus there is need to identify most appropriate one from the existing recommended varieties of durum wheat species under prevailing conditions in context to changes in planting pattern. Much of the research work was focused on such issues in recent past but mainly in bread wheat (*Triticum aestivum*). Since *durum* wheat may also find ample scope in near future in India due to changing food habits, it was realized to conduct the present investigation to study the effect resource conservation techniques, cultivars and pendimethalin on weeds and performance of durum wheat.

MATERIALS AND METHODS

A field experiment was conducted on *durum* wheat during *Rabi* of 2005-06 and 2006-07 in a field having soil sandy loam in texture, slightly alkaline in reaction (8.2), low in available N (209.6 kg/ha), medium in available P (15.7 kg/ha) and high in available K (408.0 kg/ha) at Research Farm, Department of Agronomy, CCS Haryana Agricultural University, Hisar, India. The experiment including three resource conservation techniques, *viz.* ZT, CT and FIRBS in main plot and three cultivars (*WH 896*, *WH 912* and *PDW 291*) and two weed control treatments (pendimethalin 1.5 kg/ha and weedy check) in sub-plots was laid out in split-plot design in four replications. ZT plots were kept undisturbed after harvesting of mungbean

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crop. CT plots were prepared by harrowing thrice followed by cultivator and planking. The plots marked for FIRBS were harrowed thrice followed by cultivator twice and a planking to prepare a finer seed bed. Beds were made using a bed planter, having bed dimension of 37.5 on top with 30 cm wide furrows (between two beds). Under ZT plots, glyphosate (1.5 kg/ha) was sprayed 7 days before sowing to control the pre-emerged perennial weeds. The experimental crop was raised using recommended dose of N (150 kg/ha) and P_2O_5 (60 kg/ha) through DAP and urea. As per treatments, sowing under ZT, CT and FIRBS was done using ZT drill, CT drill and bed planter each at a seed rate of 100 kg/ha on 12th November 2005 and 14th November 2006 during first and second year of experimentation, respectively.

Pendimethalin (1.5 kg/ha) was applied as pre-emergence using knapsack sprayer fitted with flat fan nozzle using a spray volume of 500 l/ha. Weeds from two randomly selected places of 1 m^2 were counted species wise, removed and dried at 70^{0}C for recording the dry matter at 30 and 60 days after sowing (DAS). All other agronomic practices were adopted as per recommended package of practices. The crop was harvested on 7th April 2006 during the first year and 13th April 2007, during the second year. Harvesting was done manually by cutting the plants from the ground level with the help of sickles. The crop was left in the field for one week for sun drying. The crop was threshed plot wise with the help of mini-thresher and the grain yield was recorded. Data was analyzed by the method of analysis of variance (ANOVA) as described by Panse and Sukhatme(1985).

RESULTS AND DISCUSSION

Effect on weeds

During both the years, ZT, CT and FIRBS were dominated by similar weed species, *viz. Phalaris minor, Avena ludoviciana, Chenopodium album, Anagallis arvensis* and *Melilotus indica*. Weeds like *Coronopus didymus, Convolvulus arvensis* and *Rumex dentatus* were present in lesser number and were therefore grouped as miscellaneous weeds (Table 1).

Among the complex weed flora at 30 DAS, the grassy weeds accounted for 30.2, 41.1 and 39.4% during 2005-06 and 32.1, 40.6 and 42.2% during 2006-07 under ZT, CT and FIRBS, respectively. The corresponding values for broad-leaved weeds were 69.8, 58.9 and 60.6%, during 2005-06 and 67.9, 59.4 and 57.8% during 2006-07. ZT significantly lowered the population of *P. minor* (14.1 plants/m^2) as compared to FIRBS (27.3 plants/m^2) and CT (24.0 plants /m^2) at 60 DAS (Table 2). This could be due to undisturbed inter-row space in ZT, where seeds of *P. minor* lying at lower depths did not germinate. Malik *et al.* (2000a) have already reported less germination of *P. minor* under ZT. In FIRBS and CT, repeated ploughing brought the weed seeds on upper soil surface and create favorable conditions for weed seed emergence. Tillage practices did not influence the population of *A. ludoviciana*, while the population of *C. album, A. arvensis* and miscellaneous broad-leaved weeds were significantly lower under CT than recorded under ZT. Singh *et al.* (2002b) and Yadav *et al.* (2002) also reported similar results. ZT significantly reduced the dry matter accumulation by grassy weeds to the tune of 27.9 and 32.3% over CT and FIRBS,

Table 1. Per cent composition of weed flora in weedy check at 30 DAS

Weed species	2005-06			2006-07		
	ZT	CT	FIRBS	ZT	CT	FIRBS
Grassy						
Phalaris minor	16.5	27.2	26.5	17.1	27.2	29.0
Avena ludoviciana	13.7	13.9	12.9	14.9	13.4	13.2
Total	30.2	41.1	39.4	32.1	40.6	42.2
Broad-leaved						
Chenopodium album	19.5	16.3	17.9	21.3	16.0	16.5
Melilotus indica	16.2	15.5	14.1	16.5	15.9	14.0
Anagallis arvensis	17.3	14.4	13.4	13.4	13.2	13.2
Rumex dentatus	16.7	12.7	15.3	16.8	14.3	14.1
Total	69.8	58.9	60.6	67.9	59.4	57.8

ZT-Zero tillage, CT- Conventional tillage, FIRBS- Furrow irrigated raised bed system respectively (Table 3). Better tilth and exposure of weed seeds to upper soil in CT and FIRBS might have increased the population and thereby dry weight of weeds in these systems. Malik *et al*. (2000b) also reported similar results. The dry matter accumulation by broad-leaved weeds was significantly higher under ZT in comparison to CT. This might be due to more congenial environment in ZT for broad-leaved weeds. These results are in conformity with the earlier findings (Singh *et al*. 2002a, Yaduraju and Mishra 2002).

On an average, cultivar *'PDW 291'* significantly reduced the population of *P. minor* (20.0 /m^2) as compared to cultivar '*WH 896*' (23.5/m^2). Population of *A. ludoviciana*, *C. album, M. indica* and miscellaneous broad-leaved weeds as well as dry matter accumulation of both grassy and broad-leaved weeds was not much influenced by different cultivars. Similar results were reported earlier by Bhat (2005).

Pre-emergence application of pendimethalin significantly lowered the density of all the weed species in comparison to weedy check plots during both the years (Table 2). Pendimethalin on an average reduced the dry matter accumulation by grassy and broad-leaved weeds to the extent of 71.6 and 59.2%, respectively at 60 DAS (Table 3). Similarly, 62% control of both grassy and broad-leaved weeds by pendimethalin was observed by Singh and Khole (1998), and Shukla and Mishra (2006).

Effect on crop

In general, yield attributes, grain, straw and biological yields were comparatively higher in second year. This might be due to combined effect of rainfall and comparatively low temperature in the month of February and March, which favored spike and grain development during the month of March, leading to increase in growing period of the crop.

The yield components of wheat crop, *viz*. number of spikes/mrl, spike length, grains per spike and 1000-grain weight were not influenced significantly by various resource conservation techniques (Table 3).

Table 2. Effect of resource conservation techniques, cultivars and weed control treatments on density (no./m^2) of different weeds

Treatment	*P. minor*		*A. ludoviciana*		*C. album*		*A. arvensis*		*M. indica*		Othor	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
RCTs												
ZT	3.6	3.6	3.8	3.7	3.9	3.8	3.9	3.7	3.6	3.6	3.9	3.6
	(14.5)	(13.7)	(14.1)	(13.9)	(16.6)	(15.8)	(16.3)	(13.8)	(13.7)	(13.5)	(15.5)	(13.3)
CT	4.7	4.8	3.7	3.8	3.7	3.6	3.8	3.5	3.6	3.6	3.5	3.5
	(23.6)	(24.5)	(13.9)	(14.0)	(14.1)	(13.1)	(15.2)	(12.8)	(12.8)	(12.8)	(12.3)	(12.1)
FIRBS	5.1	5.1	3.7	3.6	3.9	3.7	3.8	3.8	3.6	3.6	3.8	3.6
	(27.4)	(27.2)	(13.6)	(12.9)	(15.9)	(14.2)	(14.6)	(12.7)	(13.0)	(12.8)	(14.6)	(13.3)
LSD (P=0.05)	0.2	0.2	NS	NS	0.1	0.1	0.1	0.1	NS	NS	0.1	0.1
Cultivars												
'WH 896'	4.6	4.7	3.9	3.7	3.8	3.8	3.9	3.8	3.6	3.6	3.8	3.6
	(23.3)	(23.7)	(14.6)	(13.8)	(15.7)	(14.8)	(16.1)	(14.9)	(13.2)	(13.2)	(14.8)	(13.3)
'WH 912'	4.5	4.5	3.7	3.7	3.8	3.7	3.9	3.6	3.6	3.6	3. 8	3.6
	(22.1)	(21.6)	(13.1)	(13.6)	(15.1)	(14.5)	(15.6)	(12.7)	(13.2)	(13.3)	(14.0)	(13.1)
'PDW 291''	4.3	4.4	3.7	3.7	3.9	3.6	3.7	3.4	3.6	3.5	3.6	3.5
	(20.0)	(20.0)	(13.8)	(13.3)	(15.8)	(13.9)	(14.4)	(11.6)	(13.2)	(12.6)	(13.6)	(12.3)
LSD (P=0.05)	0.2	0.2	NS	NS	NS	NS	0.2	0.2	NS	NS	NS	NS
Herbicide												
Pendimethalin	3.0	3.2	3.1	2.9	2.7	2.5	2.7	2.6	2.5	2.5	2.8	2.7
(1.5 kg/ha)	(8.6)	(9.3)	(8.6)	(7.9)	(6.6)	(5.3)	(6.7)	(5.6)	(5.6)	(5.4)	(7.1)	(6.4)
Weedy check	5.9	5.8	4.5	4.5	5.0	4.9	4.9	4.6	4.6	4.6	4.7	4.5
	(35.0)	(34.3)	(19.1)	(19.3)	(24.4)	(23.5)	(24.0)	(20.5)	(20.8)	(20.7)	(21.2)	(19.4)
LSD (P=0.05)	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.14

Original data given in parentheses were subjected to square root ($\sqrt{x+1}$) transformation before analysis; ZT - Zero tillage; CT - Conventional tillage; FIRBS- Furrow-irrigated raised-bed system

The two years average grain yield of *durum* wheat under ZT, CT and FIRBS was 5.46, 5.33 and 5.31 t/ha, respectively. Similar or higher yield attributes in ZT than CT were reported earlier by many researchers (Malik *et al.* 2000b, Yadav *et al.* 2005, Kakkar *et al.* 2005).

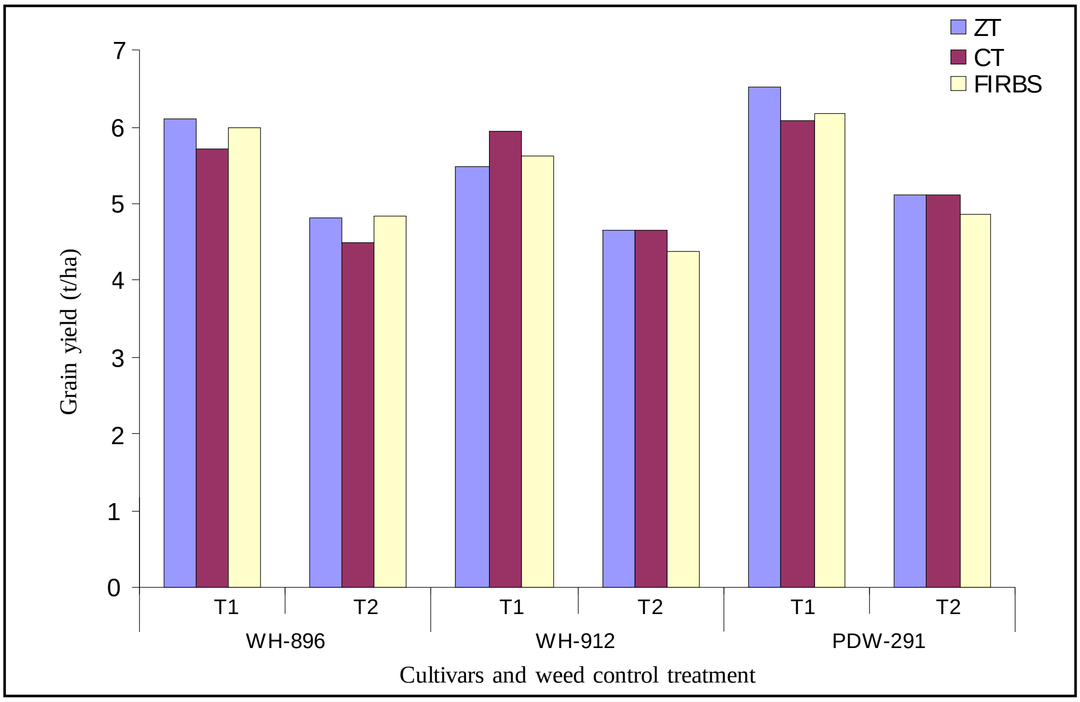
Among three cultivars, '*PDW 291*' produced highest number of spikes, longer spike, more grain per spike and improved 1000-grain weight. Cultivar '*PDW 291*' on an average produced 6.5 and 9.7% higher number of spikes than that produced by '*WH 896*' and '*WH 912*', respectively. Average spike length of cultivars, '*PDW 291*', '*WH 912*' and '*WH 896*' was 9.8, 9.2 and 9.5 cm, respectively. Cultivar, '*PDW 291*' produced 7.1 and 11.6 % more grains per spike than that produced by cultivars '*WH 912*' and '*WH 896*', respectively. During each year of study, cultivar, '*PDW 291*' recorded significantly highest 1000-grain weight and it was lowest in '*WH 912*'. Cultivar '*PDW 291*' produced significantly higher grain yield by 6.0 and 10.2% over the cultivars '*WH 896' and 'WH 912*', respectively. Mahajan *et al.* (2004), Kumar *et al.* (2005) and Bhat (2005) also reported similar results. The marked increase in number of spikes of '*PDW 291*' might be due to improved growth of plants at successive stages as reflected by higher dry matter accumulation. This subscribes to view that there was adequate supply of metabolites in cultivar '*PDW 291*' compared to other cultivars for growth and development of effective tillers. Besides number of spikes, higher grains per spike, spike length and 1000-grain weight under '*PDW 29*' also seems to be on account of higher dry matter accumulation and its inherent characters. It is well documented that in wheat crop, the potential number of various yield components are decided during vegetative phase while reproductive stage determines their realizable number and size. Meisner *et al.* (1992) also opined that efficient partitioning of dry matter to harvestable part (grains) from rest of the plant parts is most important for realization of higher wheat yield.

Application of pendimethalin as pre-emergence significantly increased the yield attributing parameters *i.e.* the number of spikes, spike length and grains per spike over weedy check (Table 3). The average increment in number of spikes, spike length and grains per spike was 26.5, 7.2 and 16.7%, respectively over weedy plots. The average 1000-grain weight under pendimethalin treated plots (41.6 g) and weedy check (40.6 g) was similar. The increase in grain and straw yields due to pendimethalin application was 25.0 and 19.7% over weedy check, respectively. Higher yield attributes and yield with pendimethalin over weedy check have also been reported by Singh and Singh (1996) and Shukla and Mishra (2006). Pendimethalin reduced the density and dry matter accumulation by grassy as well as broadleaf weeds very effectively and on an average, it increased the grain yield of wheat by 25% over weedy check.

The concomitant effect of resource conservation techniques, cultivars and weed control significantly influenced

Table 3. Effect of resource conservation techniques, cultivars and weed control treatments on weed dry matter (60 DAS), yield attributes and yield of *durum* wheat

Treatment	Dry matter (g/m^2)				Spike length (cm)		Grains/ spike		1000-grain weight (g)		Grain yield (t/ha)	
	Grassy weeds		Broad-leaved weeds									
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
RCTs												
ZT	13.3	12.8	14.2	12.8	9.4	9.7	47.3	49.5	41.2	42.2	5.28	5.64
CT	17.8	18.4	12.5	11.7	9.3	9.5	45.7	48.3	39.9	40.5	5.12	5.54
FIRBS	19.5	19.1	13.6	12.5	9.5	9.8	46.2	47.8	40.9	41.9	5.14	5.49
LSD (P=0.05)	1.1	1.2	1.0	0.7	NS	NS	NS	NS	NS	NS	NS	NS
Cultivars												
'WH 896'	18	17.8	13.7	12.7	9.4	9.7	46	48	40.3	41.3	5.13	5.53
'WH 912'	16.7	16.7	13.7	12.5	9.1	9.4	44.1	46.1	39.2	40.1	4.96	5.31
'PDW 291'	16	15.8	13	11.8	9.7	9.9	49.2	51.5	42.4	43.3	5.46	5.84
LSD (P=0.05)	2.4	2.3	NS	NS	0.5	0.5	2.4	2.5	2.1	2.1	0.27	0.29
Herbicide												
Pendimethalin (1.5 kg /ha)	7	8.1	6.8	8.1	9.7	10	50.3	51.8	41.1	42	5.76	6.17
Weedy check	26.8	26.5	20	16.6	9.1	9.3	42.5	45.2	40.1	41	4.60	4.94
LSD (P=0.05)	0.2	0.4	0.3	0.2	0.1	0.2	0.4	0.4	NS	NS	0.04	0.04



T1 - Pendimethalin (1.5 kg/ha); T2 - Weedy check; ZT - Zero tillage; CT - Conventional tillage; FIRBS- Furrow-irrigated raised-bed system

Fig. 1. Interactive effect of resource conservation techniques, cultivars and weed control treatments on grain yield of *durum* wheat.

the grain yield of durum wheat during both the years (Fig.1). During 2005-06 cultivar, '*WH 896*' under ZT and FIRBS, when treated with pendimethalin gave statistically same yield of 5.92 and 5.74 t/ha, however, the grain yield significantly decreased when cultivar '*WH 896*' (5.51 t/ha) sown under CT and treated with pendimethalin. Similarly, cultivar, '*WH 912*' under CT and cultivar '*PDW 291*' under ZT gave significantly higher grain yield of 5.73 and 6.33 t/ha compared to the situation when these cultivars were sown under ZT and CT, respectively at same weed control treatment (pendimethalin). Highest grain yield of 6.33 t/ha was produced by cultivar '*PDW 291*' under ZT when treated with pendimethalin. This treatment combination produced 46.2% higher grain yield than that produced under cultivar '*WH 912*' under CT without weed control (4.33 t/ha). Similar interaction effects among resource conservation techniques, cultivars and weed control were observed in 2006-07.

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Nutrient removal by weeds and crops as affected by herbicide combinations in soybean-wheat cropping system

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ABSTRACT

Eight weed control treatments in soybean and three in wheat were evaluated in soybean-wheat cropping system during 2009-10 and 2010-11 at Palampur. *Commelina benghalensis* followed by *Echinochloa colona* were the most competitive weeds in soybean. In wheat, *Phalaris minor* and *Avena ludoviciana* were the most predominant weeds. Pendimethalin *fb* chlorimuron reduced dry weight of *Aeschynomene, Ageratum, Cyperus*, *Echinochloa* and *Panicum* significantly over the unweeded check. Isoproturon 1000 g/ha + 2, 4-D 500 g/ha reduced dry weight of *Phalaris minor* over the weedy check. In soybean, application of pendimethalin *fb* chlorimuron-ethyl allowed weeds to remove 89.2, 89.1 and 88.9% less N, P and K, respectively as compared to the unweeded check. Application of isoproturon 1000 g/ha + 2,4-D 500 g/ha reduced N, P and K depletion by weeds by more than 24% over the unweeded check. Application of pendimethalin *fb* chlorimuron-ethyl resulted in 187.5% higher N and 166.3% higher K uptake by soybean over weedy check. Unchecked weed growth reduced P uptake by 62.4% as compared to pendimethalin *fb* chlorimuron ethyl. Isoproturon 1000 g/ha + 2,4-D 500 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly higher N, P and K uptake by wheat over unweeded check. Weedy check reduced soybean equivalent yield by 37.4 and 28.8% during 2009 and 2010, respectively. Imazethapyr *fb* imazethapyr produced higher soybean equivalent yield (3.34 t/ha) during 2009, whereas, pendimethalin *fb* chlorimuron (3.16 t/ha) was better during 2010. Isoproturon 1000 g/ha + 2,4-D 500 g/ha (₹ 1,17,736) and isoproturon 750 g/ha + 2,4-D 500 g/ha (₹ 1,16,861) resulted in higher net returns and net per ₹ invested as compared to weedy check.

Key words: Chlorimuron, Herbicide, Imazethapyr, Nutrient removal, Pendimethalin, Quizalofop, Soybean

Soybean-wheat cropping system has a great potential in northern plains of India. With many problems in the traditional rice-wheat (Verma and Sharma 2007) or maize-wheat cropping systems, the soybean-wheat has emerged as a good alternative both for crop diversification as well as for maintaining the sustainable soil health. In fact, soil nutrient supply is improved when crops with relatively high nutrient demands are rotated with crops leaving relatively high amount of residues containing substantial amount of nutrients. Soybean is one crop, which builds up the soil fertility by atmospheric nitrogen fixation through the root nodules and also through leaves falling on the ground at maturity. Besides residual effect on soil fertility, soybean has great potential as an exceptionally nutritive and very rich protein food. Being long duration crop, wheat also exhausts the soil to maximum potential. Infestation of weeds removes nutrients from the soil thus, adversely affects the production of both the crops. Weeds increase cost of cultivation and deplete the resource base (Buriro *et al.* 2003 and Upadhyay *et al.* 2012). In order to achieve enhanced crop production and higher benefits from applied inputs, weeds must be kept under check by any of the safe and effective mean. Herbicide combinations are more effective weapons in tackling weed menace and thereby nutrient depletion by them than a single herbicide approach (Pisal and Sagarka 2013 and Upadhyay *et al.* 2013). Therefore, present study works out nutrient removal by weeds and crops and impact on system productivity as influenced by herbicide combinations in soybean-wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 2009-10 and 2010-11 at Palampur (32º 62 N Latitude, 76º 32 E longitude, 1280 m above msl). The soil of experimental site was silty clay loam in texture, acidic in reaction (5.6), low in available nitrogen (204.6 kg/ha), medium in available phosphorus (18.1 kg/ha) and high in

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available potassium (308.2 kg/ha). Eight weed control treatments, *viz.* pendimethalin 1.5 kg/ha (pre), imazethepyr 200 g/ha (pre), quizalofop-ethyl 60 g/ha (early post), imazethapyr 75 g/ha (pre) *fb* imazethapyr 75 g/ha (early post), quizalofop-ethyl 50 g/ha + chlorimuron-ethyl 4 g/ha (early post), pendimethalin 1.5 kg/ha (pre) *fb* chlorimuron-ethyl 4 g/ha (early post), hand weeding (twice) and weedy check in soybean as main plot factors and weedy check, isoproturon 1.0 kg/ha + 2,4-D 0.50 kg/ha and isoproturon 0.75 kg/ha + 2,4-D 0.50 kg/ha (post emergence) in wheat as sub-plot factors were tested in split plot design with three replications. The seeds of soybean variety '*Harit Soya*' were sown in rows 45 cm apart on June 18, 2009 and June 5, 2010 using 75 kg seed/ha. The crop was fertilized with 20 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha as basal dose. Wheat variety '*HPW-155*' was sown on November 11, 2009 and November 3, 2010 using 100 kg seed/ha. The crop was fertilized with 120 kg N, 60 kg P_2O_5 and 30 kg K_2O/ha. In each crop, required amount of N, P and K was supplied through urea, single super phosphate and muriate of potash, respectively. Herbicides were applied with the help of Maruyama power sprayer using flat fan nozzle. Rest of the management practices were in accordance with the recommended package of practices for individual crop. Weed dry weight was recorded by placing 50 x 50 cm quadrates at two random places in each plot and after drying them in hot air oven (72^0C for 72 hours). Yields were harvested from net plot.

RESULTS AND DISCUSSION

Effect on weeds

Soybean: The experimental field was infested with *Commelina benghalensis* (43.36 and 57.87% during 2009 and 2010, respectively), *Echinochloa colona* (18.04 and 15.02%), *Aeschynomene indica* (3.78 and 2.73%), *Ageratum conyzoides* (3.68 and 4.91%), *Panicum dichotomiflorum* (11.53 and 5.12%), *Digitaria sanguinalis* (4.25 and 3.69%), *Eleusine indica* (3.54 and 3.48%) and *Cyperus* sp. (9.21 and 5.12%). *Commelina benghalensis* was the most dominant weed in soybean (Singh *et al.* 1992, Rajput and Kushwah 2004 and Kumar *et al.* 2008).

Weeds accumulated maximum dry matter by 60 DAS. On dry weight basis *Commelina* was most competitive weed in soybean and assumed alarming growth particularly in 2009. All the three combinations of herbicides were comparable to hand weeding twice in influemcing its growth. Imazethapyr and quizalofop-ethyl also could bring down its dry weight during 2009 and were as good as the above treatments in reducing its dry weight. However, pendimethalin was not effective against *Commelina* during both the years. Application of imazethapyr, pendimethalin, pendimethalin *fb* chlorimuron-ethyl and hand weeding (twice) significantly reduced the dry weight of *Aeschynomene* over the unweeded check during 2009. Pendimethalin *fb* chlorimuron-ethyl remaining at par with pendimethalin alone and hand weeding (twice) resulted in significantly lower dry weight of *Ageratum* during 2010. All treatments were significantly superior to unweeded check in controlling *Cyperus* during both the years and *Digitaria* during 2010. Application of quizalofop-ethyl, imazethapyr *fb* imazethapyr, quizalofop-ethyl + chlorimuron-ethyl and pendimethalin *fb* chlorimuron-ethyl remaining at par with each other resulted in significant lower dry weight of *Echinochloa* during both the years. Dry weight of *Panicum dichotomiflorum* was significantly affected during 2009. All treatments except imazethapyr *fb* imazethapyr significantly reduced dry weight of *Panicum dichotomiflorum* over weedy check. However, weed control treatments could not significantly reduced the dry weight of *Polygonum alatum* and *Eleusine indica*. All treatments except pendimethalin during 2009 significantly decreased total weed dry weight over the untreated check. Pendimethalin *fb* chlorimuron resulted in significantly lower total weed dry weight. However other herbicidal mixtures during both the years and imazethapyr, quizalofop-ethyl and hand weeding during 2009 were compareable to pendimethalin *fb* chlorimuron. Herbicide combinations had an edge over the individual application of herbicides in reducing total weed dry weight. Superiority of herbicide combinations has been documented (Singh *et al.*, 2006a Upadhyay *et al.*, 2013 and Jadhav and Gadade 2012). The residual effects of treatments in wheat were not significant on weeds in soybean.

Wheat: *Phalaris minor* and *Avena ludoviciana* were the most predominant weeds constituting 66.5 and 27.65% of the total weed flora. The other weeds found growing in association with wheat crop were *Lolium temulentum* (2.0%), *Vicia sativa* (3.0%) and *Coronopus didymus* (0.6%).

The application of herbicides in soybean did not cause any residual activity in influencing the dry weight of weeds in wheat as dry weight of different weeds in wheat was not significantly affected under weed control treatments in soybean. Application of isoproturon 1000 g/ha + 2,4-D 500 g/ha behaved statistically alike to isoproturon 750 g/ha+ 2,4-D 500 g/ ha resulted in significantly lower dry weight of *Phalaris minor* and *Avena ludoviciana* at 90 DAS as compared to weedy check. Weed control treatments in wheat did not significantly influence the dry weight of *Lolium temulentum*. Application of isoproturon

Table 1. Effect of treatments on dry weight (g/m²) of weeds at 60 DAS in soybean

Treatment	Rate (g/ha)	Time	*Commelina*		*Aeschynomene*		*Ageratum*		*Cyperus*		*Echinochloa*		*Panicum*		*Digitaria*		Total	
			2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Soybean																		
T_1- Pendimethalin	1500	Pre	18.6 (403)	12.1 (148)	2.9 (10)	2.0 (7)	3.3 (16)	7.4 (61)	2.2 (7)	2.5 (10)	7.1 (68)	5.2 (30)	1.7 (3)	2.5 (9)	1.0 (0)	2.5 (10)	21.5 (497)	15.3 (238)
T_2- Imazethapyr	200	Pre	3.7 (15)	12.3 (167)	1.2 (0)	3.0 (12)	3.3 (20)	4.9 (32)	2.2 (5)	4.4 (22)	7.0 (65)	7.2 (60)	2.8 (9)	3.3 (17)	3.9 (41)	3.1 (15)	10.0 (107)	17.1 (307)
T_3- Quizalofop-ethyl	60	EP	10.4 (145)	11.5 (157)	4.0 (20)	2.8 (10)	2.5 (8)	4.4 (26)	1.9 (3)	3.5 (17)	1.3 (2)	2.4 (7)	1.2 (1)	2.2 (7)	2.8 (18)	4.2 (24)	12.0 (179)	13.9 (216)
T_4- Imazethapyr *fb* imazethapyr	75 *fb* 75	Pre *fb* EP	4.3 (32)	6.9 (48)	3.6 (18)	2.0 (5)	1.8 (3)	4.8 (33)	1.3 (1)	1.1 (0)	1.0 (0)	3.1 (11)	4.8 (31)	3.8 (24)	4.3 (28)	2.7 (9)	9.0 (96)	10.3 (110)
T_5- Quizalofop-ethyl + chlorimuron-ethyl	50 + 4	EP	10.3 (127)	6.6 (45)	4.7 (29)	2.8 (11)	1.1 (0)	3.1 (13)	1.1 (0)	2.4 (8)	1.5 (2)	2.6 (11)	1.0 (0)	2.4 (8)	1.5 (3)	2.0 (5)	11.7 (160)	9.5 (94)
T_6- Pendimethalin *fb* chlorimuron-ethyl	1500 *fb* 4	Pre *fb* EP	4.9 (30)	6.7 (45)	1.3 (1)	2.6 (10)	1.3 (1)	2.5 (10)	1.2 (0)	1.0 (0)	3.2 (12)	3.2 (12)	1.8 (3)	1.9 (4)	1.9 (4)	1.7 (3)	6.7 (49)	8.9 (82)
T_7- Hand weeding	twice	25&40 DAS	3.6 (18)	8.6 (75)	1.3 (1)	2.6 (12)	2.3 (6)	7.9 (69)	2.1 (4)	3.8 (19)	8.4 (76)	7.1 (59)	2.1 (4)	3.5 (15)	1.7 (6)	3.3 (15)	10.6 (116)	14.7 (221)
T_8- Weedy check			21.1 (535)	15.5 (243)	4.8 (36)	3.3 (15)	4.0 (19)	8.1 (71)	4.3 (21)	4.9 (29)	9.0 (81)	8.3 (73)	6.2 (44)	4.8 (30)	5.2 (63)	7.4 (62)	26.7 (817)	21.6 (475)
LSD (P=0.05)			7.1	4.3	2.73	NS	NS	3.1	1.4	2.0	4.9	3.3	1.6	NS	NS	2.6	7.9	4.9
Wheat																		
S_1- Weedy check			9.4 (156)	9.6 (100)	3.04 (15)	2.9 (12)	1.1 (0)	2.7 (14)	2.0 (5)	3.4 (17)	5.3 (49)	4.8 (35)	3.2 (18)	3.7 (19)	1.6 (3)	2.4 (10)	14.2 (258)	14.2 (219)
S_2- Isoproturon + 2,4-D	1000 + 500	Post	10.9 (200)	10.1 (119)	3.14 (17)	2.3 (8)	1.2 (1)	2.2 (7)	2.3 (8)	2.9 (13)	4.8 (41)	5.5 (40)	2.5 (10)	2.8 (11)	2.0 (8)	2.6 (10)	15.1 (294)	14.1 (221)
S_3- Isoproturon + 2,4-D	750 + 500	Post	8.5 (133)	10.4 (128)	2.72 (11)	2.8 (11)	1.4 (3)	2.1 (7)	1.8 (4)	2.6 (9)	4.4 (33)	4.3 (26)	2.3 (8)	2.6 (12)	2.0 (6)	2.7 (10)	12.6 (206)	13.7 (214)
LSD (P=0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Values given in parentheses are the means of original values

Table 2. Effect of treatments on dry weight (g/m²) of weeds at 60 DAS in wheat

Treatment	*Phalaris*		*Avena*		*Lolium*		*Vicia*		Total	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Soybean										
T_1	2.8 (8)	3.6 (14)	3.4 (11)	3.5 (13)	1.2 (0)	1.1 (0)	1.2 (1)	1.0 (0)	4.5 (20)	5.2 (28)
T_2	3.3 (14)	3.3 (11)	4.1 (17)	3.3 (11)	1.1 (0)	1.1 (0)	1.0 (0)	1.3 (1)	5.3 (31)	4.8 (23)
T_3	4.3 (23)	4.2 (18)	3.1 (9)	3.0 (8)	1.0 (0)	1.4 (1)	1.2 (1)	1.1 (0)	5.4 (32)	5.3 (28)
T_4	4.1 (17)	3.7 (14)	3.8 (18)	3.5 (14)	1.1 (0)	1.1 (0)	1.2 (1)	1.4 (1)	5.9 (36)	5.3 (29)
T_5	3.4 (11)	3.3 (11)	3.0 (8)	3.4 (12)	1.2 (1)	1.2 (1)	1.6 (2)	1.4 (1)	4.7 (22)	4.9 (24)
T_6	9.6 (188)	2.6 (7)	4.0 (19)	3.5 (16)	1.1 (0)	1.0 (0)	1.4 (1)	1.2 (1)	11.4 (208)	4.5 (23)
T_7	2.6 (6)	4.1 (18)	4.6 (29)	3.7 (15)	1.0 (0)	1.4 (1)	1.0 (0)	1.5 (1)	5.3 (35)	5.8 (35)
T_8	2.4 (6)	4.8 (28)	4.9 (24)	4.6 (23)	1.1 (0)	1.1 (0)	1.2 (1)	1.1 (0)	5.5 (31)	6.8 (51)
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Wheat										
S_1	4.8 (49)	4.1 (20)	4.3 (22)	4.2 (20)	1.2 (0)	1.2 (1)	1.5 (2)	1.2 (1)	7.1 (72)	6.1 (41)
S_2	3.5 (26)	3.1 (10)	3.4 (12)	3.1 (10)	1.0 (0)	1.2 (0)	1.1 (0)	1.3 (1)	5.2 (38)	4.6 (21)
S_3	3.9 (28)	3.8 (15)	3.8 (17)	3.4 (12)	1.1 (0)	1.1 (0)	1.2 (0)	1.3 (1)	5.8 (46)	5.3 (29)
LSD (P=0.05)	0.7	0.8	0.7	0.8	NS	NS	0.2	NS	0.8	0.8

Values given in parentheses are the means of original values

1000 g/ha + 2,4-D 500 g/ha behaving statistically alike with isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly lower dry matter accumulation of *Vicia sativa*. Application of isoproturon 1000 g/ha + 2,4-D 500 g/ha behaving statistically similar to isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly lower dry matter accumulation of *Coronopus didymus* at 90 DAS during 2010. Owing to species-wise reduction in dry weight, application of isoproturon 1000 g/ha + 2,4-D 500 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly lower total weed dry weight over weedy check. Similar results have been reported by Das and Yaduraju (1999) and Punia *et al.* (2004).

Nutrient removal by weeds

***Soybean*:** There was tremendous reduction in the nutrient depletion under different weed control treatments. However, due to wide variation in nutrient content in weeds, nutrient removal by them was significantly influenced during 2010 only. All weed control treatments were significantly superior to weedy check in decreasing N and P removal by weeds. Among weed control treatments applied in soybean, pendimethalin *fb* chlorimuron-ethyl being at par to quizalofop-ethyl + chlorimuron-ethyl resulted in significantly lower nitrogen removal by weeds. Weeds removed 89.2% less nitrogen and 89.1% less phosphorus than unweeded check. Rests of the treatments being at par were comparable to hand weeding twice in depleting the soil for available nitrogen and phosphorus. Application of pendimethalin *fb* chlorimuron-ethyl resulted in significantly lowest potassium depletion by weeds. This treatment reduced potassium depletion by weeds by 88.9% due to effective weed control as compared to the unweeded check. Rests of the treatments were comparable to hand weeding twice in influencing potassium depletion by weeds. Weeds have considerably depleted the soil for N, P and K in weedy check mainly because of higher dry weight of weeds in these plots. Similar results have been reported by Kumar and Das (2008), Singh *et al.* (2006a) and Pasal and Sagarka (2013). Treatments in wheat could not significantly influence nutrient depletion by weeds in soybean.

***Wheat*:** Similar to weed dry weight, treatments in soybean did not significantly influence nutrient uptake by weeds in wheat. Inspite of having significant reduction in weed dry weight, N, P and K uptake by weeds in wheat was not significantly influenced due to weed control treatments in wheat. This clearly indicated vide variation in the content of nutrients in weeds. The application of isoproturon 1000 g/ha + 2,4-D 500 g/ha reduced N, P and K depletion by 24.2 and 24.8 and 21.1 and 24.1% over the unweeded check during 2009 and 2010, respectively.

Soybean + wheat system: Mean nutrient depletion by weeds under soybean – wheat cropping system was significantly affected due to treatments in soybean. Weeds in unweeded check removed 71.5 kg of N, 6.9 kg of P and 97.4 kg of K, thus depriving crops for that much amount of available nutrients. Out of this total removal by weeds more than 65% depletion of NPK (*i.e.* 66.7% N, 72.2% P and 65.4% K in soybean) occurred during *Kharif*. Application of pendimethalin *fb* chlorimuron could save 48.1 kg N, 9.9 kg P and 66 kg K/ha from being depleted by weeds under soybean – wheat cropping system. Treatments in wheat also brought about significant variation in total NPK depletion by weeds in soybean – wheat cropping system. Isoproturon 0.7-1.00 kg/ha + 2,4-D 0.50 kg/ha significantly reduced total N, P and K depletion by weeds in soybean – wheat cropping system.

Nutrient uptake by crops

***Soybean*:** Weed control treatments significantly increased the nitrogen uptake by soybean crop over unweeded check. In general, all the herbicide combinations were superior to alone application of herbicides in improving the nitrogen uptake by crop. Because of higher seed and straw yield, pendimethalin *fb* chlorimuron-ethyl resulted in significantly higher nitrogen uptake by crop during 2009. However, this treatment remained statistically similar with imazethapyr *fb* imazethapyr and quizalofop-ethyl + chlorimuron-ethyl during 2010. Application of pendimethalin *fb* chlorimuron-ethyl resulted in 187.5 and 52.7% higher nitrogen uptake over weedy check during 2009 and 2010, respectively. P and K content showed variation and therefore their uptake by soybean crop was not significantly affected under weed control treatments in soybean during 2010. Pendimethalin *fb* chlorimuron-ethyl remaining at par with imazethapyr *fb* imazehapyr and handweeding twice resulted in significantly higher P uptake by soybean over other treatments. Herbicides alone were alike to hand weeding twice in influencing P uptake by soybean crop. Unchecked weed growth reduced phosphorus uptake in soybean by 62.4% as compared to pendimethalin *fb* chlorimuron-ethyl.

Similar trend as that of P uptake was observed with respect to K uptake in soybean during 2009. Pendimethalin *fb* chlorimuron-ethyl recorded 166.3% higher potassium uptake by soybean than unweeded check. However, this treatment behaved statistically alike to imazethapyr *fb* imazethapyr and hand weeding (twice). Higher dry matter accumulation by soybean with application of pendimethalin *fb* chlorimuron-ethyl may be attributed to better root spread and penetration in soil due to weed free environment. Also, lower N, P and K removal by weeds allowed soybean to grow more vigorously and accumulated more biomass, which consequently led to higher uptake of these nutrients (Kumar and Dass 2008 and Singh *et al.* 2006). Treatments in wheat did not significantly influence nutrients uptake by soybean during both the years.

Table 3. Effect of treatments on nutrient uptake (kg/ha) by weeds

Treatment	Soybean						Wheat						Total*		
	N		P		K		N		P		K				
	2009	2010	2009	2010	2009	2010	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	N	P	K
Soybean															
T_1	27.2	27.8	6.0	5.0	44.4	36.0	24.3	22.0	3.6	3.3	31.3	29.7	50.7	9.0	70.7
T_2	19.8	28.2	4.7	5.2	30.9	33.1	21.9	17.7	3.7	2.6	29.4	23.2	43.8	8.1	58.3
T_3	31.5	25.0	5.7	4.7	39.1	32.2	17.2	20.1	2.7	3.2	23.2	27.2	46.9	8.2	60.9
T_4	17.0	20.1	3.5	3.9	25.4	25.3	19.9	21.1	3.0	3.3	25.7	29.0	39.1	6.9	52.7
T_5	21.5	14.1	4.5	2.7	34.0	19.2	18.8	18.8	2.9	2.8	24.5	24.3	36.6	6.5	51.0
T_6	5.2	5.8	1.3	1.1	7.2	7.9	18.1	17.6	2.7	2.8	23.5	24.2	23.4	4.0	31.4
T_7	9.0	20.6	1.6	4.0	11.6	27.4	30.1	21.6	4.8	3.4	41.2	28.7	40.7	6.9	54.5
T_8	41.8	53.5	9.8	10.2	61.8	71.4	27.2	20.4	4.5	3.2	35.0	26.5	71.5	13.9	97.4
LSD (P=0.05)	NS	9.1	NS	1.8	NS	10.3	NS	NS	NS	NS	NS	NS	8.6	2.9	10.2
Wheat															
S_1	25.1	24.6	5.5	4.6	37.0	31.6	25.6	23.1	4.1	3.5	33.8	30.8	49.2	8.9	66.6
S_2	20.8	24.1	4.5	4.6	29.9	30.8	19.4	17.4	3.1	2.8	26.2	23.4	40.9	7.5	55.2
S_3	19.0	24.5	3.9	4.6	28.6	32.3	21.6	19.2	3.3	3.0	27.7	25.5	42.2	7.4	57.1
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.5	0.9	3.5

*Mean of two years

Table 4. Effect of treatments on nutrient uptake (kg/ha) by crops

Treatment	Soybean						Wheat						Total*		
	N		P		K		N		P		K				
	2009	2010	2009	2010	2009	2010	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	N	P	K
Soybean															
T_1	110.3	116.8	12.9	14.0	125.8	138.9	134.5	125.8	24.9	25.5	149.2	155.7	243.7	38.7	284.8
T_2	106.4	123.9	13.0	14.7	126.6	150.1	123.5	122.8	23.4	23.8	139.2	144.3	238.3	37.5	280.1
T_3	110.0	124.2	12.6	14.3	122.6	141.5	124.0	120.7	22.1	22.8	135.1	148.6	239.5	35.9	273.9
T_4	142.4	140.3	16.6	16.8	151.5	151.6	144.3	130.6	27.2	27.8	163.7	165.4	278.8	44.2	316.1
T_5	133.6	138.8	14.6	16.0	140.8	155.5	128.8	117.5	24.5	24.6	144.4	150.0	259.4	39.9	295.4
T_6	170.2	148.7	20.5	15.4	192.8	148.6	134.3	133.0	25.9	25.4	147.1	170.4	293.1	43.6	329.5
T_7	136.0	129.4	16.2	14.7	150.3	138.9	143.1	122.0	25.3	23.1	156.7	137.2	265.3	39.7	291.6
T_8	59.2	97.4	7.7	12.3	72.4	130.8	122.6	108.3	22.7	21.4	129.8	131.4	193.8	32.1	232.2
LSD (P=0.05)	36.45	12.10	4.95	NS	50.09	NS	NS	NS	NS	NS	NS	NS	27.3	5.5	40.0
Wheat															
S_1	118.3	126.3	13.9	14.6	131.1	144.1	117.2	109.4	21.2	21.4	131.4	136.2	235.6	35.6	271.4
S_2	120.5	128.7	14.2	15.0	138.2	144.1	143.9	130.5	26.5	26.1	157.4	156.7	261.8	40.9	298.2
S_3	124.3	127.3	14.7	14.8	136.8	145.3	134.6	127.8	25.8	25.4	148.1	157.8	257.0	40.4	294.0
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	11.36	8.44	2.20	1.72	12.88	12.97	7.9	1.5	12.9

*Mean of two years

***Wheat*:** Weed control treatments in soybean did not bring about significant variation in uptake of N, P and K by wheat. Weed control treatments in wheat resulted in significant variation in NPK uptake by wheat. Application of isoproturon 1000 g/ha + 2,4-D 500 g/ha behaving statistically alike with isoproturon 750 g/ha + 2,4-D 500 g/ha resulted in significantly higher N, P and K uptake over unweeded check. The higher nutrient uptake can be ascribed to more grain and straw yield under isoproturon 1000 g/ha + 2,4-D 500 g/ha and isoproturon 750 g/ha + 2,4-D 500 g/ha. Similar results have been reported by Pandey *et al.* (2007) and Bharat and Kachroo (2007). Higher dry matter accumulation by wheat under herbicidal treatments might have increased the nutrient uptake (Brar and Walia 2009 and Pandey *et al.* 2001).

Table 5. Effect of treatments on soybean seed yield (t/ha), soybean equivalent yield (t/ha), net returns (₹/ha) and net returns per rupee invested in soybean-wheat cropping system

Treatment	Soybean seed yield (t/ha)		Soybean equivalent yield		Net return ($x10^3$ ₹/ha)		Net returns/ ₹ invested	
	2009	2009	2009	2010	2009	2010	2009	2010
Soybean								
T_1	1.33	1.33	2.80	2.72	65.52	68.13	1.45	1.51
T_2	1.34	1.34	2.69	2.79	61.56	69.49	1.37	1.55
T_3	1.38	1.38	2.69	2.76	61.52	68.28	1.38	1.53
T_4	1.79	1.79	3.34	3.15	83.60	82.61	1.87	1.85
T_5	1.67	1.67	3.10	2.89	75.23	75.73	1.69	1.70
T_6	1.87	1.87	3.30	3.16	85.09	85.16	1.88	1.88
T_7	1.63	1.63	3.11	2.94	73.67	64.80	1.49	1.32
T_8	0.75	0.75	2.09	2.25	40.43	45.49	0.91	1.02
LSD (P=0.05)	0.43	0.43	0.59	0.35	22.10	14.57	0.49	0.31
Wheat								
S_1	1.45	1.45	2.72	2.69	61.41	64.11	1.36	1.42
S_2	1.43	1.43	2.96	2.97	72.18	73.85	1.58	1.62
S_3	1.53	1.53	2.99	2.84	71.39	71.92	1.57	1.58
LSD (P=0.05)	NS	NS	0.17	0.11	6.22	4.10	0.14	0.09

***Soybean + wheat*:** Treatments in soybean significantly affected total NPK uptake in soybean – wheat cropping system. Under weedy check, crop uptake was only 193.8 kg N, 32.1 kg P and 232.2 kg K which increased to 293.1 kg N, 43.6 kg P and 329.5 kg K under the best treatment *i.e.* pendimethalin *fb* chlorimuron-ethyl. However, uptake of nutrients by the cropping system was tremendously higher than the recommend application rate even in the weedy check. The upake by weeds was extra. The all other treatments were also superior to weedy check in increasing N and K uptake by soybean – wheat cropping system. Treatments in wheat significantly influenced total N, P and K uptake by soybean – wheat system. Application of 0.75-1.00 kg/ha + 2,4-D 0.50 kg/ha significantly increased total NPK uptake by soybean – wheat cropping system.

System productivity

Application of pendimethalin *fb* chlorimuron-ethyl remaining statistically at par to imazethapyr *fb* imazethapyr, quizalofop-ethyl + chlorimuron-ethyl and hand weeding (twice) resulted in significantly higher soybean seed yield. Weeds in weedy check reduced the seed yield of soybean by 59.9 and 41.0% during 2009 and 2010, respectively as compared to pendimethalin *fb* chlorimuron ethyl. Mishra and Singh (2009) have reported 86% reduction in seed yield of soybean due to weeds. There were no residual effects of treatments applied in wheat on seed yield of soybean as the treatments were not significantly different. Herbicide combinations and hand weeding twice were better than herbicides alone in influencing soybean equivalent yield (Table 5). During 2009, pendimethalin alone was also at par with herbicide combinations. Application of imazethapyr *fb* imazethapyr produced higher soybean equivalent yield (3.34 t/ha) during 2009, whereas during 2010, application of pendimethalin *fb* chlorimuron (3.16 t/ha) was better. Weedy check reduced soybean equivalent yield by 37.4 and 28.8% during 2009 and 2010, respectively. Among treatments in wheat, application of isoproturon 0.75 kg/ha + 2,4-D 0.50 kg/ha and isoproturon 1000 g/ha+ 2,4-D 500 g/ha was statistically similar in influencing soybean equivalent yield over weedy check during 2009. During 2010, application of isoproturon 1000 g/ha + 2,4-D 500 g/ha produced highest soybean equivalent yield (2.97 t/ha).

Profitability

Pendimethalin *fb* chlorimuron remaining at par with pendimethalin, imazethapyre *fb* imazethapyre, quizalofop + chlorimuron and hand weeding twice during 2009 and imazethapyre *fb* imazethapyre and quizalofop + chlorimuron during 2010 resulted significantly higher net returns (₹ 85,096, 85,165) and net returns per rupee invested (1.88 and 1.88). Among treatments in wheat, isoproturon 1000 g/ha + 2,4-D 500 g/ha (₹ 1,17,736 and 1.60) and isoproturon 750 g/ha + 2,4-D 500 g/ha (₹ 1,16,861 and 1.58) remaining statistically at par resulted in higher net returns and net return per rupee invested as compared to weedy check.

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Effect of nitrogen and weed control on productivity of wheat

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ABSTRACT

A field experiment was conducted during winter season of 2005-06 and 2006-07 to evaluate the effect of nitrogen levels and weed control on weed growth, productivity and economics of wheat. The treatments comprised of 4 levels of nitrogen, *viz.* 0, 40, 80, and 120 kg/ha in main plots and 5 weed control methods, *viz.* weedy control, 2,4-D Na 0.75 kg/ha as post-emergence, isoproturon 1.0 kg/ha as post-emergence, isoproturon 1.0 kg/ha + 2,4-D Na 0.75 kg/ha as post-emergence and weeding by Dutch hoe at 15, 30 and 45 days after sowing. Maximum density and dry weight were recorded with 120 kg N/ha and minimum under N_0. Increasing levels of nitrogen from 0 to 40, 40 to 80 and 80 to 120 kg/ha increased weed density by 33.7, 39.9 and 47.3% and weed dry matter by 35.2, 24.9 and 13.5%, respectively while N up take by 68.8, 56.7 and 18.7% phosphorus 13.2, 4.6 and 4.4% and potassium 16.2, 7.0 and 8.7% over preceding lower levels. 120 kg N/ha recorded significantly higher grain (2.90 t/ha) and straw (4.6 t/ha) yield, net return (₹ 26,616/ha) and B:C ratio (1.52).

Key words: Economics Nutrient up take, Weed control efficiency, Weed dry matter, Weed population

Generally weeds are considered harmful plants and are one of the biggest threats to agriculture. They use the soil fertility, available nutrients and moisture and compete for space and sunlight with the crop plants. This not only results in yield reduction but also deteriorates the quality of the produce, hence reducing the market value of crops (Heyne 1987). It has been estimated that crop losses due to weed competition throughout the world as a whole are greater than those resulting from the combined effects of insect pests and diseases (Khan *et al*. 2005). Fertilization is an important agronomic strategy used extensively to increase crop yield. Nevertheless, although nutrients clearly promote crop growth, many studies have shown that in some cases, fertilizers benefit weeds more than crops (DiTomaso 1995). For example, Carlson and Hill (1986) found that addition of N fertilizer to wild oat-infested wheat increased the density of wild oat panicles without increasing crop yield. However, Satorre EH and RW Snaydon (1992) showed that N fertilizer reduced the severity of competition experienced by wild oat from six spring cereals. The increase in weed competition at higher N rates has been suggested to be related to an increase in the efficiency of nutrient accumulation and use by weeds. The weeds removed significantly higher quantity of nitrogen, phosphorus and potash from plots receiving 120 kg N/ha than from those receiving lower levels of nitrogen.

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MATERIALS AND METHODS

A field experiment was conducted during winter season of 2005-06 and 2006-07 to evaluate the effect of weed management and nitrogen levels on weed growth and productivity of wheat. The treatments comprised of 4 levels of nitrogen, *viz.* 0, 40, 80, and 120 kg/ha in main plots and 5 weed control methods, *viz.* weedy control, isoproturon 1.0 kg/ha as post-emergence, 2,4-D Na salt 0.75 kg/ha as post-emergence and weeding by Dutch hoe at 15, 30 and 45 days after sowing. Wheat variety '*K 9107*' with 120 kg/ha seed rate was sown on 6th November, 2005 and 10th November, 2006, receiving 60 kg P_2O_5 and 40 kg K_2O/ha. Nitrogen 40 kg/ha was applied in single dose basal, whereas 80 kg/ha was applied in 2 splits – half basal + half at tillering stage; and 120 kg N/ha was applied in 3 splits, one third each at basal, tillering and at flowering. All herbicides were applied at post-emergence stage at 30 days after sowing using spray volume of 500 l/ha. Weeds were collected at randomly placing 50 x 50 cm quadrant in each plot. Weeds were cut from ground level and then identified, counted and samples were kept in an oven at 65± 5^{0}C until they attained constant weight. The data on weeds were square root transformed ($\sqrt{x+0.5}$) for statistical analysis (Panse and Sukhatme 1967).

RESULTS AND DISCUSSION

Effect on weed

Weed flora of the experimental field consisted mainly *Loilium temulentum* and *Avena fatua* among grasses and

Chenopodium album, *Anagalis arvensis*, *Vicia sativa*, *Ageratum conzoides*, *Medicago polymorpha* and *Oxalis corniculata* among broad-leaved weeds

Significant increase in weed density and dry matter accumulation at 90 days after sowing was observed with increase in each nitrogen level. Maximum density and dry weight were recorded with 120 kg N/ha and minimum under N_0. Increasing levels of N from 0 to 40, 40 to 80 and 80 to 120 kg/ha increased weed density by 33.7, 39.9 and 47.3% and weed dry matter by 35.2, 24.9 and 13.5%, respectively (Table 1). The significant increase in weed population and dry matter accumulation might be due to utilization of soil applied nitrogen in greater quantity by weeds, resulting in more growth and high dry matter accumulation. All weed control measures significantly reduced the weed density and dry weight of weeds at 90 days after sowing compared with weedy control. Weeding by Dutch hoe at 15, 30 and 45 days after sowing being similar to post-emergence application of isoproturon 1.0 kg/ha + 2,4-D Na 0.75 kg/ha proved most effective in arresting the population of weeds and dry matter accumulation. The highest weed control efficiency (86.1%) was recorded under weeding by Dutch hoe at 15, 30 and 45 days after sowing closely followed by isoproturon 1.0 kg/ha + 2,4-D Na 0.75 kg/ha post-emergence (84.1%). Similar results were also observed by Rajput *et al.* (1993).

Nutrient uptake by weeds and crop

The weeds removed significantly higher quantity of nitrogen, phosphorus and potassium from plots receiving 120 kg N/ha than from receiving lower levels of nitrogen. Increasing level of nitrogen from 0 to 40, 40 to 80 and 80 to 120 kg/ha increased nitrogen uptake by 68.8, 56.7 and 18.7% phosphorus 13.2, 4.6 and 4.4% and potassium 16.2, 7.0 and 8.7% over preceding lower levels (Table 1). It appeared that higher nitrogen application favored higher weed population and weed dry matter production resulting in higher nutrient uptake while under control treatment (0 kg N/ha) nutrient uptake was less owing to less availability of nitrogen resulting lower weed density and weed dry matter. Sankpal and Mahalle (1991) also reported similar finding.

All weed control treatments reduced the nitrogen, phosphorus and potash uptake by weeds significantly compared to weedy control. Weeding by Dutch hoe being comparable to isoproturon 1.0 kg/ha + 2, 4-D Na 0.75 kg/ha

Table 1. Effect of nitrogen level and weed control on weed growth, nutrient uptake, yield and economics of wheat

Treatment	Weed density/m^2 at 90 DAS	Dry weight of weeds at 90 DAS	Weed control efficiency (%)	Nutrient uptake (kg/ha) Weeds			Wheat			Yield (t/ha)	Gross returns (x 10^3 ₹ /ha)	Net returns (x 10^3 ₹ /ha)	B:C ratio
				N	P	K	N	P	K				
N (kg/ha)													
N_0	5.34 (28.5)	5.12 (26.1)	74.8	9.3	3.8	3.7	14.5	3.5	1.5	0.09	1.44	-14.55	-0.91
N_{40}	6.17 (38.1)	5.95 (35.3)	66.0	15.7	4.3	4.3	29.6	6.1	18.2	1.11	16.23	-0.26	-0.02
N_{80}	7.30 (53.3)	6.80 (43.8)	57.8	24.6	4.5	4.6	69.6	18.2	42.5	2.82	41.17	24.14	1.42
N_{120}	8.89 (78.5)	7.65 (49.7)	52.1	29.2	4.7	5.0	73.7	21.6	48.6	2.90	44.17	26.61	1.52
LSD (P=0.05)	0.82	0.79	-	3.8	0.17	0.38	3.85	3.8	6.8	0.14	3.10	2.50	0.82
Weed control													
Isoproturon 1.0 kg/ha	6.82 (46.5)	5.58 (31.1)	70.0	17.2	4.5	3.2	46.4	12.5	29.6	1.93	28.44	12.56	0.79
2,4-D 1.0 kg/ha	6.43 (41.3)	5.28 (27.8	73.2	18.5	3.5	2.4	42.9	11.4	27.5	1.74	25.30	9.58	0.61
Isoproturon 1.0 kg/ha + 2,4-D 1.0 kg/ha	4.92 (24.2)	4.06 (16.5)	84.1	10.5	2.2	1.5	59.7	17.0	36.8	2.20	33.06	16.98	1.06
Weeding by Dutch hoe	4.78 (21.0)	3.80 (14.4)	86.1	9.9	2.5	1.2	60.7	18.6	40.2	2.37	35.32	14.49	0.69
Weedy control	10.72 (114.4)	10.19 (103.8)	-	42.5	9.5	13.5	24.5	2.3	4.6	0.43	6.64	-8.68	-6.64
LSD (P=0.05)	1.48	1.40	-	6.3	0.84	0.95	4.7	3.9	4.5	0.02	2.36	2.13	0.26

Data in parentheses denote original values; Price of wheat: grain ₹ 12/kg, straw - ₹ 2/kg

Table 2. Interaction effect of nitrogen and weed control treatments on grain yield of wheat (t/ha)

Treatment	Nitrogen (kg/ha)			
	N_0	N_{40}	N_{80}	N_{120}
Isoproturon 1.0 kg/ha	1.05	1.05	3.27	3.32
2,4-D 1.0 kg/ha	0.075	0.94	2.84	3.12
Isoproturon 1.0 kg/ha + 2,4-D 1.0 kg/ha	0.090	1.54	3.63	3.53
Weeding by Dutch hoe	1.22	1.77	3.75	3.84
Weedy control	0.080	0.28	0.64	0.72
LSD (P=0.05)	398			

post-emergence resulted in 76.7, 91.1 and 59.6% lower nitrogen, phosphorus and potash uptake by weeds compared to weedy control.

Nitrogen, phosphorus and potassium uptake by wheat was maximum at 120 kg/ha and was at par with 80 kg/ha. Increasing nitrogen level from 0 to 40, 40 to 80, 80 to 120 kg/ha increased nitrogen uptake by 104, 135 and 5.89; phosphorus uptake by 69.8, 200.0 and 18.7 and potassium uptake by 1100, 133 and 14.3% over preceding lower levels of nitrogen. Among weed control methods, weeding by dutch hoe being at par with application of isoproturon 1.0 kg/ha+ 2,4-D 1.0 kg/ha recorded significantly higher nitrogen, phosphorus and potassium up take by wheat crop

Grain yield

An increase in N level significantly increased grain yield of wheat only up to 80 kg/ha (2.84 t/ha). However, maximum grain yield of wheat (2.90 t/ha) was obtained in plots receiving 120 kg N/ha. All weed control treatments recorded significantly high grain yield compared to weed control. The grain yield with isoproturon 1.0 kg/ha + 2,4-D Na 0.75 kg/ha post-emergence (2.19 t/ha) was comparable with that of 3 weeding by Dutch hoe at 15, 30 and 45 days after sowing. The interaction effect of nitrogen levels and weed control treatments (Table 2) produced significant variation in grain yield. All weed control treatments responded only up to 80 kg N/ha in increasing the grain yield of wheat. Application of isoproturon 1.0 kg/ha + 2,4-D 1.0 kg/ha or weeding by Dutch hoe at 15, 30 and 45 DAS along with 80 or 120 kg N/ha performed similarly in producing higher wheat grain yield as compared to other weed control and nitrogen combinations.

Economics

Application of 120 kg N/ha being at par with application of 80 kg N/ha recorded significantly higher net return(₹ 26,616) and benefit cost ratio (1.52) as compared to 0 and 40 kg N/ha. Among weed control methods, application of isoproturon 1.0 kg/ha + 2,4-D 1.0 kg/ha registered significantly higher net return (₹ 16,980) and benefit cost ratio (1.06) as compared to isoproturon 1.0 kg/ha, 2,4-D 1.0 kg/ha and weeding by Dutch hoe at 15, 30 and 45 DAS.

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Efficacy of herbicides on wheat and their terminal residues in soil, grain and straw

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ABSTRACT

A field experiment was conducted during *Rabi* season of 2006-07 and 2007-08 at Gwalior (M.P.) to evaluate the effect of herbicides on weed control and yield of wheat (*Triticum aestivatum* L.) and residues of herbicides in post harvest soil, grain and straw of wheat. Ten treatments consisting of post emergence application of two doses of isoproturon (1.0 and 2.0 kg/ha), clodinafop- propargyl (60 and 120 g/ha), fenoxaprop -p-ethyl (60 and 120 g/ha) and sulfosulfuron (25 and 50 g/ha) along with two hand weeding and weedy control were evaluated in randomized block design with four replications. Samples of post harvest soil, grain and straw of wheat with higher dose of herbicides were analysed for herbicide residues by HPLC using PDA detector. Lowest weed population and weed dry weight at 60 days after sowing was recorded in isoproturon at both concentrations while lowest weed biomass at harvest and weed control efficiency was recorded in sulfosulfuron 25 g/ha followed by two hand weeding. Highest wheat yield (5.4 t/ha) was recorded in two hand weeding which was at par with sulfosulfuron 50 g/ha. clodinafop 60 g/ha, sulfosulfuron 25 g/ha and isoproturon 2.0 kg/ha. A reduction of 55.4% in wheat yield in weedy check was observed as compared to two hand weeding. A residue of 0.006, 0.041 and 0.022 µg/g isoproturon was in post harvest soil, wheat grain and straw while residues of 0.021 and 0.096 (µg g/g) clodinafop was present in soil and grain at higher level of application.

Key words: Clodinafop, Fenoxaprop-p-ethyl, Herbicide residue, Isoproturon, Sulfosulfuron, Weed dry weight, Weed population

Wheat (*Triticum aestivatum* L.) is the most important winter cereal crop of India. Isoproturon was recommended for weed control in wheat during 1980-81 and it became popular among the farmers. However, with the sole use of isoproturon continuously for a longer period, resistance in *Phalaris minor* to this herbicide was developed in Haryana (Malik and Singh 1993) and Punjab (Walia *et al.* 1997). Therefore, now a days, clodinafop, fenoxaprop-p-ethyl and sulfosulfuron are being recommended for efficient weed control in wheat (Chhonkar and Malik 2002) and are being used by farmers on large scale and are required in low doses. At the recommended dose of herbicide application, generally the problem does not arise and it selectively kills the weeds. But when the dose is more than recommended rates or due to indiscriminate use and improper calibration and method of application, there is possibility of residual hazards in soil and crop produced and can be harmful for human and animals. Keeping these in view, the study was under taken to assess the efficacy of these herbicides on weeds in wheat and to find out the residues of these herbicides in post-harvest soil, grain and straw of wheat.

MATERIALS AND METHODS

The field experiment was conducted during *Rabi* season of 2006-07 and 2007-08 at Research farm, College of Agriculture, Gwalior to evaluate the effect of herbicides on weed control and wheat productivity and residues of herbicides in post harvest soil, grain and straw of wheat. The experimental soil was sandy clay loam with 55.2% sand, 19.4% silt, 25.4% clay and 0.54% organic carbon having pH 7.2. Ten treatments consisting of isoproturon (1.0 and 2.0 kg/ha), clodinafop- propargyl (60 and 120 g/ha), fenoxaprop-p-ethyl (60 and 120 g/ha), and sulfosulfuron (25 and 50 g/ha) along with two hand weeding (30 and 60 days after sowing) and weedy control were evaluated in randomized block design with four replications. The wheat crop variety MP 4010 was sown in rows 22.5cm apart on 19 and 17 November 2006 and 2007, respectively with recommended doses of nutrients (120 kg N, 26.2 kg P and 33.3 kg K/ha in both the years) applied to all the plots. The herbicides were sprayed as post emer-

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gence 30 days after sowing (DAS) using a spray volume of 500 L/ha with a knapsack sprayer fitted with flat fan nozzle. Total rainfall received during crop season were 57.5 and 1.2 mm in first and second year respectively. The data on weed count and weed dry weight were recorded 60 DAS from an area enclosed in the quadrate of 0.25 m^2 at two places under each plot. Data on weed population were subjected to logarithmic transformation. Wheat yield and weed biomass were recorded at harvest. Soil, grain and straw samples of wheat were collected at the time of harvest and only samples with double the recommended herbicide were taken for quantitative residue analysis of herbicides. The soil, grain and straw samples were extracted for the herbicides as per the methods given by Sondhia (2006) and analyzed on a Shimadzu high performance liquid chromatography equipped with diode array detector at 206, 230, 235 and 215 nm and the retention time found was 4.6 min, 2.09 min, 2.15 min and 2.18 min for isoproturon, sulfosulforon, fenoxaprop and clodinafop respectively. Acetonitrile : water (70:30) was used as mobile phase with flow rate of 1 ml/min and detection limit 0.001 µg/g. The analysis was carried out in Residue Laboratory of Directorate of Weed Science Research, Jabalpur.

RESULTS AND DISCUSSION

Effect on weeds

The experimental field was dominated by infestation of broad leaved weeds like *Spergula arvensis, Anagallis arvensis, Chenopodium album, Melilotus indica* and *Convolvulus arvensis* ; grasses like *Phalaris minor* and sedges like *Cyperus rotundus*. The maximum mean weed population of two years was recorded in weedy check followed by fenoxaprop 240 g/ha and fenoxaprop 120 g/ha (Table 1). The lowest weed density was recorded in isoproturon 1.0 kg/ha which was at par with isoproturon 2.0 kg/ha, two hand weeding , clodinafop 60 and 120 g/ha and was found to be significantly lower than rest of the treatments. Weed dry weight reflects the growth potential of the weeds and its competitive ability with the crop plants. Weedy check recorded the highest weed dry weight while lowest weed dry weight was recorded in isoproturon 2.0 kg/ha followed by isoproturon 1.0 kg/ha, sulfosulfuron 50 g/ha and sulfosulfuron 25 g/ha. Dry weight of weeds under all herbicidal treatments and two hand weeding were at par to each other except fenoxaprop at both doses which was significantly higher than all weed control treatments. Although in most of the treatments, weed population and dry weight of weeds were recorded lower in the recommonded doses of herbicides as compared to double the recommonded, the differences were non significant. At harvest weed biomass was recorded lowest in sulfosulfuron 25 g/ha followed by two hand weeding, sulfosulfuron 50 g/ha, isoproturon 2.0 kg/ha and isoproturon 1.0 kg/ha (Table 2). Similar trend was observed for weed control efficiency with highest value recorded by sulfosulfuron 25 g/ha (95.2%) followed by two hand weeding (94.0%). It indicates that sulfosulfuron checks the growth of weeds more efficiently beyond 60 DAS as compared to isoproturon and other herbicides applied. Verma *et al.* (2007) found better weed control at 90 and 120 DAS by sulfosulfuron followed by fenoxaprop 100 g/ha and isoproturon 1.0 kg/ha. In our study fenoxaprop @ 120 and 240 g/ha was not effective to control weeds as it resulted in significantly highest weed count and weed dry weight at 60 DAS and weed biomass at harvest.

Effect on crop

Maximum mean grain yield of two year was recorded in two hand weeding (5.42 t/ha) treatment. Application of

Table 1. Effect of herbicidal treatment on population and dry weight of weeds in wheat

Treatment	Weed population/m^2*			Dry weight (g/m^2)		
	2006-07	2007-08	Mean	2006-07	2007-08	Mean
Isoproturon 1.0 kg/ha	2.79 (16.2)	2.74 (15.0)	2.75 (15.6)	37.5	24.1	30.8
Isoproturon 2.0 kg/ha	3.16 (23.0)	2.42 (12.0)	2.81 (17.5)	9.4	13.5	11.5
Clodinafop 60 g/ha	3.75 (44.2)	3.36 (30.5)	3.60 (37.3)	33.2	48.5	40.8
Clodinafop 120 g/ha	3.92 (51.7)	3.14 (23.0)	3.54 (37.3)	51.2	41.8	46.5
Fenoxaprop 120 g/ha	3.63 (44.5)	4.74 (127.5)	4.32 (86.0)	81.5	204.3	142.9
Fenoxaprop 240 g/ha	3.91 (51.0)	4.93 (150.5)	4.47 (100.7)	114.5	197.1	155.8
Sulfosulfuron 25g/ha	3.86 (47.0)	3.85 (70.0)	4.05 (58.5)	30.5	45.8	38.1
Sulfosulfuron 50 g/ha	3.51 (33.5)	3.87 (68.5)	3.87 (52.0)	45.3	31.7	38.5
Weedy check	5.19 (180.7)	5.73 (291.2)	5.44 (235.9)	204.5	373.8	289.2
Weed Free (Twice)	3.80 (48.0)	2.00 (7.2)	2.92 (27.6)	109.0	8.7	58.8
LSD (P=0.05)	0.56	0.80	0.76	69.9	59.5	82.1

*Data subjected to Logarithmic transformation. Figures in the parentheses are the original values

Table 2. Effect of different treatments on seed yield, weed biomass, weed control efficiency, net returns and B :C ratio in wheat

Treatment	Seed yield (t/ha)			Weed biomass at harvest (kg/ha)			Mean of two years		
	2006-07	2007-08	Mean	2006-07	2007-08	Mean	WCE (%)	Net returns (x10^3 ₹/ha)	BCR
Isoproturon 1.0 kg/ha (POE)	4.29	3.79	4.04	117	173	145	89.0	36.97	3.10
Isoproturon 1.0 kg/ha (POE)	4.95	4.19	4.57	110	163	136	89.7	43.56	3.40
Clodinafop 60 g/ha (POE)	5.50	3.89	4.70	83	315	199	84.9	43.53	3.55
Clodinafop 120 g/ha (POE)	3.55	4.14	3.85	58	272	165	87.5	33.19	2.77
Fenoxaprop 120 g/ha (POE)	2.72	3.46	3.09	418	986	702	46.9	23.71	2.32
Fenoxaprop 240 g/ha (POE)	2.26	2.74	2.50	517	1271	894	32.4	14.82	1.78
Sulfosulfuron 25 g/ha (POE)	5.31	3.98	4.65	69	58	63	95.2	45.02	3.54
Sulfosulfuron 50 g/ha (POE)	5.76	4.42	5.09	113	74	93	93.0	50.29	3.72
Weedy check	2.38	2.46	2.42	775	1871	1323	-	15.64	1.92
Weed free	5.63	5.22	5.42	137	22	79	94.0	52.03	3.45
LSD (P=0.05)	0.92	1.04	1.04	1111	403	798	-	-	-

sulfosulfuron 50 g/ha (5.09 t/ha), clodinafop 60 g/ha (4.6 t/ha), sulfosulfuron 25 g/ ha (4.6 t/ha) and IPU 2.0 kg/ha (4.5 t/ha) were at par with two hand weeding treatment in respect of grain yield and they were superior to all other treatments during both years. Better performance of these treatments in terms of yield could be owing to better control of complex weed flora tilting the crop weed competition in favour of the crop. Higher weed population and weed dry weight showed reduction of 55.42% grain yield (Table 2) in weedy check compared to hand weeding twice. In both the years fenoxaprop showed phytotoxicity as yellowing of plants at both the doses which was recovered after 70-80 DAS. Fenoxaprop at both doses failed to increase the seed yield significantly over weedy check possibly due to its lower WCE and phytotoxicity. Shukla and Mishra (2006) also found highest wheat grain yield in sulfosulfuron (25 g/ha) followed by clodinafop (60 g/ha), isoproturon (1.0 kg/ha) and fenoxaprop (90 g/ha) under bed planted late sown wheat.

Economics

The economic analysis based on mean of two years (Table 2)indicated that maximum net return was obtained with two hand weeding (₹52,035), followed by sulfosulfuron 50g/ha (₹ 50,287) and sulfosulfuron 25g/ha (₹ 45,019) while highest benefit cost ratio (BCR) was obtained with sulfosulfuron 50 g/ha (3.72) followed by clodinafop 60 g/ha (3.55), sulfosulfuron 25 g/ha (3.54) and two hand weeding (3.45).

Herbicide residues

The analysis of terminal residue of herbicides in post harvest soil (Table 3) indicated that residue of 0.006 and 0.021 µg/g isoproturon and clodinofop respectively were detected in post harvest soil whereas no residues of fenoxaprop and sulfosulfuron were detected in soil. Similarly in wheat grain, isoproturon and clodinofop residues were present at the level of 0.041 and 0.096 µg/g, which were below the MRL (0.05 mg/kg for isoproturon and 0.1 mg/kg for clodinofop). In wheat grain sulfosulfuron residues were below detectable limit. In straw only isoproturon residue could be detected to the level of 0.022 µg/g. Sondhia (2006) reported isoproturon and fenoxaprop residues in post harvest soil, grains and straw of wheat, while residues of sulfosulfuron were detected in wheat grain and straw only. Sulfosulfuron residues were not found in wheat grains, straw and subsequent vegetables in natural ecosystem as well as in model ecosystem at 25 and 50 g/ ha in wheat crop (Ramesh and Maheshwari, 2003; Sondhia *et al*. 2007). Chandi *et al.* (2005) also revealed that grains and straw of Durum wheat contained the residues of isoproturon and sulfosulfuron below the detectable limits. The residues of clodinofop (60-120 g/ha) were not detected in wheat grain and soil at harvest, however, 0.0089 ppm residues were detected in wheat grains at 240 g/ha (Sondhia and Mishra 2005).

Table 3. Residues of herbicides (µg/g) in post-harvest soil, grain and straw of wheat crop

Herbicide	Soil	Grain	Straw
IPU 2.0 kg/ha	0.006	0.041	0.022
Clodinafop 120 g/ha	0.021	0.096	BDL
Fenoxaprop 240 g/ha	BDL	ND	ND
Sulfosulfuron 50 g/ha	BDL	BDL	BDL

BDL – Below detectable limit (0.001 µg/g); ND – Not done

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Weed management in lentil

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ABSTRACT

A field experiment was conducted to explore the feasibility of growing lentil with integration of weed management practices using herbicide, increased plant population and manual weeding at Meerut during 2008-09 and 2009-10. The experiment was laid out in randomized block design with four replications and ten treatments. The major weeds in experimental field were *Chenopodium album, Phalaris minor, Anagalis arvensis* and *Convolvulus arvensis* were recorded with some other minor weed species. Lowest weed density (4 m^2) and dry weight (2.64 g/m^2) was recorded where pendimethalin was applied 0.75 kg/ha as PE plus one hand weeding, which was statistically on par with pendimethalin 1.0 kg/ha. Whereas, the highest grain yield of 1662 kg/ha was recorded by pendimethalin 0.75 kg/ha plus one hand weeding, which was statistically at par with weed free as well as pendimethalin 1.0 kg/ha. Increased seed rate of 25% significantly decreased the weed dry weight (32.0%) and increased seed yield (22.8%) in comparison to their respective treatments. On an average of 37.7% yield reduction was recorded due to weed infestation. The highest gross returns of ₹ 23,268, net returns of ₹ 15,918 and B:C was recorded by pendimethalin 0.75 kg/ha PE + one hand weeding.

Key words: Chemical weed control, Integrated weed management, Lentil, Weed Management

Lentil is an important crop among *Rabi* pulses and usually grown on marginal and sub-marginal lands of western Uttar Pradesh without weed management. Presently not only the productivity and production are diminishing but area is also shrinking under this crop. Among various barriers like hungry and discarded soil, lack of promising cultivars, improper fertilization, pest, disease, poor weed management is the most important yield limiting factors. Weed reduces yield of lentil to the extent of 73% (Phogat *et al.* 2003). Mechanical/manual weeding is normally tedious, labour consuming and costlier. weed management, which includes use of herbicides and different planting methods, can prove more economical and beneficial in lentil crop.

MATERIALS AND METHODS

A field experiment was conducted at Crop Research Station of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, during *Rabi* season of 2008-09 and 2009-10. Ten treatments consisted with pendimethalin 1.0 kg/ha PE, pendimethalin 0.75 kg/ha PE + 1 HW, isoproturon 1.0 kg/ha PE, isoproturon 0.75 kg/ha PoE, isoproturon 0.75 kg/ha PoE + 1 HW, 25% more seed, 25% more seed + 1 HW, one hand weeding, weed free check and weedy check were laid out in randomized block design with four replications. The soil of experimental site was loam in texture, normal in reaction (pH 7.8), low in nitrogen and phosphorus and medium in potassium status. Lentil variety '*PL-406*' was sown in last week of October during both the seasons of investigation. Recommended package of practices, except weed control treatments was adopted to grow the experimental crop. Herbicides were applied with knapsack foot sprayer fitted with flat fan nozzle. Species-wise weed population, their dry matter accumulations and finally seed yield and yield attributes were recorded.

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RESULTS AND DISCUSSION

Effect on weeds

The major weeds in experimental field were *Chenopodium album, Phalaris minor, Anagalis arvensis* and *Convolvulus arvensis* with some other minor weed species. The annual dicot weeds were dominant among the weed flora throughout the crop season during both the years. On an average of 37.7%, yield reduction was recorded due to weed infestation in comparison to weed free conditions. All the treatments of weed management practices proved significantly superior to weedy check in reducing weed density and dry matter at 90 DAS (Table

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

Treatment	Species-wise weed density (no./m²)					Total weed density/m²	Weed dry weight (g/m²)	Weed control efficiency (%)
	Chenopodium album	*Phalaris minor*	*Anagalis arvensis*	*Convolvulus arvensis*	Other weeds			
Pendimethalin 1.0 kg/ ha PE	2.2 (4)	2.6 (6)	2.8 (7)	2.0 (3)	2.4 (5)	5.1 (25)	3.1(8.9)	91.2
Pendimethalin 0.75 kg/ ha PE + 1 HW	1.7(2)	2.2 (4)	2.0 (3)	1.7 (2)	2.2 (2)	4.0 (15)	2.6 (6.0)	94.1
Isoproturon 1.0 kg/ ha PE	4.4 (18)	2.6 (6)	4.6 (20)	4.0 (15)	3.0 (8)	8.2 (67)	5.2 (25.8)	74.6
Isoproturon 0.75 kg/ ha PoE	4.4 (18)	2.0 (3)	3.9 (14)	3.9 (14)	2.6 (6)	7.5 (55)	20.0 (20.0)	83.7
Isoproturon 0.75 kg/ ha PoE + 1 HW	4.8 (22)	3.0 (8)	4.9 (23)	4.6 (20)	2.8 (7)	9.0 (80)	5.4 (27.7)	72.7
25% more seed	6.1 (36)	5.2 (26)	5.7 (32)	4.7 (21)	3.0 (8)	11.1 (123)	6.9 (46.3)	45.4
25% more seed + 1 HW	5.6 (30)	3.9 (14)	4.7 (21)	3.2 (9)	4.0 (15)	9.5 (89)	4.8 (22.0)	78.3
One hand weeding	5.3 (27)	3.5 (11)	5.2 (26)	4.9 (23)	2.6 (6)	9.7 (93)	5.7 (31.1)	69.4
Weed free check	1.0 (1)	1.0 (1)	1.4 (1)	1.0 (0)	1.4 (1)	1.7 (2)	1.5 (1.2)	98.8
Weedy check	7.7 (59)	7.0 (48)	6.3 (39)	4.1 (16)	4.9 (23)	13.6 (185)	10.1(101.5)	-
LSD (P=0.05)	0.8	0.9	0.7	0.6	0.6	1.3	0.7	-

Values given in parentheses are mean of original values, which are transformed to $\sqrt{x+1}$, DAS: Days after sowing; HW: Hand weeding; PE: Pre-emergence (just after sowing); PoE: Post-emergence

Table 2. Effect of weed control treatments on yield and economics of lentil (pooled data of two years)

Treatment	Pods/ plant	Grains/ pod	1000-seed weight (g)	Seed yield (t/ha)	Straw yield (t/ha)	HI (%)	Gross return (x 10³ ₹/ha)	Net return (x 10³ ₹/ha)	B:C ratio
Pendimethalin 1.0 kg/ha PE	95.2	1.3	31.3	1.59	2.20	0.42	22.34	15.14	2.1
Pendimethalin 0.75 kg/ha PE+1 HW	96.2	1.4	31.3	1.66	2.29	0.42	23.26	15.91	2.3
Isoproturon 1.0 kg/ha PE	90.1	1.3	30.4	1.50	2.16	0.41	21.07	14.57	2.2
Isoproturon 0.75 kg/ha PoE	95.4	1.3	31.5	1.55	2.15	0.42	21.81	15.13	2.2
Isoproturon 0.75 kg/ha PoE+1 HW	88.9	1.3	31.2	1.42	2.04	0.41	19.93	13.56	2.1
25% more seed	69.5	1.2	29.3	1.29	2.28	0.36	18.17	12.08	2.0
25% more seed + 1 HW	72.5	1.3	29.8	1.54	2.37	0.39	21.67	15.04	2.3
One hand weeding	93.8	1.3	33.0	1.48	2.14	0.41	20.84	14.49	2.2
Weed-free	94.2	1.5	33.8	1.69	2.54	0.40	23.75	15.75	2.0
Weedy check	72.5	1.2	29.3	1.05	2.00	0.34	14.79	8.79	1.5
LSD (P=0.05)	10.7	0.2	1.0	0.21	0.27	0.02	-	-	-

1). Lowest weed density (4 m²) and dry weight (2.64 g/m²) was recorded where pendimethalin was applied 0.75 kg/ha as PE plus one hand weeding, which was statistically at par with pendimethalin 1.0 kg/ha PE and significantly lower than that of other treatments, involving isoproturon irrespective of dose, time or with or without hand weeding. Increased seed rate of 25% significantly decreased the weed dry weight (32%) in comparison to their respective treatments. The maximum weed control efficiency of 94.1% was recorded with pendimethalin 0.75 kg/ha with one hand weeding followed by pendimethalin 1.0 kg/ha this may be attributed to inhibition of weed seed germination. Similar findings were also reported by Singh *et al.* (1994) and Jain (2007).

Effect on crop

Application of herbicides had significant effect on yields and yield attributes of lentil (Table 2). The highest grain yield of 1.66 t/ha was produced by pendimethalin 0.75 kg/ha plus one hand weeding was statically at par with pendimethalin 1 kg/ha as well as weed free and proved superior over rest of the treatments with respect to grain yield. However, similar trends were observed for straw yield. Twenty five per cent increase in seed rate also significantly influenced the grain and straw yield as comparison to their respective treatments. On an average 22.8% increase in yield was recorded by 25% increase in seed rate, while 19.26 and 40.87% increment in yield was observed by one hand weeding in the treatment of 25% increased seed and normal seed rate conditions, respectively.

Weed-free conditions provided 60% increased in yield over weedy. Similar results were also reported by Jain (2007).

Economics

Data presented in Table 2 revealed that the highest gross returns (₹ 23,268), net returns (₹ 15,918) and B:C was recorded with application of pendimethalin 0.75 kg/ ha PE + one hand weeding among different herbicidal treatments, while it was almost similar to the weed free conditions. Whereas lowest gross return and net return were recorded in weedy check. Similar findings were also reported by Turk and Tawaha (2001) and Jain (2007).

Therefore, it was concluded that pendimethalin 0.75 kg/ha PE followed by one hand weeding is better for broad-spectrum weed control, including grassy as well as broad-leaved weeds.

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Integration of chemical and cultural methods for weed management in groundnut

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ABSTRACT

A field experiment was conducted to study the integrated weed management in groundnut (*Arachis hypogaea* L.) for consecutive two *Kharif* seasons in 2010 and 2011 at Rahuri with combination of 12 weed management treatments in three replications. Weed free check (two hand weeding at 20 and 40 DAS and manually uprooting of weeds at 60 DAS) was found more effective to control weeds in groundnut and recorded lowest weed density, wed dry matter and weed index and highest weed control efficiency. It was also recorded significantly highest growth and yield attributes in groundnut over all the other treatments *viz.* plant height, dry matter weight of plant, number of pods/plant and pod yield/hectare. Though highest gross monetary returns (₹ 1,09,845/ha) was recorded in treatment weed free check, maximum net monetary returns (₹ 61,460/ha) and B:C ratio (2.42) were recorded in the treatment application of pendimethalin 1.5 kg/ha as pre-emergence + imazethapyr 0.150 kg/ha as post-emergence + one hand weeding at 40 DAS which was found most economically feasible weed management practice for groundnut.

Key words: Cultural methods, Economics, Groundnut, Herbicides, Weed dynamics, Weed management, Yield

Groundnut is an important oilseed crop of India which is cultivated in nearly 6 million ha area with the production of 7.5 million tones and average productivity of 1.27 t/ha. Though India ranks first in the world under groundnut area, there is need to import 8.03 million tons of edible oil. The principle reasons behind this are lower productivity and losses of commodity at the time of various stages of crop production. Cultivation of groundnut as rain fed crop, lack of knowledge among the farmers about cultivation of groundnut with modern technology, unawareness of improved varieties and improper fertilization *etc.* are some causes of lower productivity of groundnut in India. Along with these, the major cause of minimizing production is severe weed infestation in crop. In India, yield losses of groundnut due to weeds ranged from 13-80% (Ghosh *et al.* 2000).

Weeding and hoeing are common cultural and manual weed management methods for groundnut, but with considering the scarcity of labours, these methods are very costly and tedious. Mechanically operated power weeder can not be used after peg initiation of groundnut. On the other hand, use of herbicides is also limited due to their selectivity. Hence the agronomic investigation was conducted to find out practically convenient and economically feasible combination of chemical and cultural methods of weed management in groundnut.

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MATERIALS AND METHODS

The experiment was conducted at Breeder Seed Production Farm of Mahatma Phule Krishi Vidyapeeth, Rahuri for two consecutive *Kharif* seasons of the years 2010 and 2011 in randomized block design with 12 treatments replicated thrice. The experimental site was located at 19^0 47' N latitudes and 74^0 81' E longitudes with average annual rainfall of 520 mm. The soil of experimental field was medium deep with pH 6.2, available N 380 kg/ha, $P_2O_5$14.5 kg/ha and K_2O 275 kg/ha. The treatments consisted of combination of hand weeding with pre-plant incorporation of fluchloralin 1.5 kg/ha, pre-emergence application of pendimethalin 1.5 kg/ha and post-emergence application of imazethapyr 0.150 kg/ha (Table 1).

Groundnut variety *'TAG- 24'* was sown in first fortnight of July during both the experimental years with plant spacing of 45 x 15 cm^2 on flat beds. The recommended dose of fertilizer 25 : 50 : 00 kg/ha N, P_2O_5 and K_2O was applied as half of N and full P_2O_2 and K_2O at the time of sowing and remaining N was applied one month after sowing the crop. Protective irrigations were applied whenever it was necessary during the crop growth. Fluchloralin was applied one day before sowing as pre-plant incorporation in soil and pendimethalin was applied one day after sowing as pre-emergence, whereas imazethapyr was applied 20 days after sowing as post-emergence as per the treatment details (Table 1) with knapsack sprayer. Weed free check was achieved by two hand weedings at 20 and 40 DAS and manual uprooting of weeds at 60 DAS. Randomly five plants were selected from each plot and regular biometric observations of crop and weed parameters were recorded from 30 DAS up to harvest. However, observation data recorded at the peck growth period of crop *i.e.* 90 DAS is given in tables for study the results and discussion. Weed density (no./m^2) and dry weight of weeds (g/m^2) were recorded by putting a quadrate of 0.25m^2 at two random spots in each plot. Weed control efficiency and weed index was calculated by standard formulae. For economic study, prevailing market price was used for different outputs and inputs.

RESULTS AND DISCUSSION

Effect on weeds

Predominant weeds in experimental groundnut field were: *Parthenium hysterophorus, Amaranthus viridis, Portulaca oleracea, Argemone mexicana, Euphorbia* spp., *Solanum nigrum, Echinochloa colonum, Cyperus rotundus* and *Cynodon dactylon*.

All the treatments were responsible for significant reduction in weed density and dry weight of weeds over control. Treatment of weed free check resulted in lowest weed density and dry weight of weeds. However, treatment weed free check, pendimethalin 1.5 kg/ha as PE + imazethapyr 0.150 kg/ha as POE+ one hand weeding at 40 DAS and fluchloralin 1.5 kg/ha as PPI + imazethapyr 0.150 kg/ha as POE + one hand weeding at 40 DAS were found to be at par with each other in respect of these weed parameters.

Highest weed control efficiency and lowest weed index percentage were observed in weed free check. Pendimethalin 1.5 kg/ha as PE + imazethapyr 0.150 kg/ha as POE + one hand weeding at 40 DAS was found next superior treatment after weed free check in respect of all weed parameters. This might be due to pre-plant soil incorporation of fluchloralin and pre-emergence application of pendimethalin which prevented emergence of monocot and grassy weeds by inhibiting root and shoot growth, while imazethapyr was responsible for inhibition of acetolactate synthase (ALS) or acetohydroxyacid synthase (AHAS) in broad-leaved weeds which caused destruction of these weeds at 3-4 leaf stage. Remaining monocot weeds were controlled by hand weeding at 40 DAS and manual uprooting at 60 DAS. Lowest weed control efficiency and highest weed index percentage were recorded in weedy check (control). Integration of hand weeding with pre- and post-emergence herbicides resulted significant reduction in dry matter production by weeds (Walia *et al*. 2007). Dubey and Gangwar (2012) have also found lower weed biomass, weed index and higher weed control efficiency with post-emergence application of imazethapyr and two hand weeding in groundnut.

Table 1. Effect of different weed management practices on weed parameters in groundnut at 90 DAS (pooled mean)

Treatment	Weed density (no./m^2)	Weed control efficiency (%)	Weed index (%)
Fluchloralin 1.5 kg/ha as PPI + imazethapyr 0.150 kg/ha as POE	37.88	74.60	43.93
Imazethapyr 0.150 kg/ha as POE + one hand weeding at 40 DAS	26.62	87.44	26.98
Pendimethalin 1.5 kg /ha as PE	47.94	67.94	61.78
Fluchloralin 1.5 kg/ha as PPI + imazethapyr 0.150 kg/ha as POE + one hand weeding at 40 DAS	22.19	87.83	18.26
Imazethapyr 0.150 kg/ha as POE	41.54	69.31	54.52
Fluchloralin 1.5 kg/ha as PPI + one hand weeding at 20 DAS	31.34	78.71	38.22
Pendimethalin 1.5 kg/ ha as PE+ imazethapyr 0.150 kg/ha as POE+ one hand weeding at 40 DAS	19.54	89.94	5.13
Pendimethalin 1.5 kg/ha as PE+ one hand weeding at 20 DAS	30.71	82.53	35.37
Fluchloralin 1.5 kg/ha as PPI	50.28	65.66	57.91
Pendimethalin 1.5 kg/ha as PE+ imazethapyr 0.150 kg/ha as POE	36.29	73.82	41.97
Weed-free	16.66	91.40	0.00
Weedy check	124.39	0.00	69.52
LSD (P=0.05)	7.63	-	-

PPI- Pre-plant incorporation; PE- Pre-emergence; POE- Post-emergence

Effect on crop

Weed-free recorded significantly taller plants and higher dry matter production and pod yield/hectare over all the other treatments. This was followed by treatment pendimethalin 1.5 kg/ha as PE + imazethapyr 0.150 kg/ha as POE + one hand weeding at 40 DAS. However in respect of number of pods/plant, weed free check and pendimethalin 1.5 kg/ha as PE + imazethapyr 0.150 kg/ha as POE + one hand weeding at 40 DAS were found at par with each other. This might be due to minimizing the competition of weeds with main crop for resources *viz*. space, light, nutrients and moisture with adaption of effective weed control methods. Singh and Giri (2001) has also concluded that proper weed control was responsible for increase in plant height and dry matter production in groundnut. Weed free environment in crop also facilitated better peg initiation and development at the critical growth stages of groundnut which tends to increase in number of pods/plant and pod yield/hectare. Higher profitable pod yield of summer groundnut was also reported by Raj *et al*. (2008) with keeping the crop in weed free condition. Significantly lower values of plant height, number of pods and pod yield were recorded in treatment weedy check.

Number of kernels/pod was recorded highest in weed free check, but there was no significant effect of weed management practices on number of kernels per pod in groundnut.

Economics

Weed-free check recorded significantly highest gross returns, which was ₹ 1,09,845/ha, whereas highest net returns (₹ 61,460) and B:C ratio (2.42) were recorded in treatment pendimethalin 1.5 kg/ha as PE + imazethapyr 0.150 kg/ha as POE+ one hand weeding at 40 DAS. This might be due to the cost of cultivation of groundnut crop was increased in treatment weed free check due to the higher need of human labours and their higher wages. This cost was reduced in treatment pendimethalin 1.5 kg/ha as PE + imazethapyr 0.150 kg/ha as POE+ one hand weeding at 40 DAS by using herbicides to effective control of weeds with minimizing human labours. Sasikala *et. al*. (2004) and Rao *et. al*. (2011) have also reported higher net return and B:C ratio with integration of pre- and post-emergence application of herbicides with hand weeding in groundnut. Weedy check (control) recorded lowest gross monetary return (₹ 33,660/ha), net monetary return (₹ 2,140/ha) and B:C ratio (0.94).

Table 2. Effect of different weed management practices on growth, yield and economics of groundnut (pooled mean)

Treatment	Plant height at 90 DAS (cm)	No. of pods/plant	No. of kernels/pod	Pod yield (t/ha)	Gross returns (x 10^3 ₹/ha)	Net returns (x 10^3 ₹/ha)	B:C ratio
Fluchloralin 1.5 kg/ ha as PPI+ imazethapyr 0.150 kg/ ha as POE	22.27	16.8	2.19	1.38	61.92	22.66	1.58
Imazethapyr 0.150 kg/ha as POE+ one hand weeding at 40 DAS	25.18	19.5	2.34	1.79	80.64	38.84	1.93
Pendimethalin 1.5 kg /ha as PE	21.61	14.8	2.27	0.94	42.21	4.91	1.13
Fluchloralin 1.5 kg/ha as PPI+ imazethapyr 0.150 kg/ha as POE + one hand weeding at 40 DAS	25.37	19.5	2.34	2.01	90.27	46.97	2.08
Imazethapyr 0.150 kg/ha as POE	22.03	16.3	2.19	1.12	50.22	12.42	1.32
Fluchloralin 1.5 kg/ha as PPI + one hand weeding at 20 DAS	24.21	17.3	2.34	1.52	68.22	26.92	1.65
Pendimethalin 1.5 kg/ ha as PE+ imazethapyr 0.150 kg/ha as POE+ one hand weeding at 40 DAS	26.49	21.2	2.36	2.33	104.76	61.46	2.42
Pendimethalin 1.5 kg/ha as PE+ one hand weeding at 20 DAS	24.9	18.3	2.26	1.58	71.14	29.84	1.72
Fluchloralin 1.5 kg/ha as PPI	20.06	14.7	2.26	1.03	46.48	9.18	1.25
Pendimethalin 1.5 kg/ha as PE+ imazethapyr 0.150 kg/ha as POE	22.46	17.3	2.24	1.42	64.08	24.78	1.63
Weed-free	29.12	22.0	2.41	2.45	109.84	60.04	2.21
Weedy check	16.84	11.2	2.17	0.75	33.66	-2.14	0.94
LSD (P=0.05)	2.01	1.6	NS	0.12	3.33	2.90	-

Treatment pendimethalin 1.5 kg/ha as PE + imazethapyr 0.150 kg/ha as POE + one hand weeding at 40 DAS proved practically more convenient and economically best feasible integrated weed management practice for groundnut. Considering the present condition of scarcity and high cost of labours, quality of weed control, yield and B:C ratio of cultivation of groundnut,

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Yield and quality analysis of spring–planted sugarcane as influenced by nutrient and weed management

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ABSTRACT

A field study was conducted during spring season in 2007-08 and 2008-09 at Muzaffarnagar to evaluate the influence of nutrient and weed management practices on yield attributes, yield, quality, nutrient uptake and economics of sugarcane. Results showed that application of 125% of recommended dose of fertilizer (RDF) enhanced the cane yield to the tune of 15.52 and 3.60% over 75 and 100% RDF owing to remarkable improvement in cane length, cane girth, cane weight and NMC. Sucrose, available sugar and commercial cane sugar (CCS) yield were also improved by 17.3, 23.4 and 42.6% over 75% RDF while 2.73, 3.15 and 6.84% over 100% RDF, respectively under application of 25% higher RDF. The values of juice extraction and purity per cent were remained statistically unchanged under 100 and 125% RDF but significantly improved over 75% RDF. The uptake of NPK in cane, green tops, trash as well as in total produce along with net return and B:C ratio were also noticed higher under fertility enrichment with 125% in comparison to lower ones. Weed free treatment produced maximum values of cane and CCS yield, yield components, juice extraction and nutrient uptake which was followed by application of glyphosate 1.0 kg/ha at 25 days after planting followed by one hand weeding at 60 DAP and performing of three hand weeding at intervals of 30, 60 and 90 days after planting (DAP). Although, the higher B:C ratio was registered under application of glyphosate 1.0 kg/ha, at 25 DAP followed by one hand weeding at 60 DAP owing to lower cost of cultivation. Consequently, application of 125% recommended dose of N: P_2O_5:K_2O along with glyphosate applied 1.0 kg/ha at 25 DAP followed by one hand weeding at 60 DAP proved valuable in enhancing the yield, quality and economics of spring planted sugarcane.

Key words: Nutrient levels, Quality, Sugarcane, Weed management, Yield

Sugarcane (*Saccharum officinarum* L.) is grown extensively in tropical and sub- tropical regions of India as cash crop and plays a pivotal role in both agricultural and industrial economy of the country. In India, sugarcane is grown under different agro-climatic conditions and occupies about 2.54% (5.08 mha) of gross cropped area with an average productivity of 68.4 t/ha. Sugarcane production coupled with improved quality traits needs sufficient amount of plant nutrients in the soil. Imbalanced and inadequate use of plant nutrients results in poor cane yield and emergence of multiple nutrient deficiencies.

Nitrogen, phosphorus and potassium account for bulk of essential nutrients, which many soils are deficient and need supplementation through organic and inorganic sources. Higher fertilizer doses proved to be superior in respect to growth and yield. Thus, to make the sugarcane cultivation more remunerative, there is need to refine NPK recommendation upto the desired level. Due to slow germination and initial growth, wide row spacing, slow lateral spread, adequate supply of nutrients and moisture, long duration and diversity in weed population, sugarcane generally suffers from the tremendous weed problems. Uncontrolled weeds may cause 12 - 72% cane yield reduction. It is well established fact that a mechanical method of weed management is most effective to control weeds. However, higher cost involvement and lack of labour availability in proper time make it difficult to adopt by the farmers. On the other hand, only application of herbicide is not proved so effective method. Similarly, alternative herbicides should be tested to minimize the chances of weed resurgence against commonly used herbicides having same mode of action. Therefore, there is need to develop the most effective and economical fertilizer management and weed control practices for obtaining maximum yield as well as profitability. Keeping in view, a field experiment was conducted to recommend the best suitable fertilizer management and weed management technique for spring planted sugarcane crop.

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MATERIALS AND METHODS

An investigation was carried out during spring seasons of 2007-08 and 2008-09 at Agricultural Research farm of Chaudhary Chhotu Ram (P.G.) College, Muzaffarnagar (Uttar Pradesh) geographically situated at 28.0^0N latitude and 77.0^0E longitude at an altitude of 245.82 meters above the mean sea level. The soil of the experimental field was sandy- loam of Indo-Gangetic alluvial origin, very deep (>2m), well drained, flat and classified as non-calcareous mixed hyperthermic *Udic Ustochrept*, having pH 7.5 and was low in organic carbon (0.48%), medium in both available phosphorus (14.24 kg/ha), potassium (203.92 kg/ha) and low in available nitrogen (155.45 kg/ha) contents.

The experiment was laid out in a factorial randomized block design. The treatments consisted of total 21 combinations of three levels of NPK and seven weed control measures with three replications. The NPK levels were the application of 75% N: P_2O_5: K_2O (F_1), 100% (150 :60 : 60 kg/ha) N: P_2O_5: K_2O (F_2) and 125% N: P_2O_5: K_2O (F_3) of the recommended dose of fertilizer (RDF). Under weed control measures, the treatments were: three hand weedings at 30, 60 and 90 DAP (W_1), one hand weeding at 30 DAP followed by post emergence spray of atrazine 2.0 kg/ha (W_2) , atrazine 2.0 kg/ha as pre-emergence + 2, 4-D 1.0 kg/ha at 60 DAP (W_3), glyphosate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP (W_4) and *Sesbania sesbane* L. (Dhaincha) sowing in inter space followed by 2,4-D spray 1.0 kg/ha at 45 DAP (W_5), weedy check (W_7), weed free (W_6).

Urea, diammonium phosphate and muriate of potash were taken as fertilizer sources for N, P and K, respectively. The amount of fertilizers and herbicides were calculated on the basis of gross plot area. Full dose of P and K and half dose of N were applied as basal. Remaining half N was top dressed in two equal splits after first irrigation and at the time of earthing up. All the herbicides were applied with the help of manually operated knapsack sprayer fitted with flat fan nozzle using a volume spray of 600 litres water/ha.

A mid-late variety of sugarcane *'CoS-97264'* was planted on 23^{rd} and 24^{th} March of 2007 and 2008, respectively on leveled soil by opening 15 cm deep furrow at 75 cm row spacing. During 2008-09, the experiment was conducted in the adjacent to the experimental plot of 2007-08. All the recommended agronomic practices were followed throughout the cropping period. The crop was harvested on 20^{th} and 21^{st} February 2008 and 2009, respectively.

Whole cane samples were taken at the time of harvest and analyzed for quality parameters through standard laboratory procedures. The economics of experiment was worked out on the basis of cost of cultivation and cane yield at prevailing market prices of the treatments. The uptake of N, P and K by sugarcane plant was calculated by multiplying the concentration with their respective dry matter yield (kg/ha). The per cent available sugar was calculated as; available sugar (%) = {S – (B – S) x 0.4 x 0.73}, where S and B are sucrose and brix per cent in cane juice, respectively. The trend of results was similar during both the years hence, data were subjected to pooled analysis for results and discussion.

RESULTS AND DISCUSSION

Yield attributes

NPK levels had significant impact on yield attributes (Table 1). Among the different fertility levels of NPK, the application of 125% (F_3) of the recommended dose of NPK was superior to all other fertility levels in terms of cane length, cane girth, number of internodes/cane, single cane weight as well as number of millable canes (NMC). It was followed by NPK application at 100% (F_2) recommended dose except in case of cane girth where both the treatments yielded statistically similar response. The lowest yield attributes of sugarcane was obtained from the plots receiving 75% (F_1) recommended dose of NPK.

The increase in yield components under higher dose of fertility might be ascribed to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication and elongation in the plant body, which ultimately increased the cane length. The maximum cane girth, number of internodes/cane, individual cane weight and number of millable canes with highest level of NPK was primarily due to the improved fertility status of soil which created congenial environment for better growth and development of sugarcane plant. The positive response with NPK on yield attributes of sugarcane was also reported by Shukla (2007).

Weed management modules under investigation also significantly influenced the yield components of sugarcane (Table 1). Weed free plots (W_6) produced maximum values of yield attributes, *viz.* cane length, cane girth, single cane weight, number of internodes/ plant and NMC being at par with application of glyphosate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP (W_4) and performing of three hand weeding at 30, 60 and 90 DAP (W_1). The latter two treatments (W_1 and W_4) were also tended the similar response except in generation of NMC where W_4 showed superiority over W_3 The lowest values of yield parameters were observed under control *i.e.* weedy check (W_7) treatment.

Sugarcane raised with weed free (W_6), application of glyphosate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP (W_4) and three hand weeding at 30, 60 and 90 DAP (W_1) produced highest yield components by virtue of reduced competition of weeds for nutrient, moisture and sunlight. These results are in agreement with the findings of Srivastava and Chauhan (2006).

Yield

Fertility levels brought significant variations among cane, green tops and trash yields (Table 1). Significantly higher commercial cane sugar (CCS) and cane, green tops as well as trash yields were obtained with 125% (F_3) recommended dose of NPK. However, fertilization of cane crop with being 100% RDF produced equal green top and trash yields as obtained with 125% recommended dose of NPK as compared to 75% (F_1) recommended dose of NPK. The increase in yield under higher doses of fertilizer might be due to enhanced cane growth and development attributed to the production of lengthiest, thickest and heaviest canes. The increased rate of cane growth coupled with better expression of yield components might have attributed for enhancing the cane yield under higher fertility. Saini *et.al.* (2007) and Naidu *et.al.* (2008) reported increase in cane yield with corresponding increase in levels of fertilizer.

The highest cane, green tops and trash yields were obtained under weed free conditions (W_6) which was found on par with the application of glyphosate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP (W_4). It was followed by adoption of weed management schedule W_1, in which three hand hoeing were performed at interval of 30, 60 and 90 DAP. While the lowest values of yields of cane, green tops and trash were noticed by un-weeded plots (W_7).

The increase in cane, green tops and trash yields with these treatments was because of the fact that the weed population and weed growth remained low under their initial crop growth period as compared to weedy check. The reduced crop-weed competition provided proper development of growth characters which enhanced the yield attributes, *viz.* cane length, cane diameter , number of internodes/cane, cane weight and NMC/ha which led to higher cane, green top and trash yield. A negative correlation between most of the growth, yield attributes and dry matter of weeds at final harvest has also been established by the earlier researchers. This finding was in conformity with Singh and Menhi (2008).

Table 1. Effect of fertilizer and weed management on yield components and yield of spring–planted sugarcane (pooled data of two cycles)

Treatment	Cane length (cm)	Cane girth (cm)	Number of internodes/ cane	Single cane weight (g)	NMC* ($x10^3$₹/ha)	Yield (t/ha)		
						Cane	Green tops	Trash
Fertilizer levels								
F_1	247.7	6.35	20.30	709.2	90.0	76.20	15.29	7.94
F_2	265.2	7.00	23.33	798.7	108.0	84.97	17.40	8.79
F_3	277.4	6.96	23.82	818.4	110.1	88.03	17.64	9.03
LSD (P=0.05)	4.8	0.17	0.24	12.1	2.3	3.24	0.66	0.37
Weed control								
W_1	269.8	7.03	23.25	802.8	112.1	89.55	17.99	9.24
W_2	262.5	6.65	22.20	778.6	103.6	84.18	16.68	8.51
W_3	253.7	6.50	21.75	757.7	88.8	78.61	16.38	7.97
W_4	276.1	7.15	23.46	818.7	117.4	90.08	18.45	9.32
W_5	257.2	6.33	22.62	780.7	93.1	81.41	16.73	8.31
W_6	283.4	7.24	23.88	826.3	127.4	97.50	18.93	9.67
W_7	241.3	5.85	20.25	663.1	76.4	60.13	12.25	7.10
LSD(P=0.05)	13.9	0.25	1.02	40.7	5.2	4.65	0.85	0.44

#Details of treatments are given in Materials and Methods; *Number of millable canes

Juice quality

Fertility levels caused significant impact on juice quality parameters except brix percentage which nullify the effect of fertility levels (Table 2). The juice quality and CCS yield were improved with each successive increase in NPK levels. The crop fertilized with NPK at 125% (F_1) of recommended dose significantly boost the sucrose and available sugar % and CCS yield but was reported on par in terms of juice extraction % and purity % with the application of 100% RDF. The lower values of these parameters were recorded under lowest fertility treatments. The remarkable improvement in CCS under high fertility conditions in comparison to sub fertility conditions was due to production of higher cane yield coupled with enhanced juice quality parameters.

The probable cause of improvement in juice quality parameters on account of 125% of RDF might be that N, P and K are the integral part of various sucrose metabolizing enzymes which are involved in sucrose synthesis and its accumulation in sugarcane. The improvement

Table 2. Effect of fertilizer and weed management on juice quality and commercial cane sugar (CCS) yield of spring–planted sugarcane (pooled data of two cycles)

Treatment	Juice extraction (%)	Brix (%)	Sucrose (%)	Purity coefficient (%)	Available sugar (%)	CCS yield (t/ha)
Fertilizer levels						
F_1	48.00	18.71	13.43	72.43	11.94	9.09
F_2	51.61	18.95	15.33	80.89	14.28	12.13
F_3	52.32	19.10	15.75	81.73	14.73	12.96
LSD (P=0.05)	1.11	NS	0.36	1.84	0.18	0.33
Weed control						
W_1	51.63	19.08	15.15	79.40	14.01	12.54
W_2	50.41	18.85	14.61	77.50	13.38	11.26
W_3	49.15	18.82	14.43	76.67	13.15	10.33
W_4	52.48	18.90	15.08	79.78	13.97	12.58
W_5	50.05	18.63	14.76	79.22	13.63	11.09
W_6	53.00	19.36	15.18	78.40	13.96	13.61
W_7	47.75	18.80	14.63	77.81	13.42	8.06
LSD(P=0.05)	2.56	NS	NS	NS	NS	0.53

#Details of treatments are given in Materials and Methods

Table 3. Effect of fertilizer and weed management on nutrient uptake (kg/ha) of sugarcane (pooled data of two cycles)

Treatment	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
	Cane	Green tops	Trash	Total	Cane	Green tops	Trash	Total	Cane	Green tops	Trash	Total
Fertilizer levels												
F_1	79.10	35.94	16.19	131.23	23.71	7.33	4.17	35.21	142.24	72.92	24.05	239.19
F_2	105.71	52.15	23.86	181.72	30.05	9.45	5.34	44.84	166.01	78.71	27.99	273.72
F_3	110.10	53.76	24.24	188.10	31.02	9.91	5.52	46.45	166.9	80.20	28.89	275.99
LSD (P=0.05)	2.05	1.15	0.38	3.43	0.59	0.30	0.12	1.38	5.36	3.35	0.40	8.52
Weed control												
W_1	106.21	52.21	23.90	182.32	30.37	9.64	5.41	45.42	163.90	84.91	28.95	277.75
W_2	94.93	47.76	20.95	163.64	27.88	8.94	4.76	41.58	156.24	77.61	27.99	261.83
W_3	86.64	41.96	18.53	147.13	23.70	7.70	4.25	35.65	144.48	72.90	24.59	176.39
W_4	111.70	55.30	24.99	191.99	32.22	10.47	6.25	48.94	168.85	85.91	30.04	207.48
W_5	97.17	45.04	20.76	162.97	26.58	8.18	4.94	39.70	154.01	74.90	25.01	253.92
W_6	120.22	57.98	25.95	204.15	35.61	11.32	6.52	53.44	182.00	87.93	31.09	301.02
W_7	71.22	30.78	14.91	116.91	21.50	6.04	2.94	30.43	129.39	60.50	21.05	210.94
LSD(P=0.05)	4.91	2.62	1.20	8.35	1.54	0.45	0.28	2.11	6.30	4.21	0.73	11.90

in purity percent might have been attributed to higher phosphorus content in cane that help in better flocculation of non-sugar colloids during purification process and results in minimum turbidity of clarified juice. The beneficial effect of NPK fertilization on the juice quality has also been reported by Singh *et al.* (2008).

Weed management options did not result in significant variations with respect to brix, sucrose, purity and available sugar % except juice extraction and CCS yield (Table 2). Nevertheless, performing three hoeing at intervals of 30, 60 and 90 DAP (W_1) numerically improved the sucrose, purity and available sugar % values.

The highest juice extraction% and CCS yield were recorded from the weed free plots (W_6) which were found at par with glyphosphate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP (W_4) and followed by adoption of three hoeing at intervals of 30, 60 and 90 DAP (W_1) in case of juice extraction, while no perceivable difference was observed in generation of CCS yield under the treatments application of glyphosphate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP (W_4) and three hoeing did at intervals of 30, 60 and 90 DAP (W_1). The lowest values of juice recovery and CCS yield (t/ha) was registered under control plots (W_7).

Available sugar is dependent on brix %, sucrose % and purity% of cane juice, which showed non-significant variation under different weed management practices. Non-significant variations in brix, sucrose, reducing sugar and available sugar has also been reported by Singh and Menhi (2008). The highest CCS yield obtained with weed free situations was owing to maximum cane yield and juice recovery % along with numerically improved values of juice quality parameters.

Nutrient uptake

NPK uptake by cane, green top, trash and total uptake differed significantly with varying fertility levels (Table 3). The maximum uptake of NPK in cane as well as in green tops, trash and total was recorded at 125% RDF followed by 100% RDF. The lowest NPK uptake by different sugarcane plant parts (cane, green tops, trash and total) was found under 75% RDF of NPK. The uptake of NPK under 125% RDF was increased to the tune of 43.34, 31.92 and 35.67, respectively over 75% RDF. The higher values of NPK uptake by sugarcane plant parts, *viz.* cane, green top and trash under increased fertility levels was mainly due to increased concentration of these nutrients in root zone followed by better expression of growth and yield attributes. Venkatakrishnan and Ravichandran (2007) also corroborated the similar findings.

All the weed control treatments significantly increased the NPK status in various plant parts of sugarcane over weedy check (Table 3). The highest uptake of NPK was noticed in crop with weed free plots (W_6) which was followed by glyphosate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP and three hand weeding carried out at 30, 60 and 90 DAP (W_1). The per cent increase in NPK uptake under weed free (W_6) treatment was to the tune of 74.62, 75.62 and 45.37, respectively over weedy check.

The maximum uptake of NPK by different sugarcane plant parts under weed free, glyphosate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP and three hand weeding at 30, 60 and 90 DAP were due to the suppression of weed growth which might have been the deriving force behind higher dry matter accumulation and nutrient uptake in sugarcane under these treatments. A similar result was also reported by Singh *et al.*

Economics

The highest gross and net return and B:C ratio were recorded when the crop was fertilized with 125% RDF and these values recorded lowest in the crop grown under 75% RDF (Table 4) . The second best treatment was 100% RDF, which fetched a gross return of Rs 11,8212/ha, net return of Rs 82,786/ha with B: C ratio of 2.33. The superiority of 125% RDF over other fertility levels in terms of gross, net returns and B : C ratio was primarily due to production of highest cane yield.

The maximum gross and net returns were recorded under weed free plots (W_6) followed by application of glyphosate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP (W_4), whereas the lowest values of gross, net re-

Table 4. Economic analysis of spring–planted sugarcane as influenced by fertilizer and weed management (pooled data of two cycles)

Treatment	Cost of cultivation (x10^3 ₹/ha)	Gross returns (x10^3 ₹/ha)	Net returns (x10^3 ₹/ha)	B : C ratio
Fertilizer levels				
F_1	34.05	106.89	72.85	2.14
F_2	35.43	118.21	82.79	2.33
F_3	36.64	123.38	86.74	2.36
Weed control				
W_1	37.12	125.52	88.40	2.38
W_2	35.19	117.73	82.54	2.34
W_3	33.78	110.56	76.78	2.27
W_4	35.07	126.54	91.47	2.61
W_5	35.65	114.35	78.71	2.21
W_6	39.00	135.98	96.98	2.48
W_7	31.77	84.96	53.08	1.67

turns and B : C ratio were observed under weedy check plots (W_7). While the higher B :C ratio was noticed under the glyphosphate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP (W_4) treatment over weed-free treatment (W_6) was registered owing to lower cost of cultivation. The lowest of gross, net returns and B : C ratio under the weedy check treatment was due to production of lowered cane yield.

From the present study, it can be ascertained that application of 125% RDF (187.5: 75: 75, $N:P_2O_5:K_2O$ kg/ha) along with post-emergence spray of glyphosate 1.0 kg/ha at 25 DAP + one hand weeding at 60 DAP were the best options for realizing higher productivity, juice quality, net returns and B :C ratio of spring planted sugarcane in Indo-Gangetic plains of Uttar Pradesh.

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Integrated weed management in garlic

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ABSTRACT

Four herbicides (oxyflurofen 0.25 kg/ha, pendimethalin 1.50 kg/ha, trifluralin 1.50 kg/ha and metachlor 1.50 kg/ha) at recommended rates alone and at half of the recommended rates integrated with one hand weeding were compared with hand weeding 30, 60, 90 days after planting (DAP) and untreated check in silty clay loam soil during *Rabi* 2008-09 and 2009-10 at Palampur. *Phalaris minor* followed by *Avena ludoviciana* were the predominant associated weeds. All treatments resulted in significantly lower density of *Phalais minor, Alopecurous myosuroides* and *Coronopus didymus*. Metolachlor 1.50 kg/ha effectively reduced the density of *Poa annua*. Metolachlor + hand weeding, pendimethalin and pendimethalin + hand weeding effectively reduced the density of *Stellaria media.* Integration of hand weeding with half dose of oxyflourfen, pendimethalin and metolachlor resulted in significantly higher yield of garlic than their respective higher dose alone. Weed index was lowest and weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) were highest under pendimethalin + hand weeding. Herbicide efficiency index (HEI) was highest with oxyflourfen + hand weeding. Pendimethalin + hand weeding gave highest net return due to weed control (NRwc) and was followed by pendimethalin and metolachlor + hand weeding. Pendimethalin gave highest marginal benefit cost ratio (MBCR) of 40.7 followed by pendimethalin + hand weeding and metolachlor + hand weeding. Weeds reduced the garlic bulb yield by 72.5% over the best treatment pendimethalin 0.75 kg/ha + HW.

Key words: Garlic, Hand weeding, Herbicides, Integrated weed management, Pendimethalin

Garlic (*Allium sativum*) is grown for its pungent flavoured bulbs world-wide to season foods. It is cultivated commercially throughout tropical and subtropical belt of the world. It is an important cash crop of Himachal Pradesh. It is usually grown between the months of October-May, during which the weather is cool and dry that favours its growth and yield. Garlic crop is highly vulnerable to weed infestation due to its slow emergence and slow initial growth, non-branching habit, sparse foliage, shallow root system (Rahman *et al.* 2012, Lawande *et al.* 2009), frequent irrigation and high fertilizer application. It never forms a canopy with its short, vertical leaf arrangement.

Weed infestation in garlic is one of the major factors for loss in yield and bulb yield loss due to weed infestation to the tune of 30-60% (Lawande *et al.* 2009). In garlic, very close spacing and a shallow root system make mechanical method of weed control difficult and sometimes course damage to developing bulbs (Lawande *et al.* 2009). Besides non-availability and higher cost of labour, manual weeding make the method uneconomical. Moreover, being a long duration crop, single hand weeding is not sufficient to control weeds. Thus, all these situations make it necessary to rely on herbicides for an effective and timely control of weed in garlic. Pendimethalin (Mehmood *et al.* 2002), oxyfluorfen (Vora and Mehta 1999, Qasem 1996), metolachlor and trifluralin were found effective for managing weeds in garlic. Single application of any of herbicide is not sufficient to obtain yield equal to weed free treatment (Mehmood *et al.* 2002, Vora and Mehta 1998). However, use of herbicides at low doses in conjunction with manual weeding (Madan *et al.* 1994; Ankur *et al.* 2002, Singh and Nandal 2002) is more effective, environmentally safe, socially acceptable and economically viable. Information on integrated weed management methods in garlic in the agro-climatic conditions of mid-hills of Himachal Pradesh (India) is meager. Hence, the present investigation was undertaken to identify effective integrated weed management options in garlic.

MATERIALS AND METHODS

The field experiment was conducted during *Rabi* 2008-2009 and 2009-2010 at Palampur ($32^0 6'$ N Latitude, $76^0 3'$ E longitude, 1280 m above mean sea level). The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 6.1), medium in available N (333.4

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kg/ha) and P (18.9 kg/ha) and high in K (226.4 kg/ha). The treatments consisted of four herbicides (oxyflurofen 0.25 kg/ha, pendimethalin 1.50 kg/ha, trifluralin 1.50 kg/ha and metachlor 1.50 kg/ha) at recommended rates alone and at half of the recommended rate with one hand weeding, three hand weedings (30, 60, 90 days after planting DAP) and unweeded check (Table 1). Well decomposed FYM 10 t/ha was applied uniformly at the time of field preparation. Garlic variety '*GCH-1*' was planted on 5 October 2008 and 17 October 2009. The crop was fertilized with 60 kg N, 50 kg P_2O_5 and 30 kg K_2O/ha. Required amount of N, P and K was supplied through urea, single super phosphate and muriate of potash, respectively. Except weed control treatments, the recommended cultural practices and plant protection measures were followed to raise the crop. Weeding was done manually with the help of hand tool '*Khuni'*. Herbicides were applied with the help of Maruyama power sprayer using flat fan nozzle delivering 700 litres of water per ha. Trifluralin was applied as pre-plant soil incorporation (PPI) (Just before planting), pendimethalin, oxyflurofen and metachlor as pre-emergence (just after planting). Weed density and biomass at 90 DAS and at harvest were recorded by placing 50 x 50 cm quadrates at two random places in each plot. After drying samples in hot air oven (70 ± 1^0C for 72 h), weed dry weight was recorded. Data were subjected to square root transformation ($\sqrt{x+1}$). The crop was harvested on 23 May 2009 and 26 May 2010, respectively. Yields were harvested from net plot. The different impact indices were worked out after Walia (2003)

RESULTS AND DISCUSSION

Effect on weeds

Garlic crop was infested with a large number of weeds owing to longer duration, slow initial growth, non-tillering/branching habit and sparce canopy development besides frequent irrigation and high fertilizer application. *Phalaris minor* was the most predominant weed constituting 30.9 and 40% of the total weed flora at 90 DAP and at harvest, respectively. The count of *Phalaris* during 2009-10 was twice of its count during 2008-09. Similarly, density of *Avena ludoviciana* was higher during 2009-10 as compared to 2008-09. Its density was greater at harvest than at 90 DAP during both the years. It constituted 12.8% of total weed flora at 90 DAP and 13.5% at harvest. Similar trend was observed with *Vicia sativa*. While density of *Poa annua* (11.8 and 3.5%, respectively at 90 DAP and at harvest), *Stellaria media* (14.5 and 6.2%), *Lolium temulentum* (3.6 and 0.0%) and other weeds (*Anagallis arvensis, Spergulla arvensis, Polygonum alatum* and *Gallinsoga parviflora*) (20.3 and 3.8%) decreased at harvest when compared to its density at 90 DAP. *Coronopus didymus* (14.1%), *Ranunculus arvensis* (1.8%) and *Alopecurous myosuroides* (8.5%) were present only at harvest.

All weed control treatments were more effective during 2008-09 than during 2009-10 (Table 1) and their efficacy was higher on grasses than broad-leaved weeds. *Vicia sativa* and the other weeds were not effectively controlled by oxyflurofen 0.25 kg/ha, pendimethalin 1.5 kg/ha, triflurolin 1.5 kg/ha and metolachlor 1.5 kg/ha especially during 2008-09. Mehmood *et al.* (2002) have reported similar results. However, when hand weeding was integrated with half dose of these herbicides, control of these weeds has improved.

At harvest, hand weeding thrice resulted in significantly lower density of *Phalaris minor* and *Avena ludoviciana* during 2008-09 (Table 2). All other treatments resulted in significantly lower density of *Phalais minor* but oxyflourfen 0.25 kg/ha could not significantly lower down the density of *Avena ludoviciana* over weedy check during 2008-09. Metolachlor 1.50 kg/ha effectively reduced the density of *Poa annua*. However, all the other treatments had statistically equal count of *Poa* as under weedy check. All weed control treatments were significantly superior to weedy check in reducing the count of *Vicia sativa* and *Ranunculus arvensis* at harvest during 2008-09. Pendimethalin, pendimethalin + hand weeding and metolachlor + hand weeding were as good as hand weeding thrice in reducing density of *Vicia sativa*. All the weed control treatments except trifluralin + hand weeding were comparable to hand weeding thrice in influencing the count of *Ranunculus*. Density of *Coronopus didymus* was significantly lower under all the treatments at harvest during 2008-09. However, during 2009-10, *Coronopus didymus* and *Steallaria media* were observed to be suppressed under weedy check and the population of the weed under the weed control treatments was either significantly higher or not different from that under weedy check. Metolachlor + hand weeding was at par with pendimethalin and pendimethalin + hand weeding in effectively reducing the density of *Stellaria media* than other treatments. Oxyflourfen and oxyflourfen + hand weeding were as good as hand weeding thrice in reducing the density of other weeds. But, all the other treatments were not effective against other weeds during 2008-09. There was build up of *Alopecurous myosuroides* under hand weeding thrice at harvest during 2009-10.

All the weed control treatments resulted in significantly lower total weed density and total weed biomass (Table 3). Owing to species-wise reduction in the density of weeds, oxyfluorfen 0.15 kg/ha + HW,

Table 1. Effect of different weed management treatments on weed density (no./m^2) at 90 days after planting of garlic

Treatment	*Phalaris*		*Avena*		*Lolium*		*Poa*		*Vicia*		*Stellaria*		*Others*	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1- Oxyflurofen	1.0	3.4	1.0	1.8	1.0	1.0	1.0	1.7	4.0	1.4	3.2	1.7	1.0	1.0
0.25 kg/ha	(0.0)	(10.7)	(0.0)	(2.7)	(0.0)	(0.0)	(0.0)	(2.7)	(14.7)	(1.3)	(9.3)	(2.7)	(0.0)	(0.0)
T_2- Oxyflurofen + HW	1.0	2.1	1.0	3.5	1.0	1.0	1.0	1.0	1.0	1.4	1.0	1.4	1.0	1.4
0.25 kg/ha	(0.0)	(4.0)	(0.0)	(12.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(1.3)	(0.0)	(1.3)	(0.0)	(1.3)
T_3- Pendimethalin	1.0	2.9	1.0	2.6	1.0	1.0	1.0	2.3	3.2	2.2	1.0	1.4	2.9	1.7
1.50 kg/ha	(0.0)	(8.0)	(0.0)	(8.0)	(0.0)	(0.0)	(0.0)	(5.3)	(9.3)	(4.0)	(0.0)	(1.3)	(8.0)	(2.7)
T_4- Pendimethalin +	1.0	2.5	1.0	2.1	1.0	1.0	1.0	2.1	1.0	2.1	1.0	1.4	1.0	1.4
HW 1.50 kg/ha	(0.0)	(5.3)	(0.0)	(4.0)	(0.0)	(0.0)	(0.0)	(4.0)	(0.0)	(4.0)	(0.0)	(1.3)	(0.0)	(1.3)
T_5- Trifluralin	3.0	3.3	1.0	1.8	1.0	1.0	1.4	1.4	3.8	2.1	1.4	1.8	5.4	1.0
1.50 kg/ha	(8.0)	(10.7)	(0.0)	(2.7)	(0.0)	(0.0)	(1.3)	(1.3)	(13.3)	(4.0)	(1.3)	(2.7)	(28.0)	(0.0)
T_6- Trifluralin + HW	1.0	3.0	1.0	2.1	1.0	1.4	2.1	1.4	1.0	2.1	1.0	1.4	1.0	1.4
1.50 kg/ha	(0.0)	(8.0)	(0.0)	(4.0)	(0.0)	(1.3)	(4.0)	(1.3)	(0.0)	(2.0)	(0.0)	(1.3)	(0.0)	(1.3)
T_7- Metolachlor	1.0	3.6	1.0	2.9	1.0	1.0	1.7	2.1	3.4	2.5	1.8	1.8	4.9	1.0
1.50 kg/ha	(0.0)	(12.0)	(0.0)	(9.3)	(0.0)	(0.0)	(2.7)	(4.0)	(10.7)	(5.3)	(2.7)	(2.7)	(22.7)	(0.0)
T_8- Metolachlor +	1.0	2.5	1.0	3.4	1.0	1.0	2.3	1.0	1.0	1.4	1.0	1.8	1.0	1.9
HW 1.50 kg/ha	(0.0)	(5.3)	(0.0)	(10.7)	(0.0)	(0.0)	(5.3)	(0.0)	(0.0)	(1.3)	(0.0)	(2.7)	(0.0)	(4.0)
T_9- Hand weeding	1.0	2.3	1.0	1.4	1.0	1.4	1.0	2.5	1.0	2.5	1.0	1.4	1.0	1.0
(HW)	(0.0)	(5.3)	(0.0)	(1.3)	(0.0)	(1.3)	(0.0)	(6.7)	(0.0)	(5.3)	(0.0)	(1.3)	(0.0)	(0.0)
T_{10}- Unweeded	7.9	11.3	4.2	7.9	3.2	3.8	5.8	6.3	4.6	4.3	4.4	8.5	10.4	4.1
	(61.3)	(128.0)	(17.3)	(61.3)	(9.)	(13.3)	(33.3)	(38.7)	(20.)	(17.3)	(18.)	(70.7)	(108.)	(16.0)
LSD (P=0.05)	0.1	1.3	0.6	1.7	0.2	0.3	1.2	1.4	0.4	1.2	0.6	1.1	0.5	1.1

Values given in the parentheses are the original means

Table 2. Effect of different weed management treatments on different weed species density (no./m^2) at the harvest of garlic

Treatment	*Phalaris*		*Avena*		*Poa annua*		*Vicia*		*Ranunculus*		*Stellaria*		*Alopecurous*		*Others*	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	3.6	3.0	5.3	2.9	3.5	1.9	4.1	2.7	1.4	1.0	2.9	3.8	1.0	1.9	1.0	1.0
	(12.0)	(8.0)	(26.7)	(8.0)	(12.0)	(4.0)	(16.0)	(6.7)	(1.3)	(0.0)	(8.0)	(13.3)	(0.0)	(4.0)	(0.0)	(0.0)
T_2	4.0	4.1	3.4	1.0	4.1	2.7	3.8	2.3	1.4	1.4	4.1	3.2	1.0	1.0	1.9	1.7
	(14.7)	(16.0)	(10.7)	(0.0)	(16.0)	(6.7)	(13.3)	(5.3)	(1.3)	(1.3)	(16.0)	(9.3)	(0.0)	(0.0)	(4.0)	(2.7)
T_3	4.7	2.7	3.4	2.7	3.6	1.7	3.4	3.6	1.0	1.8	2.2	1.4	1.0	2.7	4.4	3.2
	(21.3)	(6.7)	(10.0)	(6.7)	(12.0)	(2.7)	(10.7)	(12.0)	(0.0)	(2.7)	(4.0)	(1.3)	(0.0)	(8.0)	(18.7)	(12.0)
T_4	3.4	3.6	2.5	4.1	4.1	1.9	3.2	1.7	1.4	1.0	2.2	1.8	1.0	1.7	3.6	3.8
	(10.7)	(12.0)	(5.3)	(16.0)	(16.0)	(4.0)	(9.3)	(2.7)	(1.3)	(0.0)	(4.0)	(2.7)	(0.0)	(2.7)	(12.0)	(13.3)
T_5	3.6	2.0	3.8	3.1	4.4	1.9	4.0	3.6	1.0	1.4	3.6	1.9	1.0	1.4	7.1	2.7
	(12.0)	(5.3)	(13.3)	(10.7)	(18.7)	(4.0)	(14.7)	(12.0)	(0.0)	(1.3)	(12.0)	(4.0)	(0.0)	(1.3)	(49.3)	(8.0)
T_6	4.1	3.6	3.6	3.8	3.7	3.3	4.4	3.6	2.1	1.8	3.6	2.3	1.0	2.3	4.1	2.9
	(16.0)	(12.0)	(12.0)	(13.3)	(13.3)	(10.7)	(18.7)	(12.0)	(4.0)	(2.7)	(12.0)	(5.3)	(0.0)	(5.3)	(16.0)	(8.0)
T_7	3.1	5.0	3.1	4.5	1.0	1.0	4.0	3.0	1.0	1.4	3.4	6.6	1.0	1.7	7.8	4.9
	(9.3)	(24.0)	(9.3)	(20.0)	(0.0)	(0.0)	(14.7)	(8.0)	(0.0)	(1.3)	(10.7)	(52.0)	(0.0)	(2.7)	(60.0)	(30.7)
T_8	4.4	4.6	3.6	4.4	2.5	2.3	3.2	3.4	1.0	1.0	1.8	1.7	1.0	1.0	8.3	4.5
	(18.)7	(20.0)	(12.0)	(18.7)	(5.3)	(5.3)	(9.3)	(10.7)	(0.0)	(0.0)	(2.7)	(2.7)	(0.0)	(0.0)	(68.0)	(25.3)
T_9	1.8	6.3	1.0	3.9	4.3	3.6	3.0	2.5	1.0	1.0	3.2	3.2	1.0	3.4	2.2	7.2
	(2.7)	(38.7)	(0.0)	(14.7)	(17.3)	(12.0)	(8.0)	(6.7)	(0.0)	(0.0)	(9.3)	(9.3)	(0.0)	(10.7)	(6.7)	(50.7)
T_{10}	7.6	11.2	5.0	6.2	3.8	1.7	5.2	3.6	3.0	1.0	5.1	1.7	5.0	4.0	4.3	1.0
	(57.3)	(124.0)	(24.0)	(37.3)	(13.3)	(2.7)	(26.7)	(12.0)	(8.0)	(0.0)	(25.3)	(2.7)	(24.0)	(14.7)	(17.3)	(0.0)
LSD (P=0.05)	0.9	1.2	0.8	1.2	0.9	1.2	0.6	NS	0.9	NS	0.9	2.4	0.4	1.5	1.5	2.7

Values given in the parentheses are the original means

Table 3. Effect of different weed management treatments on yield of garlic, density and weed biomass

Treatment	Total weed density (no./m^2)				Total weed biomass (g/m^2)				Garlic yield (t/ha)		
	2008-09		2009-10		2008-09		2009-10		2008-09	2009-10	Mean
	90 DAP	At harvest	90 DAP	At harvest	90 DAP	At harvest	90 DAP	At harvest			
T_1	5.0	9.2	4.5	6.8	1.4	3.2	1.4	3.4	2.87	1.85	2.36
	(24.0)	(84.0)	(20.00	(45.3)	(1.1	(9.2)	(0.9)	(11.2)			
T_2	1.0	9.4	4..5	6.7	1.0	1.9	1.9	3.2	3.88	3.38	3.64
	(0.0)	(88.0)	(20.0)	(44.0)	(0.0)	(2.9)	(3.0)	(9.5)			
T_3	5.0	9.6	5.5	7.4	1.4	1.9	2.2	3.8	4.22	3.23	3.73
	(24.0)	(92.0)	(29.3)	(53.3)	(1.0)	(3.1)	(3.9)	(13.9)			
T_4	1.0	9.1	4.6	9.0	1.0	1.7	1.1	6.4	4.11	4.77	4.44
	(0.0)	(82.7)	(20.0)	(81.3)	(0.0)	(2.1)	(0.3)	(40.9)			
T_5	8.5	12.4	4.8	7.7	1.8	4.0	1.5	4.5	2.72	2.15	2.44
	(70.7)	(153.3)	(22.7)	(61.3)	(2.2)	(15.3)	(1.6)	(23.5)			
T_6	2.1	10.2	4.9	9.1	1.0	2.1	1.2	5.3	2.98	1.69	2.34
	(4.0)	(102.7)	(24.0)	(82.7)	(0.0)	(3.8)	(0.3)	(28.1)			
T_7	7.4	11.6	5.8	7.2	1.7	4.2	1.8	3.7	2.81	1.38	2.10
	(53.3)	(134.7)	(33.3)	(50.7)	(1.8)	(17.0)	(2.4)	(13.2)			
T_8	2.3	11.3	4.9	7.6	1.0	4.4	1.4	4.9	3.78	3.38	3.58
	(5.3)	(126.7)	(24.0)	(57.3)	(0.0)	(19.2)	(1.1)	(23.4)			
T_9	1.0	7.3	4.8	8.8	1.0	1.6	1.3	4.9	4.11	1.88	2.99
	(0.0)	(53.3)	(22.7)	(77.3)	(0.0)	(1.8)	(0.7)	(23.4)			
T_{10}	20.8	17.0	18.9	11.8	5.6	7.4	11.2	8.0	1.39	1.05	1.22
	(432.0)	(289.3)	(356.0)	(137.3)	(30.3)	(54.3)	(123.6)	(63.9)			
LSD (P=0.05)	1.0	1.2	1.4	1.7	0.2	1.1	0.8	1.7	0.60	0.31	0.46

Values given in the parentheses are the original means

pendimethalin 0.75 kg/ha + HW and hand weeding thrice were statistically on par with each other in reducing weed density at 90 DAS. At harvest, oxyflurofen 0.25 kg/ha, pendimethalin 1.5 kg/ha and trifluralin 0.75 kg/ha + HW were on par with above treatments. Oxyflurofen 0.15 kg/ha + HW, pendimethalin 1.5 kg/ha, pendimethalin 0.75 kg/ha + HW, trifluoralin 0.75 kg/ha + HW and metolachlor 0.75 kg/ha + HW were statistically equally effective in significantly lowering total weed biomassas compared to other weed control treatments.

Effect on crop

Weeds in unweeded check reduced the garlic bulb yield by 72.5% over the best treatment pendimethalin 0.75 kg/ha + HW (Table 3). Among the herbicides, pendimethalin resulted in highest bulb yield. The other herbicides, *viz.* oxyflourfen, metolachlor and trifluralin were comparable to each other. Integration of hand weeding with half dose of oxyflourfen, pendimethalin and metolachlor resulted in significantly higher yield of garlic than their respective higher dose alone. This indicated that hand weeding could economies the dose of the herbicides by 50%. Pendimethalin and pendimethalin/metolachlor/oxyflourfen + hand weeding were superior to hand weeding thrice in increasing bulb yield of garlic. Sandhu *et al.* (1997), Ankur *et al.* (2002), Singh and Nandal (2002) have reported similar results with the integration of hand weeding with pendimethalin. The bulb yield of garlic was negatively associated with weed density (r= -0.320 to -0.852) and weed biomass (r= - 0.13 to -0.832); with significantly higher association during 2008-09 than during 2009-10. Irrespective of species, with every one weed/m^2 increase in density of weeds, garlic bulb yield would be expected to fall by 5.3 kg/ha ($Y= 3199.4 – 5.328 x$, $R^2= 0.298$). Similarly, every g/m^2 increase in biomass of weeds would result in 35 kg/ha loss in bulb yield of garlic ($Y= 3547.5 – 34.963 x$, $R^2= 0.430$).

Impact assessment

Weed control efficiency under treatments ranged from 77.7 (in trifluralin) to 93.5% (oxyflourfen + hand weeding) (Table 4). Weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) were highest under pendimethalin + hand weeding. It was followed by metolachlor + hand weeding, pendimethalin, oxyflourfen + hand weeding and hand weeding thrice. Herbicide efficiency index (HEI) which indicates weed killing potential and phytotoxicity

Table 4. Impact assessment indices and economics of weed management treatments

Treatment	WCE (%)	WMI	AMI	IWMI	HEI	WI	GR (x10^3 ₹ /ha)	GRwc (x10^3 ₹ /ha)	CWC (x10^3 ₹ /ha)	NRwc (x10^3 ₹ /ha)	MBCR
Oxyflurofen	88.6	2.33	1.33	1.83	5.39	21.3	109.29	52.38	2.16	50.22	23.2
Oxyflurofen + HW	93.5	3.33	2.33	2.83	18.85	-21.3	170.18	113.27	3.85	109.41	28.4
Pendimethalin	89.4	3.56	2.56	3.06	14.26	-24.3	173.65	116.75	2.80	113.95	40.7
Pendimethalin + HW	80.5	5.71	4.71	5.21	7.24	-48.1	209.66	152.75	3.80	148.95	39.2
Trifluralin	77.7	2.97	1.97	2.47	3.03	18.7	113.70	56.80	1.86	54.94	29.5
Trifluralin + HW	84.7	2.62	1.62	2.12	3.38	22.0	107.90	50.99	3.70	47.29	12.8
Metolachlor	81.7	2.31	1.31	1.81	2.81	30.0	96.55	39.64	1.50	38.14	25.4
Metolachlor + HW	80.1	4.58	3.58	4.08	5.36	-19.5	167.74	110.83	3.30	107.53	32.6
Hand weeding (HW)	87.9	3.12	2.12	2.62	6.82	0.0	137.56	80.65	9.82	70.83	7.2
Unweeded	0.0	-	-	-	0.00	59.3	56.90	0	0	0	0.0

WCE - weed control efficiency; WMI - weed management index; AMI - agronomic management index; IWMI - integrated weed management index; HEI - Herbicide efficiency index; WI - weed index; GR - gross returns; GRwc - gross returns due to weed control; CWC - cost of weed control; NRwc - net returns due to weed control; MBCR - marginal benefit: cost ratio

on the crop (Walia 2003), was highest under oxyflourfen + hand weeding. This was followed by pendimethalin, pendimethalin + hand weeding, hand weeding thrice and oxyflourfen. Pendimethalin + hand weeding had lowest weed index (WI) and was followed by pendimethalin, oxyflourfen + hand weeding and metolachlor + hand weeding. Rest of the treatments had higher weed index indicating lower yield than hand weeding thrice.

Gross returns (GR) and gross returns due to weed control (GRwc) followed the trend of yield and were highest under pendimethalin + hand weeding, pendimethalin, oxyflourfen + hand weeding and metolachlor + hand weeding. Cost of weed control was lower with herbicides/integrated weed control treatments than with hand weeding thrice. Net return due to weed control (NRwc) followed the trend of GRwc and was higher under pandimethalin + hand weeding, pendimethalin, oxyflourfen + hand weeding and metolachlor + hand weeding. All treatments resulted in higher MBCR over hand weeding thrice. Pendimethalin gave highest MBCR of 40.7 followed by pendimethalin + hand weeding, metolachlor + hand weeding, trifluralin + hand weeding, oxyflourfen + hand weeding and metolachlor.

Pendimethalin 0.75 kg/ha + hand weeding, oxyflourfen 0.125 kg/ha + hand weeding and metolachlor + hand weeding may be recommended for economically viable weed management in garlic, under mid-hills conditions of Himachal Pradesh.

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Evaluation of toxins of phytopathogenic fungus for eco-friendly management of *Parthenium*

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ABSTRACT

Herbicidal potential of CFCF (cell free culture filtrate) of *Phoma herbarum* (FGCCPH#27) against *Parthenium hysterophorus* was determined by shoot cut, seedling and detached leaf bioassays. Maximum mortality was shown by the inoculum formulated with sucrose + Tween-20 followed by Tween-80. Triton-X was found to be highly inhibiting in its action. Maximum average leaf area damage (LAD) of 85% on the seventh day and 65% of leaf damage by fourth day was observed when treated with CFCF obtained from 14 day's old fermented broth at 50% concentration followed by 75 and 100%. Maximum phytotoxicity was obtained from 14 day's old fermented broth with sucrose + tween 20 0.5% as formulating agent. Chlorophyll and protein contents were also significantly affected when treated with CFCF. The contents were gradually decreased with increased incubation. Maximum reduction was recorded in shoots treated with CFCF obtained from 14 days old fermented broth at 50% concentration followed by 75% and 100 % (Table 4). 14 days old fermented broth showed the maximum biological activity as depicted by the significant reduction in the chlorophyll and protein content of the host leaves. While extract obtained from 7 days old broth failed to show any remarkable reduction in these contents at similar concentration. The effect was comparatively more on chlorophyll-a and total chlorophyll while chlorophyll-b and protein contents were less affected.

Key words: Herbicidal potential, Formulation, *Parthnium hysterophorus Phoma herbarum*, Phytotoxicity

Parthenium hysterophorus L., commonly known as carrot weed, is an obnoxious, annual and deadly weed of compositae family, native of North America. It poses serious threat to crops, livestock and human beings. It is responsible for the substantial losses to the crops. It reduces agricultural yield by 40% and forage production by 90% (Knox *et al.* 2006). Conventional methods of its management rely mainly on the use of chemical herbicides. Public concern over the safety due to indiscriminate use of synthetic herbicides has generated significant pressure on weed scientists to search an alternative of these chemicals. Exploitation of microorganisms and especially their biorationals (natural products) as herbicides have generated significant interest world wide. (Pandey *et al.* 2002, 2005). Survey conducted at various habitats of central India for weed pathogens yielded an isolate of *Phoma herbarum* (FGCCPH#27) which incites severe collar rot disease in *Parthenium* (Pandey *et al.* 1996). Mycoherbicidal potential of the pathogen is known to influence by environmental factors. To overcome these constraints, secondary metabolites especially oxalic acid synthesized by the pathogen have also tried (Pandey *et al.* 2003). Oxalic acid produced by the pathogen showed high herbicidal potential against *Parthenium*. Normal application of oxalic acid did not produced noticeable results and need a suitable formulating agent for its effective herbicidal potential. Therefore, the present investigation was under taken with the formulation and *in vitro* evaluation of herbicidal potential of the pathogen against *Parthenium* by shoot cut, seedling and detached leaf bioassay, methods.

MATERIALS AND METHODS

Phoma herbarum (FGCCPH#27) was obtained from fungal germplasm collection Centre, BCRBC, Jabalpur, previously isolated from the diseased part of the target weed and maintained on Potato Dextrose Agar (PDA) medium .

Preparation and extraction of CFCF

1000 ml Erlenmeyer flasks containing 500 ml of Richard's broth were seeded with 5 mm disc obtained from 7 days old cultures grown on PDA medium at 28°C. Inoculated flasks were incubated at 38 ±2°C for 7 and 14 days. Fermented broth was filtered through Whatman's

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filter paper No.1 and the filtrate was centrifuged at 4000 rpm for 10 min. Supernatant was discarded and the crude filtrate was again passed through 0.251In Sartorious filter *in vacuo* condition (Abbas *et al.* 1992).

Formulation

To test the compatibility of the toxin synthesized by the pathogen a total of 15 formulating agents were tried. All the formulating agents were added at the rate of 0.5% to the toxin and its herbicidal potential was determined by shoot cut assay and observations were made for three days (Daigle and Conick 2002).

Bioassay

Seedlings were raised in pots containing soil, sand and peat in 1:1:1 ratio. Different formulations containing 50% toxin of *P. herbarum* (7 and 14 days old) sprayed at different concentration on host seedlings 30 ml per plant grown in pots and maintained in green house. Each treatment was replicated thrice and observations were recorded after 3 days based on a score chart. Per cent disease index was calculated by using the following formula (Praveena 2003).

$$\text{Per cent disease index} = \frac{\text{Sum of score of each leaf}}{\text{No. of leaves scored} \times \text{maximum score}} \times 100$$

Leaves from the host target weed were surface sterilized with 2% NaOCI and were kept on a sterilized moisture chamber prepared by using cotton and filter paper in a Petridish. (Thapar *et al.* 2002). Various dilutions of toxic metabolites were used of 7 and 14 days old fermented broth, *viz.* 50% and 100% with Tween 80 0.5% and the effects were observed after 24 hrs.

Chlorophyll and protein contents

One g of fresh leaves were homogenized with ethanol in a mortar and pestle and centrifuged at 8000 rpm for 2 min., with 80% ethanol. Supernatant was taken in other flask and diluted with ethanol. Absorbance of the extract was measured by UV-Vis Systronics Spectrophotometer at 645 and 663 nm for the determination of chlorophyll a, b and total chlorophyll. The protein content was determined as per Lowry *et al.* (1951).

RESULTS AND DISCUSSION

Formulation

Maximum mortality was shown by the inoculum formulated with sucrose + Tween-20 followed by Tween-80. Triton-X was found to be highly inhibiting in its action. Rest of the agents produced average effect on the host shoots. Findings obtained in the above study clearly revealed the herbicidal potential of the pathogen against *Parthenium* (Table 1). Maximum toxicity obtained at 50% concentration with sucrose + Tween 20 indicated the toxin compatibility with the formulating agent. However, others did not produce significant damage to the host shoots. Variations in different formulation might be due to the compatibility of the organism with various formulating agent. Similar findings have also been made by Singh (2002).

Bioassay

Cell free culture filtrate (CFCF) obtained from different incubations had varied effect on host seedlings. Maximum average leaf area damage (LAD) of 85% on the seventh day and 65% of leaf damage by fourth day was observed when treated with CFCF obtained from 14 day's old fermented broth at 50% concentration followed by 75 and 100%. CFCF obtained from 14 days old fermented broth showed the maximum toxicity due to the maximum production of oxalic acid (Table 2). CFCF obtained from 7 days old fermented broth also showed considerable toxicity at higher concentration. Similar observations have also reported by other workers (Saxena *et al.*

Table 1. Effect of different formulations on host seedings

Formulating agent	% disease intensity (day)				
	2	4	6	8	10
Sorbitol	1	4	4	4	4
Tween-20+ water	2	5	5	5	5
Tween -20+sucrose	5	6	6	6	6
Water + gelatin	5	5	5	5	5
Toxin + triton-X	2	5	5	5	5
Toxin + water	5	5	6	6	6
Tween-80+ sucrose+water	4	3	4	5	5
Tween 80	2	4	4	4	4
Toxin	6	6	6	6	6
Toxin + acrylamide	2	4	4	4	4
Toxin+ glycerol	1	1	1	1	1
Toxin+ coconut oil	1	1	1	1	I
Toxin+ soyabean	3	3	3	3	3
Toxin+mustard oil	3	3	3	4	4
Toxin+ Tween 80	6	7	8	9	9
Control (tichart's broth)	0	0	0	0	0

Disease rating index; 1=99%, 2=95%, 3=91%, 4=82%, 5=62%, 6=38%, 7=18%, 8=9%, 9=5%, 10=1%, below 10 = 0%; Amount of agrochemical sprayed: 30 ml/plant; RH: 85%; Incubation period: 14 days

Table 2. Effect of different concentrations of toxin on host seedlings

Concentration (%)	Incubation period % disease index	
	7 days	14 days
25	25±0.01	36±0.04
50	59±0.04	80±0.02
75	50±0.25	75±0.25
100	48±0.01	73±0.15
0	No effect	No effect

Amount of agrochemical sprayed: 30 ml/plant; RH: 85%; Values given in the table are mean ± SEm

Table 3. Effect of different concentrations of toxin on detached leaves of host

Concentration (%)	Incubation period % disease index	
	7 days	14 days
25	33±0.01	55±0.01
50	66±0.05	95±0.25
75	52±0.02	78±0.03
100	49±0.01	70±0.15
0	No effect	No effect

Values are mean ± SEm; Amount of agrochemical sprayed: 5 ml/ plant; RH: 85%

Table 4. Effect of different concentrations of toxin on biological contents of host seedlings

Concentration (%)	Biological activity of CFCF							
	7 days				14 days			
	Chl a	Chl b	Total chl	Protein	Chl a	Chl b	Total chl	Protein
25	10.4±0.25	12.1±0.06	32.6±0.32	36.1±0.04	50.3±0.02	40.8±0.02	45.9±0.2	35.5±0.04
50	72.1±0.07	58.4±0.07	65.4±0.28	56.9±0.07	97.8±0.01	74.7±0.02	72.5±0.0	76.1±0.01
75	68.8±0.04	56.1±0.65	60.3±0.62	36.9±0.04	82.2±0.25	68.5±0.01	65.3±0.2	54.1±0.01
100	69.6±0.05	53.4±0.025	59.9±O.73	27.8±0.07	78.1 ±0.01	65.2±.03	63.4±0.3	42.2±0.02
0	0	0	0	0	0	0	0	0

Values are mean ± SEm; Amount of agrochemical sprayed - 30 ml/plant; RH: 85%; Chl - Chlorophyll

2001, Pandey *et al.* 2002). In contrast to this, workers recorded maximum toxin production after 7 days of incubation (Pandey *et al.* 2003) while the CFCF obtained from 14 d old fermented broth showed the maximum mortality to the host seedlings, however 7 days old broth didn't cause significant damage to the host seedlings. Similar findings have also been made by other workers. (Shukla and Pandey 2006), which indicated significant difference between the mean leaf area damage (LAD) at different concentration with a P value of 5%.

Noticeable symptoms were also observed when detached leaves were treated with CFCF of 7 and 14 days old fermented broth at various concentrations, *viz.* 25, 50, 75 and 100%. Leaves were completely killed at 100% concentration and more than 80% of damage was recorded at 50% concentration (Table 3). Results obtained by detached leaf assay were quite prompting to use this pathogen as herbicidal agent against the weed. Similar damage ratings were also recorded by other Effect on chlorophyll and protein contents workers (Joseph *et al.* 2002).

Effect on chlorophyll and protein contents

Chlorophyll and protein contents were also significantly affected when treated with CFCF. The contents were gradually decreased with increased incubation. Maximum reduction was recorded in shoots treated with CFCF obtained from 14 days old fermented broth at 50% concentration followed by 75% and 100 % (Table 4). 14 days old fermented broth showed the maximum biological activity as depicted by the significant reduction in the chlorophyll and protein content of the host leaves. While extract obtained from 7 days old broth failed to show any remarkable reduction in these contents at similar concentration. The effect was comparatively more on chlorophyll-a and total chlorophyll while chlorophyll-b and protein contents were less affected. Variation in toxicity in relation to incubation period might be due to different phase of growth of the fungus. Metabolites required for own growth are normally synthesized during initial phase whereas most of the toxicants are formed during idiophase *i.e.* stationary phase of the fungus. (Abbas *et al.* 1995) also recorded 25 to 78% reduction in chlorophyll content in *Datura* sp. (jimson weed) tissues treated with fumonisin. Similarly, significant biological activity of CFCF of many other microorganism including fungi have also been recorded by several workers (Kovics *et al.* 2005, Pandey and Pandey 2005).

Based on the results, it was inferred that the present isolate *P. herbarum* have significant potential to produce phytotoxic compounds with high herbicidal properties against *P. hysterophorus.* However, detailed investigation regarding characterization, standardization of large scale production of herbicidal compounds are to be carried out before its field application.

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Short communication

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Efficacy of chlorimuron-ethyl against weeds in transplanted rice

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Key words : Chlorimuron-ethyl, Transplanted rice, Weed density

Rice (*Oryza sativa* L.) is one of the predominant food crops of the world. It is the staple food crop for more than 70% of the Asian population. In Madhya Pradesh, rice is grown in 1.71 million ha area, with an annual production of 13.13 lakh tones but the average productivity is quite low (1.2 t/ha) as compared to national productivity of rice (Agriculture Statistics 2011). In general, rice is preferably transplanted under irrigated agro-ecosystem but weeds are the serious constraints for higher yields. Mukherjee *et al*. (2008) reported that weedy situation throughout the crop growth caused yield reduction to the tune of 57 to 61% in case of transplanted rice. The choice of suitable herbicide is a major problem in many cases. The new herbicide molecule *i.e.* chlorimuron-ethyl has been launched in India for controlling of broad-leaved weeds in transplanted rice. However, very meagre information is available about the selectivity and bio-efficacy of this herbicide in transplanted rice. Keeping above facts in views, the present work was done.

The experiment was conducted at research farm of JNKVV, Jabalpur during *Kharif* season 2011. Jabalpur is situated at $23^0$90' North latitude and $79^0$58' East longitude with an altitude of 411.78 metre above the mean sea level. The mean annual rainfall of Jabalpur, based on last 20 years data, is 1350 mm due to south-west monsoon between mid June to end of September with little occasional rainfall during other months. The rainfall during the crop season was 1546.3 mm and was received in 63 rainy days. Minimum and maximum temperature was 11.26^0C and 32.95^0C which were ideal for growth of rice crop. The soil of the experimental field was clay loam in texture, medium in available nitrogen (236.8 kg/ha), phosphorus (20.10 kg/ha) and potassium (272.3 kg/ha) but low in organic carbon (0.62%) and neutral soil reaction (7.3 pH). The experiment was laid out in randomized block design with seven treatments during *Kharif* 2011 in four replications. Seven weed control treatments with different doses of chlorimuron-ethyl (3, 6, 9 and12 g/ha), one hand weeding (20 and 40 DAT), one hand hoeing and control were observed. Studies in relation to weed like density, dry weight were observed at 25, 45 DAT and harvest. Crop parameters like plant height, number of tillers/m^2, grains/panicle, unfilled grains/panicle, sound grains/panicle, 1000 grain weight and finally the yields was observed and analyzed. The economic viability of the treatments was also studied.

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The dominated weed flora of the experimental field were: *Echinochloa colona, Cyperus iria, Commelina communis, Eclipta alba, Ceasulia axillarius* and *Alternanthera sessilis*. Soni *et al*. (2012) also observed predominance of weeds like *Echinochloa crusgalli, Cyperus iria, Ceasulia axillarius, Commelina communis* and *Eclipta alba* in transplanted rice in Jabalpur (M.P.). The results showed that twice hand weeding at 20 and 40 DAT found best for weed control in transplanted rice. The control plot where no weed control practices was done, reduced 53.40% crop yield due to infestation of these weed flora, however mechanical (hand hoeing at 20 DAT) and chemical (chlorimuron-ethyl 12 g/ha) weed control treatments recorded lowest crop yield reduction 6.31 and 7.71%, respectively.

The density and dry weight of weeds at 25 DAT and harvest was significantly reduced under the different doses of chlorimuron-ethyl than control plot. The weed density and dry weight was found lowest under the hand weeded treatments. Among different weed control practices, hand weeding at 20 and 40 DAT found significantly superior for reducing the grasses, sedges and broad-leaved weed density and dry weight of dominated weed flora at 25 DAT and harvest stages, respectively. However, the higher dose of chlorimuron-ethyl 12 g/ha found significant for reducing density (49.21 and 3.19/m^2) and dry weight (50.84 and 3.34 g/m^2) of broad-leaved weeds at 25 DAT and at harvest, respectively. Similar findings were also reported that application of chlorimuron-ethyl 9 and 12 g/ha post-emergence reduced the population of sedges and broad-leaved weeds (Table 1) over its lower dose of 6 gm/ha and weed control plot (Dubey *et al*. 2000).

Crop parameters like number of effective tillers/m^2 (185.2), grains/panicle (162.7) and 1000 grain weight (25) was found higher under hand weeded treatments which was at par with the treatments where hand hoeing was done at 20 DAT (Table 2). Among the different herbicide treated plots, chlorimuron-ethyl 12 g/ha found significant on the crop growth parameters. Number of tillers/m^2 (179.6), grains/panicle (157.3) and 1000 grain weight (24.31 g)

Table 1. Weed density (no./m^2) and weed dry weight (g/m^2) under different treatments in transplanted rice

Treatment	Dose (g/ha)	Weed density (no./m^2)						Weed dry weight (g/m^2)					
		Grassy weeds		Sedges		Broad-leaved weeds		Grassy weeds		Sedges		Broad-leaved weeds	
		25 DAT	Harvest	25 DAT	Harves t	25 DAT	Harvest	25 DAT	Harvest	25 DAT	Harvest	25 DAT	Harvest
Chlorimuron-ethyl	3	5.69	5.90	4.04	2.15	9.15	3.57	2.15	1.55	2.29	1.22	8.38	3.35
		(31.9)	(34.3)	(15.8)	(4.1)	(83.2)	(12.3)	(4.1)	(1.9)	(4.7)	(1.0)	(69.7)	(10.7)
Chlorimuron-ethyl	6	5.40	6.21	2.24	1.74	7.72	2.87	1.65	1.11	1.72	0.89	11.61	2.36
		(28.6)	(38.1)	(4.5)	(2.5)	(59.0)	(7.8)	(2.2)	(0.7)	(2.5)	(0.3)	(134.2)	(5.1)
Chlorimuron-ethyl	9	5.30	6.16	3.06	1.29	8.27	2.52	1.97	1.26	1.83	1.22	7.57	2.52
		(27.6)	(37.5)	(8.9)	(1.2)	(67.8)	(5.8)	(3.4)	(1.1)	(2.8)	(1.0)	(56.8)	(5.8)
Chlorimuron-ethyl	12	5.55	6.16	2.84	0.84	7.05	1.92	1.72	1.30	1.60	0.75	7.17	1.96
		(30.3)	(37.5)	(7.5)	(0.2)	(49.2)	(3.2)	(2.5)	(1.2)	(2.1)	(0.1)	(50.8)	(3.3)
Hand hoeing	20 DAT	2.90	0.85	2.00	0.79	5.99	1.09	1.06	0.82	0.94	0.75	5.49	1.06
		(7.9)	(0.2)	(3.5)	(0.1)	(35.4)	(0.7)	(0.6)	(0.2)	(0.4)	(0.1)	(29.6)	(0.6)
Hand weeding	20 & 40 DAT	0.77	0.71	0.77	0.71	5.62	1.08	1.05	0.71	0.71	0.71	3.56	1.22
		(0.1)	(0.0)	(0.1)	(0.0)	(31.1)	(0.7)	(0.6)	(0.0)	(0.0)	(0.0)	(12.1)	(1.0)
Control		5.56	6.22	6.22	5.94	13.12	12.64	4.31	3.80	5.72	4.26	12.15	11.87
		(30.5)	(38.1)	(38.2)	(34.8)	(171.7)	(159.4)	(18.0)	(14.0)	(32.2)	(17.6)	(147.2)	(140.4)
LSD (P=0.05)		0.96	0.56	0.69	0.42	7.14	3.30	0.36	0.50	0.24	0.15	3.75	1.35

Figures in parentheses are original values

Table 2. Crop growth, yield, weed index and weed control efficiency under different treatments in transplanted rice

Treatment	Dose (g/ha)	Plant height (cm)	Effective tillers/m^2	Grains/ panicle	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index	Weed index	WCE at harvest	B:C ratio
Chlorimuron-ethyl	3	72.2	169.8	146.2	24.5	4.1	9.2	44.2	30.8	70.6	2.3
Chlorimuron-ethyl	6	75.0	178.0	156.0	24.2	4.4	9.8	45.3	24.4	77.4	2.5
Chlorimuron-ethyl	9	74.9	176.9	156.5	25.0	5.0	10.2	48.7	15.3	81.8	2.7
Chlorimuron-ethyl	12	74.2	179.6	157.2	24.3	5.4	10.5	51.5	7.7	85.5	3.0
Hand hoeing	20 DAT	74.6	182.9	158.2	24.9	5.5	10.4	54.6	6.3	87.9	3.1
Hand weedings	20 & 40 DAT	76.6	185.2	162.7	24.9	5.9	10.6	56.3	0.0	90.7	2.6
Control		76.2	144.2	93.2	22.1	2.7	8.0	34.3	53.4	-	1.7
LSD (P=0.05)		5.6	3.2	0.7		5.5	6.4	4.2	5.7		

was recorded highest under 12 g/ha chlorimuron-ethyl treated plot. The control plot recorded lowest effective number of tillers/m^2 (144.2), grains/panicle (93.2) and 1000 grain weight (22.2 g). Rice grain yield (5.89 t/ha), straw yield (10.57 t/ha) and weed control efficiency (90.71%) was higher under two hand weeding done at 20 and 40 DAT which was followed by hand hoeing (5.52 and 10.4 t/ha, 87.9%). Among the different doses, chlorimuron-ethyl 12 g/ha recorded higher grain yield (5.4 t/ha), straw yield (10.6 t/ha) and weed control efficiency (85.5%). Due to higher cost of cultivation hand weeded plot recorded lowest B:C ratio (1.7). However, hand hoeing and chlorimuron-ethyl 12 g/ha recorded highest B:C ratio (3.1 and 3.0), which was found at par to each other.

SUMMARY

Chlorimuron-ethyl was found very effective to control broad-leaved weeds and sedges, however it was less effective on grassy weeds. Chlorimuron-ethyl 12 g/ha was found much effective than lower dose for controlling the existing weed flora with higher crop yield and benefit: cost ratio.

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Short communication

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Pre- and post-emergence herbicides for integrated weed management in summer greengram

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Weed infestation is one of the major constraints in greengram cultivation. In view of severe infestation of annual and perennial weeds in summer greengram, the potential yield is generally not realized. The available pre- and post-emergence herbicide, pendimethalin, oxyfluorfen, fenaxaprop-p-ethyl and quizalofop-ethyl are able to check the emergence and growth of annual grasses and broad-leaved weeds. This study was done to find out the relative efficiency of different herbicide when applied alone or in combination with cultural operation in summer greengram.

The experiment was carried out during summer season of 2011 at Junagadh Agricultural University, Junagadh (Gujarat). The soil of the experimental field was medium black soil having pH 8.10 and EC 0.49 dS/m. It was medium, low and high in available N, P and K, respectively. Summer greengram variety *'Greengram-4'* was drilled at 20 kg/ha at 45 cm row spacing on February 18, 2011. The crop was grown with recommended package of practices except weed management. Ten treatment comprising inter-culture with weeding once (30 DAS), two inter-culture with weeding (20 DAS, 30 DAS, 40 DAS), pendimethalin 0.900 kg/ha, oxyfluorfen 0.180 kg/ha, fenaxaprop-p-ethyl 0.075 kg/ha and quizalofop-ethyl 0.040 kg/ha and integration each of pendimethalin 0.900 kg/ha and oxyfluorfen 0.180 kg/ha with an intercultural and weeding (30 DAS), weed free (weeding at 15, 30, 45 and 55 DAS) and unweeded control were tried in randomized block design with three replication. Inter-culturing operation was carried out in inter row space through bullock drawn implement and simultaneous removal of weeds manually in intra row space. All the herbicide were applied with manually operate knapsack sprayer fitted with flood jet nozzle at a spray volume of 500 l/ha. Weed count were recorded at 30 DAS , 60 DAS and at harvest and were subjected to $\sqrt{x + 0.5}$ transformation, while dry weight of weeds was recorded at harvest.

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Experimental field was infested with *Panicum colonum* L., *Cynodon dactylon* L., *Cyperus rotundus* L., *Digera arvensis* Forsk, *Euphorbia hirta* L., *Leucas aspera* Spreng., *Phyllanthus niruri* L., *Portulaca oleracea* L. and *Indigoflora glandulosa* L.

All the herbicidal and integrated treatments significantly reduced the weed density and their biomass over weedy check. At 30, 60 DAS and harvest, least weed density and dry matter were observed in monocot, dicot and sedges at two hand weeding and two inter-culturing at 20 and 40 DAS which was at par with oxyfluorfen 0.180 kg/ha + 1 hand weeding at 30 DAS and pendimethalin 0.900 kg/ha + 1 hand weeding + inter-culturing at 30 DAS. Two hand weeding and two inter-culturing at 20 DAS and 40 DAS showed its superiority by recording least weed density and their dry matter (Fig. 1). Although oxyfluorfen 0.180 kg/ha + 1 hand weeding at 30 DAS was found equally good but their effectiveness could not match with two hand weeding and two inter-culturing at 20 DAS and 40 DAS which may be due to the escape of some weed species. The excellent performance of two hand weeding and two inter-culturing at 20 DAS and 40 DAS were due to better control of weeds which constituted more than 70% of the total weed flora.

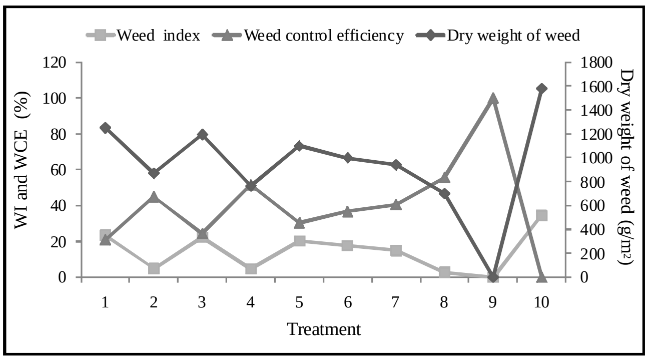

Fig. 1 Effect of different treatments on dry weight of weed, weed index and weed control efficiency

The lowest dry weight of weed was found by the application of two hand weeding and two inter-culturing at 20 DAS and 40 DAS and highest dry weight of weeds by pendimethalin 0.900 kg/ha. The lowest weed index (2.68%) and highest weed control efficiency (55.69%) was observed when two hand weeding and two inter-culturing at 20 DAS and 40 DAS followed by oxyfluorfen 0.180 kg/ha + 1 hand weeding at 30 DAS (4.68%, 51.58%, respectively). Among herbicides, quizalofop-ethyl (WCE 36.70%) was most effective in controlling weeds followed by fenoxaprop-p-ethyl (WCE 36.70%). The finding confirms the results of Bhandari *et al.* (2004) and Idapuganti *et al.* (2005).

There was vigorous growth of weed in unweeded check treatments resulted higher uptake of N, P and K nutrients. While treatment two hand weeding and two interculturing at 20 and 40 DAS recorded the least loss of nutrients by weeds followed by the oxyfluorfen 0.180 kg/ha (Table 1). It can be explained in the light of the facts that these treatments controlled the weeds effectively, might have made more nutrients available to crop and consequently encouraged higher concentration of nutrients and more yield and there by higher uptake of nutrients by the crop. Two hand weeding and two inter-culturing at 20 DAS and 40 DAS significantly increase protein content (22.2 %) followed by oxyfluorfen 0.180 kg/ha + 1 hand weeding at 30 DAS (21.87 percent). This can be ascribed to better control of weeds by manual weeding and integration with herbicidal method as compared to unweeded condition, which might have increased uptake of nutrients and water.

The effect of integrated weed management was found significantly on yield attributed and seed yield significantly. Two hand weeding and two interculturing at 20 DAS and 40 DAS and oxyfluorfen 0.180 kg/ha + 1 hand weeding at 30 DAS applied for the depressed weed growth and promoted yield parameters and seed yield (Table 2). Plant height, branches/plant, no. of pods/plant, length of pod (cm), no. of grain/pod, grain weight/plant (g), test weight (g), grain yield (t/ha), stover yield (t/ha) increased significantly due to application of two hand weeding and two interculturing at 20 DAS and 40 DAS and oxyfluorfen 0.180 kg/ha+ 1 hand weeding at 30 DAS supplemented with post-emergence herbicide. Among herbicides, application of quizalofop-ethyl resulted in significantly higher grain yield over fenoxaprop-p-ethyl, oxyfluorfen and pendimethalin. The results are in close conformity with those reported by Kohli *et al.* (2006). Among the treatment, application of two hand weeding and two interculturing at 20 DAS and 40 DAS produced highest grain and stover yield of 0.97 and 1.37 t/ha, respectively, and closely followed by oxyfluorfen 0.180 kg/ha+ 1 HW at 30 DAS with seed and stover yield of 0.95 t/ha and 1.36 t/ha. However, both these treatments were at par with weed free treatment. Higher grain yield under integrated weed control treatments (herbicide + hand weeding + interculturing) may be attributed mainly to the better control of weeds during different stages, manual removal of weeds emerging, weeding and interculturing at subsequent stages, resulting in reduced crop-weed competition and thereby providing better yield attributes (Vivek *et al.* 2008).

Table 1. Effect of weed-control treatments on protein content and nutrient uptake by greengram and weeds

Treatment	Dose (kg/ha)	Protein content (%)	Nutrient uptake (kg/ha)					
			Crop			Weeds		
			N	P	K	N	P	K
T_1- Pendimethalin	0.900	19.3	29.1	5.5	30.9	25.0	1.6	13.4
T_2- Pendimethalin +1 HW + IC at 30 DAS	0.900	21.2	36.1	6.6	35.7	19.9	1.1	10.3
T_3- Oxyfluorfen	0.180	19.6	30.2	5.5	32.4	24.0	1.5	12.7
T_4- Oxyfluorfen + 1 HW at 30 DAS	0.180	21.8	37.7	7.0	36.2	19.1	1.0	10.0
T_5- Fenoxaprop-p-ethyl at 20 DAS	0.075	20.2	31.7	5.8	33.0	23.6	1.4	11.8
T_6- Quizalofop-ethyl at 20 DAS	0.040	20.5	32.7	6.0	33.9	23.0	1.3	11.5
T_7- One hand weeding + and one inter-culturing at 30 DAS		20.7	34.3	6.3	35.0	20.5	1.2	10.6
T_8- Two hand weeding + two inter-culturing at 20 and 40 DAS		22.1	38.0	7.4	37.6	16.9	0.9	9.4
T_9- Weed free		23.0	40.5	7.8	38.4	0.0	0.0	0.0
T_{10}- Unweeded check		18.2	24.9	4.7	31.0	28.7	1.9	15.1
LSD (P=0.05)		2.6	3.8	0.2	2.2	3.85	0.27	2.20

Table 2. Effect of weed-control treatments on growth, yield and economics of greengram

Treatment	Plant height (cm)	Branches /plant	No. of pods/ plant	Length of pod (cm)	No. of grain/ pod	Grain weight/ plant (g)	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Net returns (x10³₹ /ha)	Benefit: cost ratio
T_1	26.2	4.86	11.2	5.5	5.7	5.1	30.3	0.76	1.13	12.92	2.09
T_2	36.6	6.13	14.6	7.4	6.7	6.2	35.3	0.95	1.36	17.62	2.35
T_3	28.2	5.00	12.1	5.9	5.9	5.3	32.1	0.77	1.17	13.30	2.12
T_4	37.2	6.37	15.0	7.8	6.9	6.8	35.8	0.95	1.36	18.04	2.41
T_5	31.2	5.33	12.9	6.4	6.2	5.6	32.6	0.80	1.21	14.43	2.26
T_6	33.0	5.47	13.2	6.7	6.2	5.9	33.4	0.82	1.26	15.21	2.32
T_7	35.4	5.80	13.2	6.9	6.5	6.0	34.6	0.85	1.30	15.82	2.35
T_8	39.3	6.73	15.4	8.1	7.0	6.9	35.9	0.97	1.37	18.35	2.41
T_9	40.1	7.03	16.1	8.6	7.1	7.5	36.8	1.00	1.41	18.42	2.33
T_{10}	23.4	4.50	10.2	4.7	5.3	4.9	29.1	0.65	1.06	11.07	2.07
LSD (P=0.05)	3.7	1.26	3.0	1.0	NS	1.1	4.7	0.14	0.21	-	-

DAS= Day after sowing: Treatment details are given in Table 1

The highest net monetary returns of ₹18354/ha was obtained with two hand weeding and two inter-culturing at 20 DAS and 40 DAS which was at par with oxyfluorfen 0.180 kg/ha + 1 hand weeding at 30 DAS (18040/ha). The highest benefit: cost ratio of 2.41 was obtained with two hand weeding and two inter-culturing at 20 DAS and 40 DAS and oxyfluorfen 0.180 kg/ha + 1 hand weeding at 30 DAS closely followed by pendimethalin 0.900 kg/ha + 1 hand weeding + inter-culturing at 30 DAS and one hand weeding and one inter-culturing at 30 DAS which may be due to lower cost of treatments than other. It was concluded that application of two hand weeding and two inter-culturing at 20 DAS and 40 DAS were found effective to control weeds and to improve crop yield. These findings were in close vicinity with those reported by Sardana *et al.* (2006). Thus, chemical weed control with oxyfuorfen as pre-emergence in summer greengram was found economically viable.

SUMMARY

A field experiment was carried out on the medium black soil of Junagadh Agricultural University, Junagadh (Gujarat) during summer season of 2011. The relative efficacy of pendimethalin, oxyfluorfen, fenoxaprop-p-ethyl, quizalofop-ethyl was tested applied alone or in combination with hand weeding and intercultural 30 days after sowing (DAS) to control weeds in summer green-gram. Two hand weeding with two interculturing at 20 DAS and 40 DAS proved its superiority over rest of the weed management in summer green gram. Among herbicidal treatment, application of quizalofop-ethyl at 20 DAS and fenoxaprop-p-ethyl at 20 DAS was found to be relatively more effective in controlling weeds than their sole application.

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Short communication

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Early post-emergence herbicides for weed control in soybean

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Soybean (*Glycine max* (L.) Merill) plays an important role in boosting oilseed production in the country. It stands second, among the nine oilseed crops, next only to groundnut in production in the country. It has outstanding nutritive value with 43% biological protein, 20% oil and is also very rich in vitamins, iron, mineral, salts and aminoacids. India is having soybean area of 9.52 million ha with a total production of 9.90 million tonnes and a productivity of 1.0 t/ha (DAC, Govt of India 2009). However, its productivity is low as compared to potential yield due to infestation of weeds. Weeds are the foremost biotic constraints in enhancing productivity of soybean and take yield toll ranging from 20 to 89% (Chhokar and Balyan 1999, Dubey 2002). Though the conventional method (hand weeding) of weed control is very effective, but due to high wages and non-availability of labour during the critical weeding period, the use of herbicides could be more effective and time saving. Therefore, this study was conducted on weed management in soybean grown in western zone of Tamil Nadu to find out agro-economic feasibility and its impact on grain yield.

A field experiment was carried out during *Kharif* seasons of 2009 at Agricultural Research Station, Bhavanisagar, Tamil Nadu. The soil was red sandy loam having pH 6.72, EC 0.18 dS/m, OC 0.55%, available N, P, K 230, 20, 268 kg/ha, respectively. The treatments comprised of imazethapyr 50, 75, 100 and 200 at g/ha as early post-emergence (EPOE) sprayed 15 days after sowing, oxyfluorfen 125 g/ha and pendimethalin 750 g/ha as pre-emergence (PE) were sprayed at 3 days after sowing, hand weedings at 25 and 45 days after sowing (DAS) and unweeded check (control) (T_8). All these treatments for comparison, except unweeded check were given with an earthing up at 45 DAS. The experiment was laid out in randomized block design with three replications. All the herbicides were applied by manually operated knapsack sprayer fitted with flat fan nozzle using spray volume of 500 l/ha. The density and dry weight of weeds were recorded at 30 and 60 DAS. Soybean variety '*CO (Soy) 3*' was sown in 30 cm wide rows. The crop was fertilized with 20 kg N + 80 kg P + 40 kg K/ha. Economics was worked out on the basis of prevailing market prices.

Dactyloctenium aegyptium, Acrachne racemosa and *Bracharia reptans*, were the dominant grass weeds. *Cyperus rotundus* was the only sedge present. The predominant broad-leaved weeds were *Boerhavia diffusa*, *Digera arvensis*, *Parthenium hysterophorous* and *Trichodesma indicum*. The investigations carried out by Balusamy *et al*. (1996) at Coimbatore showed that *Trianthema portulacastrum*, *Amaranthus viridis*, *Parthenium hysterophorus*, *Echinochloa* sp. and *Cyperus* sp. were dominant weeds of soybean.

All the herbicidal treatments significantly reduced the weed density and weed dry weight over unweeded control (Table 1). Significantly lower dry weed weight was recorded with hand weeding on 25 and 45 DAS. Among the herbicides, EPOE imazethapyr at 100 g/ha and EPOE imazethapyr 200 g/ha recorded significantly lesser weed dry weight than other herbicides at both the stages. Similar results were reported by Chandel and Saxena (2001), where POE imazethapyr at 100 g/ha was found to be effective in controlling weeds at various stages. At 30 and 60 DAS, early post- emergence application of imazethapyr had more pronounced effect in reducing the weed density and weed dry weight as compared to oxyfluorfen 125 g/ha and pendimethalin 750 g/ha application. EPOE imazethapyr 200 g/ha or EPOE imazethapyr 100 g/ha was effective against both dicot and monocot weeds and were at par with two hand weedings. Better performance of imazethapyr in the present study appeared to be due to better control of broad-leaved weeds as well as grassy weeds. The weed control efficiency could be enhanced (77-91%) and (93-98%) due to higher dose of imazethapyr at 30 and 60 DAS, respectively.

Seed yield was significantly influenced by different weed control treatments. Among the treatments, EPOE imazethapyr 100 g/ha recorded significantly higher seed yield followed by EPOE imazethapyr at 200 g/ha which was on par with PE pendimethalin 750 g/ha and PE

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Table 1. Effect of weed management on weed density, dry weight and weed control efficiency in soybean

Treatment	Total weed density (no./m^2)		Total weed dry weight (kg/ha)		Weed control efficiency (%)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Iimazethapyr 50 g /ha EPOE	2.45 (278.7)	1.75 (55.7)	1.80 (61.7)	1.30 (18.4)	77.7	93.1
Imazethapyr 75 g /ha EPOE	2.34 (223.3)	1.70 (51.0)	1.72 (50.8)	1.19 (13.8)	81.6	94.8
Imazethapyr 100 g /ha EPOE	2.06 (114.6)	1.45(28.3)	1.54 (33.9)	1.02 (8.58)	87.7	96.8
Imazethapyr 200 g /ha EPOE	1.93 (85.0)	1.33 (1967)	1.40 (24.6)	0.85 (5.11)	91.1	98.1
Oxyfluorfen 125 g /ha PE	2.29 (191.3)	1.82 (65.67)	1.75 (55.3)	1.40 (16.4)	80.0	93.8
Pendimethalin 750 g/ha PE	2.19 (154.0)	1.82 (65.7)	1.71 (54.5)	1.18 (13.1)	80.3	94.4
HW on 25 and 45 DAS	1.54 (34.3)	2.24 (175.0)	1.72 (51.45)	2.30 (199.8)	81.4	53.5
Unweeded control	2.97 (925.3)	2.70 (506.3)	2.44 (276.3)	2.56 (369.4)	-	-
LSD (P=0.05)	0.18	0.22	0.16	0.22	NA	NA

Values in parentheses are original values; EPOE- Early post-emergence, PE- Pre-emergence, NA- Not analysed

Table 2. Effect of weed management on productivity and economics in soybean

Treatment	Seed yield (t/ha)	Stover yield (t/ha)	Cost of cultivation (x10^3₹/ha)	Gross returns (x10^3₹/ha)	Net returns (x10^3₹/ha)	B:C ratio
Imazethapyr 50 g/ha EPOE	1.39	2.24	15.37	28.04	12.66	1.82
Imazethapyr 75 g/ha EPOE	1.47	2.39	15.50	30.99	15.49	1.99
Imazethapyr 100 g/ha EPOE	1.64	2.67	15.62	34.65	19.03	2.21
Imazethapyr 200 g/ha EPOE	1.51	2.85	16.12	34.10	17.98	2.14
Oxyfluorfen 125 g/ha PE	1.30	2.49	15.28	29.03	13.74	1.89
Pendimethalin 750 g/ha PE	1.48	2.25	15.90	31.23	15.33	1.96
HW on 25 and 45 DAS	1.23	2.03	17.12	26.65	9.57	1.56
Unweeded control	0.83	1.47	13.62	19.62	5.99	1.43
LSD (P=0.05)	0.09	0.09	NA	NA	NA	NA

oxyfluorfen 125 g/ha. The results are in corroboration with the findings of Kushwah and Vyas (2006) who have observed that the application of imazethapyr has increased the seed yield of soybean. However, EPOE imazethapyr 200 g/ha had phytotoxicity effect on soybean at initial stages causing stunted growth and chlorosis and get recovered after one or two irrigation.

EPOE imazethapyr at 100 g/ha recorded the highest gross return (₹ 34,654), net returns (₹ 19029) and B:C ratio (2.21) (Table 2.). As the cost of the treatment was lower with EPOE application of imazethapyr at 100 g/ha than hand weeding, it registered the additional return followed by EPOE application of imazethapyr 200 g/ha. The increased additional income realized with these two treatments might be due to higher seed yield obtained due to the treatment efficiency which would have reduced the competition between weeds and crop for water and nutrients. Similar results were reported by Kumar and Das (2008) by application of imazethapyr which had better control over weeds and acquired highest benefit cost ratio and net returns.

Thus, herbicidal weed management using early post-emergence imazethapyr at 100 g/ha followed by earthing up on 45 DAS might be the best method to control majority of weeds, obtaining higher productivity of soybean with better economic returns.

SUMMARY

A field experiment was conducted during *Kharif* 2009 to evaluate the economic feasibility of weed management practices in soybean (*Glycine max*) grown in red loamy soils of western zone of Tamil Nadu. Early post- emergence (EPOE) application of imazethapyr reduced the density and dry biomass of broad-leaved weeds as well as grasses significantly as compared to pre-emergence herbicide under study. The lowest weed density and biomass were recorded with hand weedings twice on 30 days after sowing (DAS) followed by imazethapyr at 200 and 100 g/ha. Imazethapyr at 100 g/ha was found to be the economic method of weed management by giving higher net returns with grain yield.

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Short communication

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Weed management in irrigated organic finger millet

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Finger millet (*Eleusine coracana* (L.) Gaertn.) ranks third in importance among millets in the country in both area (1.27 million ha) and production (1.91 million tonnes) after sorghum and pearl millet. It is commonly referred as ragi in Karnataka. It is one of the major staple foods of farming communities of southern Karnataka. Apart from human consumption, straw is also used as fodder for cattle and green straw is suitable for making silage.

Organic farming is being practiced in more than 130 countries of the world with a total area of 30.4 m ha (0.65% of the total agricultural land) with 0.7 million number of organic farmers world over (Willer 2008). It is gaining momentum in India owing to the concerns expressed on the safety of environment, soil, water and food chain. Cultivating crops organically, and at the same time maintaining higher production levels is a big challenge. Since chemical intervention is not permitted for weed management, non chemical weed management is the major limitation in field crops like ragi, paddy and other cereals under organic farming. A concern about the potential increase in weed population due to non use of herbicides is rated as serious problem in organic farming (Bond and Grundy 2001). Weeding through non-chemical means have to be undertaken within the critical period of the crop. Hence, the present study was initiated to find out effective and economical weed management practices in organic finger millet.

The field experiment was conducted during *Kharif* 2012 at the Main Research Station, Hebbal, Bengaluru, to identify the suitable methods of managing weeds in organic finger millet. It was laid out in randomized complete block design (RCBD) with three replications. The soil of the experimental field was sandy loam having pH of 6.55 with 236 kg N, 27.2 kg P_2O_5 and 176.2 kg K_2O/ha. The variety used for the experiment was '*GPU-28*'. The experiment comprised of twelve treatments, *viz.* T_1- passing wheel hoe at 20, 30 and 40 DAP, T_2- inter-cultivation twice at 20 and 35 DAP, T_3- stale seedbed technique, T_4- passing wheel hoe at 20, 30 and 40 DAP + one hand weeding at 45 DAP, T_5- inter-cultivation twice at 20 and 35 DAP + one hand weeding at 45 DAP, T_6- stale seedbed technique + inter cultivation twice at 20 and 35 DAP, T_7- organic mulching 10 t/ha after transplanting, T_8- growing cover crops (horse gram/cowpea) and mulching at 55 DAP, T_9- directed spray of *Eucalyptus* leaf extract on weeds, T_{10}- directed spray of cattle urine on weeds, T_{11}- hand weeding twice at 20 and 30 DAP, T_{12}- unweeded check.

Seedlings were raised in nursery bed of size 7.5 m long, 1.2 m width and 10 cm height prepared one month before transplanting of the crop. Nursery bed was prepared and the FYM was mixed with soil. Seeds 5 kg/ha were sown uniformly and light irrigation was given periodically. Neem cake was applied equivalent to 50 kg N/ha at the time of transplanting. Cattle urine was top dressed in three splits at 15, 30 and 40 DAP to meet remaining 50 kg N/ha. Stale seedbed treatment was initiated 15 days before transplanting of the crop. One irrigation was given to stale seedbed plots and weeds were allowed to germinate. The germinated weeds were removed by passing cultivator criscross one day before transplanting of the crop. Organic mulching was done with crop residues (paddy straw) and dried grasses 10 t/ha one week after transplanting. Seed mixture of cowpea and horse gram was sown in between two rows of finger millet. These cover crops were mulched between rows at 55 DAP.

Major weed flora observed in the experimental plot were: *Cyperus rotundus* L. among sedges; *Echinochloa colona* (L.), *Cynodon dactylon* (L.) Pers, *Dactyloctenium aegyptium* (L.) Beauv., *Digitaria marginata* (Retz.), *Eragrostis pilosa* (at initial stage) *Eleusine indica* (L.) Gaertn, (at later stages) among grasses; among broadleaved weeds *Parthenium hysterophorus*, *Alternanthera sessilis*, *Sida acuta*, *Spillanthus acmella*, *Commelina benghalensis*, *Ageratum conyzoides*, *Ocimum canum*, *Cinebra didema. etc*. Similar findings have been reported by Kumar (2004).

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At 60 DAP, the total weed density and weed dry weight was significantly lower in hand weeding twice at 20 and 30 DAP (26.32 and 6.4 g/m^2) treatment and was on par with stale seed bed technique + inter-cultivation twice at 20 and 35 DAP (29.67 and 8.0 g/m^2) and T_1 + one hand weeding (41.26 and 10.7 g/m^2). Whereas, stale seedbed alone and spray of cattle urine on weeds were not significantly controled the total weed density, which were on par with unweeded control (279.68 and 95.1 g/m^2, respectively). At harvest, total weed density and weed dry weight was significantly lower in hand weeding twice at 20 and 30 DAP (22.60 and 9.4 g/m^2, respectively) and was at par with stale seedbed technique + inter cultivation twice at 20 and 35 DAP (23.90 and 10.3 g/m^2, respectively). All the weed management treatments recorded significantly lower total weed density at harvest except stale seedbed technique alone and spray of cattle urine on weeds which were at par with unweeded control (245.90 and 105.1 g/m^2, respectively).

Table 1. Total weed density and weed dry weight at different stages in finger millet as influenced by weed management practices

Treatment	Weed density (no./m^2)		Weed dry weight (g/m^2)	
	60 DAP	Harvest	60 DAP	Harvest
T_1	1.72 (50.2)	1.68 (46.4)	1.62 (39.7)	1.67 (44.7)
T_2	1.92 (80.9)	1.79 (59.0)	1.76 (55.8)	1.76 (55.7)
T_3	2.25 (177.5)	2.23 (166.8)	1.91 (80.0)	1.96 (89.9)
T_4	1.64 (41.2)	1.64 (41.8)	1.10 (10.7)	1.55 (33.3)
T_5	1.69 (47.3)	1.68 (45.5)	1.65 (42.9)	1.63 (40.6)
T_6	1.50 (29.6)	1.41 (23.9)	1.00 (8.0)	1.09 (10.3)
T_7	2.10 (124.0)	2.04 (108.5)	1.74 (52.4)	1.78 (58.4)
T_8	1.89 (76.0)	1.83 (65.1)	1.74 (53.5)	1.67 (44.3)
T_9	2.22 (165.5)	2.18 (149.5)	1.92 (81.3)	1.94 (86.0)
T_{10}	2.27 (185.8)	2.21 (160.0)	1.84 (67.7)	1.93 (82.2)
T_{11}	1.45 (26.3)	1.39 (22.6)	0.92 (6.4)	1.06 (9.4)
T_{12}	2.45 (279.6)	2.39 (245.9)	1.99 (95.1)	2.03 (105.1)
LSD (P=0.05)	0.20	0.19	0.06	0.11

Figures in parentheses are original values; data analyzed using transformation =log (x+2); Treatment details are given in materials and methods

The WCE was higher with hand weeding twice at different growth stage of the crop (92.8, 93.2 and 91.0 % at 30, 60 DAP and at harvest, respectively) owing to the fact that it produced lesser weed dry weight. Similar findings were observed by Kumar (2004) in groundnut-finger millet cropping system, who observed hand weeding twice to be the best treatment having the lowest WI, highest WCE and higher yield. WCE of stale seedbed technique combined with inter cultivation twice (91.3, 91.6 and 90.1% at 30, 60 DAP and at harvest respectively) and passing wheel hoe at 20, 30 and 45 DAP with one hand weeding (68.5, 88.7 and 68.3% at 30, 60 DAP and at harvest, respectively,). The results of this study were similar with earlier findings of Ramamoorthy *et al.* (2009) in finger millet and Sindhu *et al.* (2010) in wet seeded rice. Similar findings were also obtained by Mynavathi *et al.* (2008) in irrigated maize and found that passing wheel hoe significantly reduced the weed dry weight and increased the maize yield compared to other mechanical weeders.

Grain yield of finger millet was significantly higher in hand weeding twice at 20 and 30 DAP (5.46 t/ha) as compared to unweeded control. However, it was on par with stale seedbed technique + inter cultivation twice and also with passing wheel hoe at 20, 30 and 45 DAP + one hand weeding (5.36 t/ha). Similar findings were obtained by Ramamoorthy *et al.* (2009). This higher yield might be

Table 2. Weed control efficiency (%) at different growth stages and grain yield of finger millet as influenced by weed management practices

Treatment	WCE			Grain yield (t/ha)
	30 DAP	60 DAP	Harvest	
T_1	33.0	58.2	57.5	4.09
T_2	18.6	41.3	47.0	3.93
T_3	26.6	15.8	14.4	3.39
T_4	68.5	88.7	68.3	5.14
T_5	31.5	54.9	61.3	4.22
T_6	91.3	91.6	90.1	5.36
T_7	84.4	45.2	44.4	3.77
T_8	8.5	43.7	57.8	3.20
T_9	12.5	14.5	18.1	2.92
T_{10}	18.5	28.8	21.8	3.30
T_{11}	92.8	93.2	91.0	5.46
T_{12}	0.0	0.0	0.0	2.73
LSD(P=0.05)	-	-	-	0.95

due to better control of weeds at tillering stage of the crop resulted in higher yield of the crop. Whereas, lower grain yield (2.73 t/ha) was obtained in unweeded control. This reduction in yield might be due to highest competition with the finger millet throughout the crop growth period.

SUMMARY

A field experiment was conducted during *Kharif* season 2012 at the Main Research Station, Hebbal, Bengaluru, to know the effect of weed management practices on weed flora and weed growth in irrigated organic finger millet. All weed management treatments had significantly lower total weed density and weed dry weight as compared to unweeded control. Stale seed bed technique + inter cultivation twice at 20 and 35 DAP (23.9/m^2 and 10.3 g/m^2) significantly lowered the total weed density as well as weed dry weight and was at par with hand weeding twice at 20 and 30 DAP (22.6/m^2 and 9.4 g/m^2, respectively). Higher total weed density and weed dry weight was found in unweeded check (245.9/m^2 and 105.1 g/m^2). Highest weed control efficiency was found in manual weeding (93.2%) followed by stale seedbed combined with inter cultivation twice (91.6%) and passing wheel hoe twice with one manual weeding (88.7%). Grain yield was significantly higher in hand weeding twice (5.46 t/ha) followed by stale seedbed combined with inter cultivation twice (5.36 t/ha).

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Short communication

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Field demonstration of integrated weed managment in sorghum

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Key words: Field demonstration, Integrated weed managment, Sorghum, Yield

Sorghum is an important cereal crop grown on 8.47 lakh ha area with 9.85 lakh tonnes production in Maharashtra. The average productivity of sorghum in state is 1.16 t/ha. The crop is a good source of fodder for animals. The sorghum is a sturdy crop grows well in semi arid climate and gives better yields even with frequent dry spells occurring in a growing season.

One of the most important constraints in low productivity of sorghum is the weed infestation. The sorghum yields reduced to the tune of 60-70% due to weed infestation (Shelke 1995). Manual weeding alone is expensive, tedious and time consuming (Rajput and Khushwah 2005). Therefore, recommended integrated weed management practice was demonstrated at farmers field to show the practicability with higher yields over farmers practice.

Demonstrations were conducted during *Kharif* season of 2010-2012 in sorghum with recommended IWM that is application of pre-emergence atrazine 1.0 kg/ha followed by one hand weeding and hoeing at 6 weeks after sowing (Jadhav 2010) at randomly selected fifteen villages of Parbhani, Nanded, Beed, Hingoli and Jalna districts. Total fifteen farmers were selected for conducting demonstrations on their fields. The data were recorded from each farmer's field. The IWM was advised to undertake and the yields under farmers practice was also recorded at the same time for comparison.

The performance of IWM was recorded at demonstration at farmers field to show its effectiveness against weed growth and yield of sorghum. The fields under demonstrations were infested with *Euphorbia geniculata, Digera arvensis, Cyperus rotundus, Cynodon dactylon* and *Parthenium hysterophorus.*

IWM under all demonstrations was effective in reducing weed growth at different locations (Table 1). Farmers practice gave higher weed count and dry matter as compared to IWM treated plots at all the locations. The IWM in all demonstrations resulted on an average 27.4% increase in yield over farmers practice. The lowest in-

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Table 1. Performence of IWM in sorghum at farmers field

Treatment and location	S_1	S_2	S_3	S_4
IWM			2010	
Parbhani	28	13	1.90	26.7
Nanded	19	10	2.10	31.1
Beed	32	19	2.00	33.3
Hingoli	18	16	1.80	50.0
Jalna	07	14	2.20	29.4
Mean			2.00	34.1
FP				
Parbhani	116	27	1.50	
Nanded	96	25	1.60	
Beed	187	35	1.50	
Hingoli	152	32	1.20	
Jalna	148	31	1.70	
Mean			1.50	
IWM			2011	
Parbhani	32	12	1.80	28.6
Nanded	35	10	2.00	25.0
Beed	46	18	1.85	19.3
Hingoli	60	13	2.01	37.7
Jalna	52	14	1.95	18.2
Mean			1.92	25.4
FP				
Parbhani	86	20	1.40	
Nanded	106	18	1.60	
Beed	118	25	1.55	
Hingoli	110	23	1.46	
Jalna	157	19	1.65	
Mean				
IWM			2012	
Parbhani	34	14	1.48	21.8
Nanded	25	12	1.58	18.1
Beed	62	22	1.28	21.9
Hingoli	44	16	1.31	21.3
Jalna	36	14	1.49	30.6
Mean			1.43	22.7
FP				
Parbhani	118	18	1.22	
Nanded	120	19	1.34	
Beed	122	26	1.05	
Hingoli	128	26	1.08	
Jalna	112	22	1.14	
Mean			1.16	

S_1 - Weed count (no./m^2) at 30 DAS; S_2 - Weed dry matter (g/m^2) at 30 DAS; S_3 - Grain yield (t/ha); S_4 - % increase over farmer's practice (FP) crease in sorghum yield was 18.1%, where as highest increase in yield was 50%. It clearly indicated that if IWM is followed yield can be increased significantly. The demonstrations at farmers' field played an important role to disseiminate the recommended IWM.

SUMMARY

Fifteen demonstrations on integrated weed managment technology were laid out during *Kharif* 2010 to 2012 in sorghum at randomly selected farmers field from various districts of Marathwada region of Maharashtra with an objective to show the performance of IWM in sorghum. The IWM was found effective in increasing grain yield of sorghum from 18-50% over farmers practice depending upon weed intensity.

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Integrated weed management in berseem

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Key words: Berseem, Integrated weed managment, Seed yield, Weed dry weight, Weed intensity

Berseem or Egyptian clover (*Trifolium alexandrinum* L.), a potential winter forage legume, is one of the most popular crops in north, north-west and central parts of India. Because of its slow growth in the initial stages, crop suffers heavily due to weed infestation. Weeds particularly *Cichorium intybus* found associated with berseem and give more competitional stress by robbing the crop of essential nutrients, light, moisture and space (Thakur *et al.* 1990). Weed competition reduces the green forage yield up to 30-40% besides deteriorating quality of green forage (Jain 1998). The present investigation was undertaken to evaluate the bioefficacy of herbicide alone or in combination with mechanical methods in berseem.

An experiment was conducted at MPKV, Rahuri situated between 19^0 48' and 19^0 49' N latitude and between 74^0 32' E and 76^0 19' E longitude during *Rabi* season 2011-12. The altitude varied from 395 to 565 m above mean sea level. The soils of the experimental field were clayey in texture, low in available nitrogen (201.4 kg/ha), medium in available phosphorus (18.4 kg/ha) and high in available potassium (495 kg/ha). It was moderately alkaline in reaction (pH 8.01) with 0.23 dS/m electrical conductivity. The organic carbon content was 0.38 per cent.

The experiment consisting of 10 treatments (Table 1) was laid out in a randomized block design replicated thrice. The gross and net plot size employed was 4.0 x 3.0 m and 3.4 x 2.4 m, respectively. The maximum and minimum temperature during the crop growth period was ranging from 29.1-33.8^{0}C and 10.1-15.9^{0}C, respectively. Herbicides were sprayed with the manually operated knapsack sprayer fitted with flat-fan nozzle at spray volume of 500 l/ha. The pre-emergence herbicides were sprayed 3 days after sowing prior to emergence of weed The crop was fertilized with the recommended dose of fertilizer, 20 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha. The variety '*Wardan*' was sown at 30 cm apart by using seed rate of 30 kg/ha. First two cuts were taken for green forage purpose there after crop was left for seed production purpose and harvesting of seed was done in the month of May. From each plot, 250 g representative fresh plant sample was taken in each cut to estimate the dry matter content for computing dry matter yield of fodder. The weed density and its dry weight were recorded from each plot by using a quadrate method (1.0 x 1.0 m) at harvest of last cut for seed. The weed control efficiency (WCE) and weed index (WI) was calculated as per the standard formula suggested by Gautam *et al.* (1975) and Gill and Vijaykumar (1969), respectively.

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Major monocot weeds were: *Cynodon dactylon* (28.5%), *Chloris barbata* (7.1%), *Digitaria longiflora* (10.7%), *Dactylocteium aegyptium* (10.7%) and *Cyperus rotundus* (42.9%). Major dicot weeds were: *Amaranthus viridis* (16.7%), *Euphorbia geniculata* (8.3%), *Celosia argentia* (4.2%), *Trianthema portulacastrum* (4.2%), *Commelina benghalensis* (12.5%), *Corchorus aestuans* (4.2%), *Parthenium hysterophorus* (33.3%), *Tridax procumbent* (4.2%), *Portulaca oleracea* (4.2%), *Cichorium intybus* (4.2%). Out of these, *P. hysterophorus E. geniculata,* and *C. rotundus* were most dominated weeds.

Weedy check recorded significantly higher total weed density at harvest (51.8/m^2). Significantly minimum weed count at harvest was found with weed free treatment followed by oxyflourfen 0.10 kg/ha as pre-emergence (PE) and imazethapyr 0.10 kg/ha as post-emergence (PoE), immediately after Ist cut and it was found at par with one hoeing at 3 week after sowing and one hand weeding at 5 week after sowing (Table 1).

The minimum weed dry weight at harvest was observed under weed free check which was followed by treatment oxyflourfen PE 0.10 kg/ha *fb* imazethapyr POE 0.10 kg/ha (immediate after harvest of Ist cut) and one hoeing at 3 week after sowing and one HW at 5 week after sowing both were found at par with each other. The results were in accordance with the findings of Jain (1998) and Tamrakar *et al.* (2002).

Significantly highest WCE was noticed in weed free check. Among the other weed control treatments, it was significantly maximum and at par with treatments oxyflourfen PE 0.10 kg/ha *fb* imazethapyr POE 0.10 kg/ha (immediate after harvest of Ist cut) and one hoeing at 3 week after sowing and one HW at 5 week after sowing as compared to weedy check (Table 1). This observation was in agreement of Tiwana *et al.* (2002).

Table 1. Weed count and dry weight as influenced by integrated weed management

Treatment	Total weed density (no./m^2)	Total weed dry weight at harvest (3 cuts) (g/m^2)	Weed control efficiency (%)	Weed index for GFY (%)	Weed index for seed yield (%)
T_1 - One hoeing at 3 week after sowing and one HW at 5 week after sowing	4.4 (18.5)	5.1 (25.3)	72.4	7.3	13.6
T_2 - Pendimethalin PE 1.0 kg/ha	6.2 (37.3)	7.1 (50.1)	45.4	59.4	46.3
T_3 - Pendimethalin PE 1.0 kg/ha *fb* one HW at 5 week after sowing	5.7 (31.5)	7.0 (48.4)	47.2	49.4	46.8
T_4 - Oxyflourfen PE 0.10 kg/ha	5.3 (27.4)	6.3 (38.2)	58.3	26.7	33.8
T_5 - Oxyflourfen PE 0.10 kg/ha *fb* one HW at 5 week after sowing	5.0 (24.0)	6.2 (36.7)	64.6	21.8	25.5
T_6 - Pendimethalin PE 1.00 kg/ha *fb* imazethapyr POE 0.10 kg/ha (immediate after harvest of Ist cut)	5.5 (29.3)	6.8 (44.7)	51.2	27.9	38.0
T_7 - Oxyflourfen PE 0.10 kg/ha *fb* imazethapyr POE 0.10 kg/ha (immediate after harvest of Ist cut)	3.9 (14.2)	4.9 (23.0)	75.0	4.1	7.7
T_8 - Imazethapyr POE 0.10 kg/ha (immediate after harvest of Ist and IInd cut)	4.9 (22.7)	5.4 (28.5)	69.0	11.7	27.7
T_9 - Weedy check (control)	7.3 (51.8)	9.6 (91.7)	-	62.4	53.2
T_{10} -Weed free check	1.0 (0.0)	1.0 (0.0)	100.0	0.0	0.0
LSD (P=0.05)	0.9	0.91	7.5	9.9	15.6

*PE- Pre-emergence, POE- Post-emergence, HW- Hand weeding, *fb*- followed by; GFY - Green forage yield

** Original values given in parentheses are square root transformed $\sqrt{X+1}$ for statistical analysis.

Among the weed control treatments, significantly minimum weed index (4.08) for green fodder yield (GFY) was with treatment oxyflourfen 0.10 kg/ha followed by imazethapyr 0.10 kg/ha immediate after harvest of Ist cut and it was at par with one hoeing at 3 week after sowing and one HW at 5 week after sowing and imazethapyr POE 0.100 kg/ha. Whereas, in respect to weed index of seed yield, it was significantly minimum with treatment oxyflourfen PE 0.10 kg/ha *fb* imazethapyr POE 0.10 kg/ha and found at par with treatment one hoeing at 3 week after sowing and one HW at 5 week after sowing (Table 1). These results were in conformity with findings of Jain (1998) and Tiwana *et al.* (2002).

Weed free check was significantly superior with respect to green forage yield (GFY) (47.27 t/ha), dry fodder yield (DFY) (7.13 t/ha), seed yield (0.35 t/ha), straw yield (1.34 t/ha) and crude protein yield (1.22 t/ha) as compared to rest of the treatment except treatment oxyflourfen *fb* imazethapyr and imazethapyr applied after harvest of Ist and IInd cut, which were found at par (Table 2). The per cent increase over control with respect to GFY, DFY, seed yield, straw yield and crude protein yield in oxyflourfen PE 0.100 kg/ha *fb* imazethapyr POE 0. 10 kg/ha (immediate after harvest of Ist cut) were 59.38, 57.95, 45.85, 49.37 and 57.70, respectively. These results were in agreement with the findings of Tamrakar *et al.* (2002) and Tiwana *et al.* (2002).

Weed free check fetched maximum and significantly higher gross monetary (₹ 1,33,031/ha) and net monetary returns (₹ 64,812/ha) over rest of the treatment except treatment one hoeing at 3 week after sowing and one HW at 5 week after sowing and oxyflourfen PE 0.100 kg/ha *fb* imazethapyr POE 0.10 kg/ha (Table 2). The maximum B: C ratio (2.01) was registered by treatment oxyflourfen PE 0.10 kg/ha *fb* imazethapyr POE 0.10 kg/ha (immediate after harvest of Ist cut) which was followed by weed-free check (1.95).

SUMMARY

Weed-free check treatment recorded significantly lowest total weed count/m^2 and its dry weight at harvest followed by oxyflourfen pre-emergence 0.10 kg/ha *fb* imazethapyr post-emergence 0.10 kg/ha (immediate after harvest of Ist cut) and one hoeing at 3 week after sowing

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

Treatment	Green forage yield (t/ha)	Dry matter yield (t/ha)	Seed yield (t/ha)	Straw yield (t/ha)	Crude protein yield (t/ha)	Gross monitory returns (x10³ ₹/ha)	Cost of cultivation (x10³ ₹/ha)	Net monitory returns (x10³ ₹/ha)	B:C ratio
T_1	46.55	6.69	0.32	1.33	1.13	127.64	64.05	59.42	1.87
T_2	20.57	4.52	0.20	0.82	0.76	80.59	52.06	28.53	1.55
T_3	25.69	3.66	0.20	0.78	0.62	74.33	52.11	22.22	1.43
T_4	37.17	5.30	0.25	1.03	0.91	100.39	56.06	44.32	1.79
T_5	39.66	5.81	0.28	1.19	1.03	108.98	60.09	48.88	1.81
T_6	36.57	5.33	0.23	0.83	0.93	96.46	56.65	39.81	1.70
T_7	47.04	6.77	0.32	1.34	1.14	128.71	59.09	64.65	2.01
T_8	43.30	6.29	0.27	1.30	1.12	110.79	59.59	51.20	1.86
T_9	19.10	2.84	0.18	0.68	0.48	60.13	52.11	8.01	1.15
T_{10}	47.27	7.13	0.35	1.39	1.22	130.31	68.22	64.81	1.95
LSD (P=0.05)	5.27	0.96	0.07	0.20	0.13	16.62	-	16.62	-

Selling rate of berseem: Green forage (₹ 1.50/kg), seed (₹ 175.00/kg), straw (₹ 1.00/kg)

and one hand weeding at 5 week after sowing which were at par with each other. The weed control efficiency was highest in weed free check and significantly superior to all the treatments. Significantly minimum weed index of berseem, green forage yield and seed yield were observed in treatment oxyflourfen pre-emergence 0.10 kg/ha *fb* imazethapyr post-emergence 0.10 kg/ha and it was at par with treatment one hoeing at 3 week after sowing and one hand weeding at 5 week after sowing and imazethapyr post-emergence 0.10 kg/ha. The economic studies indicatesed that oxyflourfen pre- emergence 0.10 kg/ha *fb* as post-emergence imazethapyr 0.10 kg/ha immediate after harvest of I^{st} cut was most cost effective and remunerative. The maximum net monitory returns of ₹ 64,658/- with B:C ratio of 2.01 was fetched by the treatment oxyflourfen pre-emergence 0.10 kg/ha followed by imazethapyr as a post- emergence application 0.10 kg/ha immediate after harvest of I^{st} cut was found effective and remunerative followed by treatment one hoeing at 3 week after sowing and one hand weeding at 5 week after sowing.

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