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Sowing time and weed management practices to enhance yield of direct-seeded rice

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ABSTRACT

A field experiment was conducted during the *Kharif* season of 2006 and 2007 at G.B. Pant University of Agriculture and Technology, Pantnagar to find out the most effective weed control method under different sowing dates in direct-seeded unpuddled rice. Highest grain yield (2.5-2.7 t/ha) was recorded from 20 June sowing. The grain yield was the highest in mechanical weedings at 20 and 40 DAS. Pendimethalin 1.0 kg/ha + anilophos 0.4 kg/ha (pre-emergence) produced significantly higher grain yield (3.1-3.3 t/ha) over rest of the herbicidal treatments. Uncontrolled weeds reduced the grain yield of rice by 67-70%.

Keywords: Date of sowing, Direct-seeded rice, Economics, Weed management, Unpuddled

Transplanting of rice seedlings is an age-old practice but in recent years, non availability of labours for transplanting at appropriate time leads to the reduction in yield of rice (Budhar and Tamilselvan 2002). Though direct-seeded rice (DSR) yield is comparable with transplanted crop, increased weed infestation is major drawback of this system. Success of DSR depends largely on effective weed control especially with chemical methods. The yield loss due to weeds is high as 40-100% in DSR (Choubey *et al.* 2001). Though the hand weeding has been found effective, yet it is very expensive. Moreover, heavy demand of labour during peak period and its scarcity necessitates the use of alternative methods of weed control. Chemical weed control being cost-effective and less labour dependent is recommended to overcome this constraint under DSR. Broad-spectrum weed flora may not be controlled by herbicide alone, as flushes of weeds come up at different stages. Sowing time is a non-monetary input, but greatly affects the productivity of rice. Several studies have shown that sowing of rice after onset of monsoon gave higher grain yield due to less infestation of weeds. However, very late sowing could reduce the vegetative and reproductive growth period of rice, resulting into lower crop yield. Hence, the present investigation was under taken to study the effectiveness of date of sowing and weed management practices on direct seeded unpuddled rice.

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MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 2006 and 2007 at G.B. Pant University of Agriculture and Technology, Pantnagar to study the effect of various weed management practices under different sowing dates on direct seeded un-puddled rice. The field experiment, laid out in split-plot design with 3 replications, included 3 dates of sowing (05 June, 20 June and 05 July) and 8 weed management practices (Table 1). The soil was loamy, medium in organic matter (0.67%), available phosphorus (17.5 kg/ha) and potassium (181.2 kg/ha), with pH 7.5. Seeding of rice variety '*Govind*' was done in lines at 20 cm apart with 50 kg seed/ha. Recommended dose of fertilizer, *i.e.*120 kg N, 80 kg P_2O_5 and 60 kg K_2O/ha was applied. The half dose of N, entire P_2O_5 and K_2O were applied basal. Remaining amount of nitrogen was applied in 2 equal splits at tillering and panicles initiation stages in both the years. For the control of 'Khaira' disease (Zn deficiency), one spray of 0.5% zinc sulphate was done at 40 days after sowing. The dry weight of weeds was recorded at 90 DAS by placing a quadrate of 0.50 x 0.50 m randomly at two places of each plot. Log (X+1) transformation was used to analyze the data in respect of weeds.

RESULTS AND DISCUSSION

Effect on weeds

Echinochloa colona among grasses, *Commelina benghalensis* and *Caesulia axillaris* among non-grasses and *Cyperus rotundus* among sedges were predominant weed species in the experimental site during both the years. Seeding time and weed management treatments had significant influence on weed population (Table 1). Sowing of crop at 20 June recorded less density and dry weight of total weeds and highest weed control efficiency than 5 June sown crop. The population and dry weight of total weeds was significantly higher in 5 June as compared to 05 July sown crop due to stale seed bed effect on weeds. It shows that weed germination might have initiated even before the onset of monsoon under dry conditions with least available water in subsoil layers. Similar results were also reported by Kathiresan *et al.* (1997). Highest weed control efficiency was observed in 5 July sown crop though being at par with 20 June and 5 June sowing dates. Two hand weedings (20 and 40 DAS) and pendimethalin 1.0 kg/ha + anilophos 0.4 kg/ha as applied pre-emergence recorded efficient control of all weeds (grasses, non-grasses and sedges) and recorded greater weed control efficiency (Table 1) as compared to weedy check as well as other weed control treatments. Bahar and Singh (2004) also reported better weed control with pendimethalin in direct-seeded rice. The population and dry weight of weeds was also reduced with the pre-emergence application of pendimethalin 1.5 kg/ha and fenoxaprop-p-ethyl 0.06 *fb* 2,4-D 0.5 kg/ha.

Effect on crop

Delay in sowing from 5 June to 20 June caused an increased in grain yield due to reduced population and dry weight of weeds to the extent of 13.2% in first year and 11.6% in the second year. Similar results were also observed by Publico and Moody (1995). However, delay in sowing from 20 June to 5 July caused 9.6% reduction in grain yield during 2006 and 10.2% during 2007 (Table 2). Similar results were also observed by Gill *et al.* (2006). The significantly higher values of yield attributing characters namely 1000-grain weight were recorded in 20 June sown crop as compared to 5 June sown crop due to less population and dry weight of weeds in 20 June sowing.

Uncontrolled weeds in weedy check plots caused an average reduction in yield to the extent of 74.4% during 2006 and 67.4% during 2007 as compared with weed free

Table 1. Effect of treatments on density and dry weight of total weeds at 30 days after sowing (DAS)

Treatment	Rate of application (kg/ha)	Time of application (DAS)	Density of weeds (no./m^2)		Weed dry weight (g/m^2)		WCE (%)	
			2006	2007	2006	2007	2006	2007
Date of sowing								
5 June	–	–	3.70 (58)	3.52 (49)	3.22 (39.2)	2.81 (30.8)	3.69 (56)	3.74 (59)
20 June	–	–	3.59 (50)	3.37 (41)	3.00 (29.6)	2.46 (21.1)	3.70 (57)	3.75 (58)
5 July	–	–	3.43 (43)	3.16 (33)	2.83 (23.5)	2.22 (15.1)	3.71 (57)	3.76 (60)
LSD (P=0.05)			0.13	0.22	0.04	0.04	0.57	0.16
Weed management								
Pendimethalin	1.5	1	3.77 (44)	3.49 (31)	2.84 (16.9)	2.21 (8.8)	4.25 (69)	4.30 (73)
Pendimethalin + anilophos	1.0 + 0.4	1	3.62 (37)	3.27 (25)	2.68 (14.0)	1.91 (6.3)	4.30 (73)	4.33 (75)
Pretilachlor	0.75	1	4.01 (54)	3.78 (46)	3.46 (31.8)	3.12 (22.8)	4.06 (57)	4.11 (60)
Fenoxaprop-p-ethyl + 2,4-D (EE)	0.06+0.5	15+30	3.92 (50)	3.68 (41)	3.37 (29.8)	3.04 (21.7)	4.09 (59)	4.13 (61)
Anilophos	0.4	10	4.14 (63)	3.93 (53)	3.73 (42.1)	3.38 (31.8)	3.74 (41)	3.84 (66)
Two hand weeding	–	20 and 40	3.43 (30)	2.97 (21)	2.27 (9.1)	0.30 (0.4)	4.48 (88)	4.50 (90)
Weed free	–	–	–	–	–	–	4.6 (100)	4.6 (100)
Weedy check	–	–	4.57 (98)	4.45 (87)	4.32 (78.2)	4.18 (67.2)	–	–
LSD (P=0.05)			0.13	0.20	0.07	0.08	0.20	0.27

Original values are in parentheses

Table 2. Effect of treatments on growth and yield of rice

Treatment	Plant height (cm) at 30 DAS		No. of tillers/m row length at 30 DAS		Crop dry weight (g) at 30 DAS		1000-grain weight (g)		Grain yield (t/ha)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Date of sowing										
5 June	23.9	25.1	43.4	45.7	38.8	41.1	22.0	22.2	2.16	2.38
20 June	28.2	29.5	47.9	50.3	41.4	43.3	22.6	22.6	2.62	2.70
5 July	26.3	27.5	45.8	47.9	38.4	40.5	22.1	22.4	2.24	2.42
LSD (P=0.05)	2.8	2.8	1.4	1.5	NS	NS	0.4	0.2	0.13	0.06
Weed management										
Pendimethalin	28.7	29.6	50.5	54.4	42.1	43.9	22.8	23.0	2.77	3.07
Pendimethalin + anilophos	30.4	31.4	52.2	54.5	43.6	45.5	23.3	23.3	3.09	3.28
Pretilachlor	23.9	25.2	44.1	45.0	32.7	34.3	22.3	22.4	1.99	2.23
Fenoxaprop-p-ethyl + 2,4-D (EE)	25.4	26.9	44.0	45.7	38.5	42.1	22.7	22.8	2.12	2.38
Anilophos	23.5	24.9	40.2	42.9	40.4	42.3	21.4	21.9	1.80	2.02
Two hand weeding	30.7	32.8	52.2	57.4	46.6	48.5	23.4	23.3	3.32	3.43
Weed free	33.1	34.4	57.8	60.9	48.3	50.0	23.4	23.6	3.43	3.56
Weedy check	19.9	21.4	29.8	31.1	25.8	27.9	19.4	19.1	1.01	1.14
LSD (P=0.05)	2.3	2.3	3.4	3.4	3.8	4.3	0.3	0.3	0.14	0.12

plots, mainly due to high density and more dry matter accumulation by weeds in weedy check plots (Table 1). The lowest grain yield obtained in weedy check was also associated with lowest crop dry matter accumulation and 1000-grain weight (Table 2). Two hand weeding (20 and 40 DAS) and pendimethalin 1.0 kg/ha + anilophos 0.4 kg/ ha applied as pre-emergence gave significantly higher grain yield than other weed control treatments due to more number of tillers per metre row length and 1000-grain weight (Table 2).

On the basis of two years study, it was concluded that sowing of direct-seeded rice around 20th June and pre-emergence application of pendimethalin 1.0 kg/ha + anilophos 0.4 kg/ha provided better weed control and higher grain yield

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Effect of pyrazosulfuron-ethyl on yield of transplanted rice

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ABSTRACT

Efficacy of pyrazosulfuron-ethyl against weeds in transplanted rice was studied during 2008 and 2009 at Regional Research Sub-station, Chakdaha under Bidhan Chandra Krishi Viswavidyalaya, West Bengal. The experiment was laid out in randomized block design with seven treatments replicated thrice. The major associated weeds were: *Echinochloa colona, Cyperus difformis, Ammania baccifera, Ludwigia octovalvis* and *Monochoria vaginalis*. Pyrazosulfuron-ethyl at 42.0 g/ha applied at 3 DAT was most effective in managing associated weed species and yielded maximum grain yield (3.3 t/ha) of rice with lower weed index (10.8%).

Key words: Pyrazosulfuron-ethyl, Transplanted rice, Weeds, Yield

Weeds are a major cause of yield reduction in rice. Hand weeding is the traditional weed control measure and still being the most popular in rice cultivation in West Bengal. However, due to high labour cost, non-availability of labour and huge time requirement for manual weeding, farmers are forced to opt for other alternative measures like chemical weed control. Many herbicides are being used successfully for weed control in rice both as pre and post-emergence spray. New herbicides are available in the market and use of herbicides of different composition is desirable to reduce the problem of residue buildup, shift in weed problem (Rajkhowa *et al.* 2006) and development of herbicide resistance in weeds (Rao 1999, Saha *et al.* 2006). The recent trend of herbicide use is to find out an effective weed control measure by using low dose high efficiency herbicides which will not only reduce the total volume of herbicide use but also the application become easier and economical (Pal and Banerjee 2007).

The herbicide pyrazosulfuron-ethyl has both foliar and soil activity (Rajkhowa *et al.* 2006). It is generally recommended as a pre-emergence herbicide in transplanted rice (Angiras and Kumar 2005). Studies on bio-efficacy and phytotoxicity of pyrazosulfuron-ethyl for pre-emergence weed control in transplanted rice are scanty and there are different reports of various dosages and time of application required for effective weed control (Chopra and Chopra 2003). The present experiment was therefore undertaken to study the bio-efficacy and phytotoxicity of pyrazosulfuron-ethyl in pre-emergence control of major weeds in transplanted *Kharif* rice and to determine an optimum dosage and time of application that can be recommended to rice farmers of West Bengal, India.

MATERIALS AND METHODS

An experiment was conducted during *Kharif* season of 2008 and 2009 at Regional Research Sub-Station (RRSS), Bidhan Chandra Krishi Viswavidyalaya, Chakdaha, Nadia under new alluvial zone of West Bengal, India (situated at $23^0$5.3' N latitude and $83^0$5.3' E longitude with an altitude of 10 m above mean sea level). The topography of land is known as medium land and the soil was sandy clay loam in texture having a pH of 7.2, EC 0.06 dS/m, organic C 0.67%, total N 0.065%, available P 18.0 kg/ha and available K 129.0 kg/ha. The experiment was laid out in a randomized block design with seven treatments, *viz.* T_1 - Pyrazosulfuron-ethyl 10.5 g/ha, T_2 - Pyrazosulfuron-ethyl 21.0 g/ha, T_3 - Pyrazosulfuron-ethyl 31.5 g/ha, T_4 - Pyrazosulfuron-ethyl 42.0 g/ha, T_5 - Standard herbicide, Metsufuron methyl + chlorimuron ethyl (Almix 20% WP) 4.0 g/ha, T_6 - Hand weeding at 15 and 30 DAT and T_7 - Untreated check and replicated thrice. The sown rice variety was *'IET 4786 (Shatabdi)'* of 123 days duration. The crop was transplanted during 1st week of August at a spacing of 20 × 15 cm and harvested during 2nd week of October in both the years. Full doses of phosphorus through single super phosphate (SSP) and potash through muriate of potash (MOP) each 30 kg/ha along with 25% recommended doses of nitrogen (60 kg/ha) through urea were applied at basal during the final land preparation. Remaining 75% nitrogen was applied

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through urea in three equal splits at 25, 45 and 65 DAT. The test herbicide pyrazosulfuron-ethyl at 4 different doses along with standard herbicide metsufuron methyl + chlorimuron ethyl were sprayed at early post-emergence stage (3 DAT) with the spray volume of 500 l/ha using knapsack sprayer with flat fan nozzle under few cm standing water. In treated plots, water level was maintained static as far as possible. Excluding the weed management practice, all others cultural practices were uniformly applied to all the treatments.

An area of 0.25 m^2 was selected randomly at two spots by throwing a quadrat of 0.5 × 0.5 m, weed species were counted from that area and density was expressed in number per m^2. The collected weeds were first sun-dried and then kept in an electric oven at 70^0C till the weight became constant and weed biomass was expressed as g/m^2. As wide variation existed in data, number and biomass of weeds were transformed through square-root ($\sqrt{(X+0.5)}$) method before analysis of variance. Comparison of treatment means for significance at 5% level was done using the critical differences as suggested by Gomez and Gomez (1984). Data on grain yield were recorded from the net plot. Weed control efficiency (WCE) and weed index (WI) were worked out using the formula as suggested by (Mani *et al.* 1973, Gill and Vijayakumar 1969).

RESULTS AND DISCUSSION

Effect on weeds

In the experimental plots, the dominant weeds were *Echinochloa* spp. (*E. colona, E. crusgalli*), *Leersia hexandra, Cyperus difformis, Cyperus iria, Fimbristylis dichotoma, Monochoria vaginalis, Ammania baccifera, Eclipta alba, Marsilea quadrifolia* and *Alternanthera philoxeroides*. All the herbicides showed effective control of all categories of dominant weeds resulting in less weed dry matter and higher weed control efficiency as compared to untreated check (Table 1). The number of dominant broad-leaved, grass and sedge weeds was gradually decreased with the increase of doses of tested herbicide pyrazosulfuron-ethyl in all the four dates of observation. Better weed control was observed with application of maximum dose of the tested herbicide. Lowest weed biomass at 45 days after herbicide application (DAHA) was recorded with pyrazosulfuron-ethyl at 42.0 g/ha. Angiras and Kumar (2005) also found that broadcast application of pyrazosulfuron-ethyl at 15 g/ha mixed with sand at 150 kg/ha was effective to control weeds in rice which re-

Table 1. Density (no./m^2) of dominant weeds as affected by different weed control treatments (mean data of two years) at different days after herbicide application (DAHA)

Treatment	*Echinochloa colona*				*Cyperus difformis*				*Ammania baccifera*			
	10	20	30	40	10	20	30	40	10	20	30	40
T_1	0.96	1.50	3.42	4.10	1.00	1.35	3.21	3.72	0.92	1.46	2.70	3.34
T_2	0.92	1.64	3.25	3.80	0.90	1.20	2.60	2.95	0.85	1.40	2.56	3.30
T_3	0.75	1.00	2.45	3.00	0.81	0.99	2.55	2.60	0.34	0.75	1.16	2.51
T_4	0.31	0.92	1.31	2.51	0.40	0.67	1.00	1.31	0.35	0.41	0.95	1.00
T_5	0.25	0.56	1.12	1.31	0.34	0.72	1.20	1.81	0.26	0.86	0.91	2.64
T_6	0.92	0.62	1.31	1.25	0.32	0.65	0.92	1.54	0.31	0.41	0.80	1.00
T_7	1.25	2.69	6.00	6.61	1.31	2.51	4.10	6.00	1.64	2.11	4.42	6.01
LSD (P=0.05)	0.56	0.75	1.80	1.91	0.43	0.80	1.05	1.70	0.71	0.82	2.25	1.80
	Ludwigia octovalvis				*Monochoria vaginalis*				Others			
	10	20	30	40	10	20	30	40	10	20	30	40
T_1	0.62	1.61	1.85	3.61	1.25	1.66	3.96	4.10	1.00	1.72	3.30	4.00
T_2	0.72	1.29	2.20	2.99	0.99	1.42	2.95	3/84	1.20	2.00	3.24	4.90
T_3	0.62	0.92	1.95	2.40	0.69	1.29	2.02	3.45	1.13	1.70	3.00	4.80
T_4	0.49	0.62	1.25	1.60	0.40	0.77	1.34	1.82	0.44	1.15	1.18	3.00
T_5	0.46	0.66	1.26	1.62	0.64	0.73	1.75	1.66	0.62	1.26	1.72	3.11
T_6	0.44	0.71	1.03	1.50	0.58	0.75	1.00	1.52	0.21	0.92	0.45	2.51
T_7	1.82	2.45	5.45	6.11	2.11	2.69	5.63	7.00	2.31	2.10	4.90	5.00
LSD (P=0.05)	0.36	0.72	0.99	1.82	0.92	1.02	2.05	2.89	0.73	0.99	2.25	1.85

T_1 - Pyrazosulfuron-ethyl 10.5 g/ha, T_2 - Pyrazosulfuron-ethyl 21.0 g/ha, T_3 - Pyrazosulfuron-ethyl 31.5 g/ha, T_4 - Pyrazosulfuron-ethyl 42.0 g/ha, T_5 - Standard herbicide, Metsufuron-methyl + chlorimuron-ethyl (almix 20% WP) 4.0 g/ha, T_6 - Hand weeding at 15 and 30 DAT and T_7 - Untreated check, DAT - Days after transplanting

Table 2. Weed biomass and weed control efficiency at 40 days after herbicide application (DAHA) in rice field as affected by different weed control treatments (mean data of two years)

Treatment	*Echinochloa colona*		*Cyperus difformis*		*Ammania baccifera*		*Ludwigia octovalvis*		*Monochoria vaginalis*		Others	
	Weed biomass (g/m^2)	WCE (%)	Weed biomass (g/m^2)	WCE (%)	Weed biomass (g/m^2)	WCE (%)	Weed biomass (g/m^2)	WCE (%)	Weed biomass (g/m^2)	WCE (%)	Weed biomass (g/m^2)	WCE (%)
T_1	8.25	34.5	7.20	40.3	6.61	49.1	7.20	43.1	8.00	46.0	8.26	22.2
T_2	7.50	40.5	6.20	49.4	5.61	56.8	6.11	51.7	7.26	51.0	7.00	34.1
T_3	6.11	51.5	5.26	57.1	5.00	61.5	5.20	58.9	6.25	57.8	6.61	37.8
T_4	5.00	60.3	3.99	675	2.62	79.8	3.31	73.8	4.00	73.0	6.42	39.5
T_5	4.61	63.4	3.64	70.3	4.11	68.4	3.30	73.9	3.21	78.3	6.00	43.5
T_6	2.49	80.2	3.01	75.4	2.00	84.6	3.00	76.3	3.04	79.5	4.61	56.6
T_7	12.61	0	12.26	0	13.00	0	12.65	0	14.82	0	10.62	0
LSD (P=0.05)	2.81	-	3.10	-	3.11	-	3.20	-	3.45	-	3.42	-

Treatment details are given in Table 1

sulted in significantly lower weed density and biomass without any phytotoxic effect on rice plant. Pyrazosulfuron-ethyl at 20 and 25 g/ha significantly reduced weed density and total weed biomass of *Cyperus iria, Echinochloa colona etc.* when applied at 3 to 10 days after transplanting (Chopra and Chopra 2003). None of tested doses was phytotoxic to transplanted rice when applied alone. Weed control efficiency (WCE) with respect to grass, sedge and broad-leaved weeds (56.60 to 84.62%) was higher with hand weeding treatment (Table 2). Pyrazosulfuron-ethyl gave higher weed control efficiency (39.55 to 79.85%) when applied at 3 DAT with higher dose *i.e.* 42 g/ha. It was closely followed by the standard herbicide metsufuron-methyl + chlorimuron-ethyl 4.0 g/ha at 3 DAT (43.50 to 78.34%). Overall result showed that the tested herbicide pyrazosulfuron-ethyl was comparatively more effective against broad-leaved weeds than grassy and sedge weeds.

Effect on crop

The highest rice grain yield (3.7 t/ha) was recorded in hand weeded plot which was statistically at par with pyrazosulfuron-ethyl applied 42.0 g/ha (3.3 t/ha). The increase in grain yield under this treatment was due to less weed density and weed biomass as compared to all other treatments tried in this study. Lowest grain yield of rice was observed in untreated check (2.1 t/ha) which was due to high weed density and biomass (Table 3). Pyrazosulfuron-ethyl at 20 and 25 g/ha provided grain yield statistically similar to weed free treatment (Chopra and Chopra 2003). Harvest index of paddy crop was higher under hand weeding treatment (53.7%) which was comparable with the treatment having application of pyrazosulfuron-ethyl 70% WG applied at 42.0 g/ha (52.6%). The weed index was also minimum (10.81%) in this treatment. No residual effect of tested herbicide in soil was observed after the harvest of rice crop.

Table 3. Grain yield, harvest index and weed index as affected by different weed control treatments (mean data of two years)

Treatment	Grain yield (t/ha)	Harvest Index (%)	Weed Index (%)
T_1	2.6	45.6	29.73
T_2	2.9	52.2	21.62
T_3	3.1	51.4	16.22
T_4	3.3	52.6	10.81
T_5	2.7	50.0	27.03
T_6	3.7	53.7	0
T_7	2.1	40.8	43.24
LSD (P=0.05)	0.51	-	-

Treatment details are given in Table 1

It is, therefore, recommended that pyrazosulfuron-ethyl 42.0 g/ha can safely be used for controlling all three categories of weeds in transplanted rice in *Kharif* as well as to get higher yield of rice in West Bengal condition.

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Bioefficacy of herbicides in relation to sowing methods in wheat

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ABSTRACT

A field experiment was conducted at Ludhiana during 2009-10 and 2010-11, study the effect of sowing methods and herbicides on weed dynamics and productivity of wheat (*Triticum aestivum* L.). Sowing methods, *viz*. bed planting, zero till, conventional till and stubbled sowing did not influence densities and dry matter accumulation of narrow- and broad-leaved weeds. Averaged over two seasons, bed planting, zero till and conventional till sowing methods recorded similar wheat grain yield and were statistically superior to stubbed sowing. Wheat grain yield under bed planting, zero till and conventional till methods was 25.4, 46.2 and 40.8% higher as compared to stubbled sowing. Among weed control, post-emergence application of carfentrazone + sulfosulfuron 45 g, metsulfuron + sulfosulfuron 30 g and fenoxaprop-p-ethyl + metribuzin 275 g/ha recorded complete control of all the narrow- and broad-leaved weeds. Mesosulfuron + iodosulfuron 12 g, sulfosulfuron 25 g, pinoxaden 50 g and clodinafop 60 g/ha recorded effective control of narrow-leaved weeds only. All these herbicidal treatments, except fenoxaprop-p-ethyl + metribuzin 275 g/ha, recorded significantly higher wheat grain yield as compared to unsprayed control. Fenoxaprop-p-ethyl + metribuzin was phototoxic to wheat plants and wheat grain yield was at par to weedy check.

Key words: Chemical control, Herbicides, Tillage, Weed dynamics, Wheat

Wheat is the most widely grown winter cereal and is the backbone of food security in India. The productivity and economic gains of wheat are reducing consistently. Excessive tillage and soil degradation limit the wheat productivity particularly under rice-wheat cropping system (Hobbs *et al*. 1997). Severe weed infestation is another formidable factor (Pandey *et al.* 2006). Yield reduction due to weeds in wheat vary from 15-50%, depending upon the weed density and type of weed flora (Jat *et al*. 2003). Selective herbicides effectively control weeds in wheat. However, continuous use of same herbicide or herbicide having similar mode of action results in weed flora shifts and evolution of resistance in weeds. Thus, their judicious use is important for getting long-term benefits. In this context, integrated use of herbicides with other weed control tools may help in solving the problems of weed shift and herbicide resistance. Tillage and establishment method are effective tools which, if used in integration with herbicides, can help in diverting the competition in favour of wheat.

Zero tillage (ZT) technology in wheat has already proven its worth in the rice-wheat cropping system and is being followed on nearly 2.1 million ha area of Indo-Gangetic plains of India (Yadav *et al.* 2009). It saves time and energy. Zero till seeding with Happy Seeder machine combines the stubble mulching and seed drilling functions into one machine and suppresses the weeds. The raised bed planting of wheat permits use of mechanical hoeing with tractor and encounters lesser population and dry weight of weeds as compared to conventionally flat sown wheat (Dhillon *et al*. 2005). Altering tillage practices change, weed seed depth in the soil which play a major role in weed species shifts and affects the efficacy of control practice. Hence, the current study was undertaken to find out the effect of tillage and herbicides on weed dynamics and productivity of wheat in rice-wheat system.

MATERIALS AND METHODS

A field experiment was conducted at Punjab Agricultural University, Ludhiana during *Rabi* 2009-10 and 2010-11. The experiment field was sandy loam, normal in reaction and low in organic carbon (0.31%), low in available N (225.8 kg/ha) and medium in available P (16.9 kg/ha) and K (128.9 kg/ha). The experiment was laid out in a split-plot design with sowing methods in main plot and weed control treatments in subplots. In 2009-10, four methods of sowing (stubbled, zero tillage (ZT), bed sowing (BS) and conventional tillage (CT) and seven weed

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control treatments, *viz.* pinoxaden 50 g, sulfosulfuron + metsulfuron 30 g + surfactant, mesosulfuron + iodosulfuron 12 g + surfactant, sulfosulfuron 25 g + surfactant, fenoxaprop-p-ethyl + metribuzin 275 g, carfentrazone + sulfosulfuron 45 g/ha + surfactant and unsprayed control were evaluated. In 2010-11, three methods of sowing (stubbled, ZT and CT) and six weed control treatments, *viz.* sulfosulfuron 25 g + surfactant, clodinafop 60 g, sulfosulfuron + metsulfuron 30 g + surfactant, mesosulfuron + iodosulfuron 12 g + surfactant, fenoxaprop-p-ethyl + metribuzin 275 g, carfentrazone + sulfosulfuron 45 g/ha + surfactant and unsprayed control were evaluated. Wheat cv '*PBW 550*' was seeded on 26 November 2009 and 30 November 2010 with tractor drawn wheat seeding drills as per treatment using 100 kg seed/ha. Recommended doses of N (125 kg/ha), P (27.5 kg P_2O_5/ha) and K (25 kg K_2O/ha) were applied through urea, diammonium phosphate and muriate of potash, respectively. Whole of phosphorous and potassium and half of N were applied at sowing and remaining N was applied with first irrigation. The wheat crop was sown after raising non-experimental crop of rice by managing rice straw for stubbled sowing treatments. Sowing of wheat in standing stubbles was done with 'Happy-seeder'. In zero tillage, the crop was directly sown in the field with zero-till drill. In bed planting, the field was prepared as per conventional tillage technique followed by preparation of beds with bed planter which were 67.5 cm wide (37.5 cm bed top and 30 cm furrow) and sowing of wheat was done in two rows 20 cm apart on the bed top. Ordinary drill was used for sowing of wheat in CT treatment. Herbicides were applied as post-emergence (after first irrigation) 30 days after sowing at their respective doses as per treatment. Spraying was done with the help of knapsack sprayer fitted with flat-fan nozzle using 250 liter of water/ha. Population and dry matter of both narrow- and broad-leaved weeds was taken from a quadrate measuring 30 x 30 cm, at harvest. Weed data were subjected to square root transformation before statistical analysis.

RESULTS AND DISCUSSION

Weed

Weed flora varied in both seasons. In 2009-10, narrow-leaved weeds and in 2010-11 broad-leaved weeds dominated. *Phalaris minor* (55%), *Avena ludoviciana* (5%) among grasses and *Chenopodium album,* (12%), *Medicago denticulata* (11%), *Rumex dentatus* (6%), *Trigonella polycerata* (2%), *Melilotus indica/Melilotus alba* (2%), *Rumex spinosus* (1%) and *Anagallis arvensis* (2%) among broad-leaved were major weeds in the experimental field.

Sowing methods did not influence densities and dry matter accumulation of narrow and broad-leaved weeds during both the years (Table 1 and 2). Among weed control treatments, carfentrazone + sulfosulfuron 45 g, metsulfuron + sulfosulfruon 30 g and fenoxaprop-p-ethyl + metribuzin 275 g/ha recorded complete control of all the narrow and broad-leaved weeds during both the years. Weed control efficacy under these treatments varied from 93 to 100%. Mesosulfuron + iodosulfuron 12 g and sulfosulfuron 25 g/ha recorded effective control of narrow-leaved weeds during both the years, however, their performance against broad-leaved weeds was relatively poor during 2009-10. Pinoxaden 50 g and clodinafop 60 g/ha recorded effective control of narrow-leaved weeds only as these are basically grass herbicides. Weed control efficacy varied from 58 to 63%.

Crop

During 2009-10, wheat plants planted on bed, recorded significantly longer panicles as compared to stubbled sowing. ZT and CT were also at par with bed planting (Table 1 and 2). During 2010-11, ZT recorded taller plants having longer panicles and higher number of effective tillers and was statistically better over stubbled sowing method. Among weed control treatments, all the herbicidal treatments except fenoxaprop-p-ethyl + metribuzin 275 g/ha recorded significantly taller plants as compared to unsprayed control. Fenoxaprop-p-ethyl + metribuzin was phytotoxic to wheat plants and reduced the plant height during both the years though the crop recovered after 25 days, the effective tillers were significantly reduced even as compared to unsprayed control during 2010-11. Carfentrazone + sulfosulfuron 45 g, metsulfuron + sulfosulfuron 30 g and mesosulfuron + iodosulfuron 12 g/ha recorded significantly taller plants having longer panicles during both the years as compared to unsprayed control. The effective tillers were significantly lower under pinoxaden 50 g and clodinafop 60 g and sulfosulfuron 25 g/ha as compared to the above treatments. Toxicity of metribuzin on wheat plants particularly at higher doses had been reported earlier (Pandey *et al.* 2002, Singh *et al.* 2004).

Averaged over two years, bed planting, zero till and conventional till sowing method recorded similar wheat grain yield and were statistically superior to stubbed sowing method. Wheat grain yield under bed planting, ZT and CT were 25.4, 46.2 and 40.8% higher as compared to stubbled sowing method (Table 1 and 2). All the herbicides, except fenoxaprop-p-ethyl + metribuzin 275 g/ha, during 2010-11 gave significantly higher grain yield as

Table 1. Effect of sowing method and weed control on weed dry matter, growth and grain yield of wheat during 2009-10

Treatment	Dose (g/ha)	Effect on weeds					Effect on crop			
		PNW	PBW	DNW	DBW	WCE	PH	ET	PL	GY
Sowing method										
Stubbled	-	1.14 (0.35)	1.07 (0.15)	149.2	123.2	-	55.2	37.5	9.1	3.23
Zero tillage (ZT)	-	1.14 (0.33)	1.07 (0.15)	161.2	121.0	-	56.2	46.3	9.3	3.78
Bed planting (BP)	-	1.07 (0.17)	1.09 (0.18)	132.5	125.4	-	58.8	56.3	9.5	4.05
Conventional tillage (CT)	-	1.10 (0.24)	1.09 (0.22)	139.2	125.4	-	54.6	48.5	9.4	3.47
LSD (P=0.05)	-	NS	NS	NS	NS	-	NS	NS	0.3	0.59
Weed control										
Pinoxaden	50	1.26 (0.61)	1.23 (0.50)	201.6	169.5	51.0	56.3	44.2	8.7	3.55
Sulfosulfuron + metsulfuron	30	1.00 (0.00)	1.00 (0.00)	0	0	100.0	57.3	48.8	9.8	3.94
Mesosulfuron + iodosulfuron	12	1.09 (0.21)	1.00 (0.00)	127.6	0	89.2	57.4	51.6	9.2	3.71
Sulfosulfuron	25	1.06 (0.15)	1.00 (0.00)	117.8	0	93.9	58.1	48	9.8	3.86
Fenoxaprop-p-ethyl + metribuzin	275	1.05 (0.13)	1.00 (0.00)	116.6	0	94.7	54.8	47.7	9.7	3.68
Carfentrazone + sulfosulfuron	45	1.02 (0.05)	1.00 (0.00)	108.1	0	97.5	57.5	50.5	9.8	4.09
Unsprayed control	-	1.40 (0.96)	1.33 (0.77)	334.9	219.0	-	51.9	35.5	7.8	2.46
LSD (P=0.05)	-	0.08	0.03	23.4	25.0	-	2.9	6	0.4	0.44

*Values given in parentheses are original values

PNW - Population of narrow-leaved weeds (no./m^2), PBW - Population of broad-leaved weeds (no./m^2), DNW - Dry matter of narrow-leaved weeds (kg/ha), DBW - Dry matter of broad-leaved weeds (kg/ha), WCE - Weed control efficiency (%), PH - Plant height (cm), ET - Effective Tillers (no./mrl), PL - Panicle length (cm), GY - Grain yield (t/ha)

Table 2. Effect of sowing method and weed control on weed dry matter, growth and grain yield of wheat during 2010-11

Treatment	Weeds					Wheat			
	PNW	PBW	DNW	DBW	WE	PH	ET	PL	GY
Sowing method									
Conventional tillage (CT)	1.5 (2.9)	2.2 (7.9)	58.0	127.0	-	65.9	55.8	10.0	3.45
Zero tillage (ZT)	1.7 (3.7)	3.2 (15.7)	74.1	251.5	-	65.9	58.2	10.2	3.55
Stubbled	1.8 (4.6)	3.5 (20.8)	93.3	333.3	-	59.4	44.4	9.8	2.43
LSD (p=0.05)	NS	NS	NS	NS	-	3.1	4.0	0.3	0.37
Weed control									
Sulfosulfuron	1.0 (0.0)	3.6 (15.4)	0	247.1	76.4	65.7	56.4	10.2	3.50
Clodinafop	1.4 (2.5)	4.3 (24.3)	49.2	389.2	58.2	65.9	49.1	10.1	3.38
Sulfosulfuron + metsulfuron	1.0 (0.0)	1.0 (0.0)	0	0	100.0	66.7	60.7	10.3	3.63
Mesosulfuron + iodosulfuron	1.9 (4.9)	2.6 (14.6)	99.5	234.1	68.2	63.2	59.4	9.8	3.41
Fenoxaprop-p-ethyl + metribuzin	1.0 (0.0)	1.0 (0.0)	0	0	100.0	52.3	36.9	9.4	2.19
Carfentrazone + sulfosulfuron	1.0 (0.0)	1.8 (7.3)	0	117.3	88.8	68.9	62.7	10.4	3.72
Unsprayed control	4.4 (18.8)	6.4 (42.0)	376.6	672.3	-	63.3	44.3	9.9	2.17
LSD (P=0.05)	0.9	2.1	132.0	273.0	-	4.7	5.1	0.5	0.54

*Original values are in parentheses

compared to unsprayed control. Averaged over two years, the increase in wheat grain yield with herbicides varied from 80.2 to 59.9% as compared to unsprayed plot. Effective control of narrow and broad-leaved weeds with herbicides increased the number of effective tillers and the wheat plant produced longer panicles and the wheat yield increased. Though fenoxaprop + metribuzin recorded complete control of all the weeds during both the years, its phototoxicity to wheat plants reduced the grain yield. Higher broad-leaved weed pressure reduced the wheat grain yield in pinoxaden treatment. Efficacy of above herbicides in wheat crop has been reported earlier (Dhillon *et al*. 2005, Singh 2007). The interaction effects between methods of sowing and weed control treatments for grain yield were non-significant. The lower wheat grain yields during both the years were attributed to late sowing and attack of yellow rust.

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Little seed canary grass resistance to sulfonyl–urea herbicides and its possible management with pendimethalin

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ABSTRACT

In this study, response of 20 *Phalaris minor* Retz. (little seed canary grass) populations against sulfosulfuron and its ready–mix formulation sulfosulfuron + metsulfuron and mesosulfuron + iodosulfuron was studied. Out of 20 populations, 12 showed high resistance, 8 showed medium resitance and none were susceptible to sulfosulfuron (25 g/ha). GR_{50} value was in the range of 30-110 g/ha in *P. minor* populations tested. In wheat, it was more than 200 g/ha. Eleven populations showed resistance to ready mix formulation of sulfosulfuron + metsulfuron, 8 populations were medium R/medium S and one population was susceptible. Similarly, 11 showed resistance to ready mix formulation of mesosulfuron + iodosulfuron, 7 populations were medium R/medium S and one biotype was susceptible. GR_{50} values tested were in the range of 30-110 g/ha in contrast to 5 g/ha at the time of recommendation.

Key words: Pendimethalin, Resistance, *Phalaris minor*, Sulfosulfuron, Sulfosulfuron + metsulfurn, mesosulfuron + iodosulfuron

Phalaris minor Retz (little seed canary grass) is a major weed of wheat crop in northern part of India. The crop suffers a yield loss of 25-30% due to infestation of this weed (Malik and Singh 1995) and it is very difficult to distinguish it from wheat plant in its early growth stages. The weed evolved insensitivity to isoproturon–a urea herbicide after its continuous use for over 15 years (Malik and Singh 1995, Walia *et al*. 1997. Alternative herbicides belonging to group I [(acetyl co-A carboxylase (ACCase) inhibitors] and group II [acetolactate synthase (ALS) inhibitors] were recommended for its management in 1997-98 (Yadav *et al.* 1995, 1997; Brar *et al.* 1999). While the impact of ACCase inhibiting herbicides has been evaluated in an earlier investigation (Dhawan *et al*. 2010), this study was carried out with the objective to evaluate the effect of sulfosulfuron singly, as a ready–mix formulation with another herbicide metsulfuron (Total), and a ready–mix formulation of sulfonylurea herbicides, *viz.* mesosulfuron + iodosulfuron–methyl sodium (Atlantis). Efficacy of pendimethalin belonging to group III herbicides with different mode of action (microtubule assembly inhibitors) was evaluated with a view to develop management options for ALS resistant populations of *P. minor*.

MATERIALS AND METHODS

Seeds of 20 populations of *P. minor* were collected randomly from cropped fields at different locations of Haryana (with and without history of herbicide resistance) in April 2010. Seeds were sown by November end during both the years in sandy loam soil in earthen pots (9" dia). Five plants were maintained in four replications for each population. Sulfosulfuron (25 g/ha), ready–mix formulation of mesosulfuron + iodosulfuron (32 g/ha) and ready mix formulation of mesosulfuron + iodosulfuron (14.4 and 28.8 g/ha) were sprayed at 2-3 leaf stage *i.e.* 30-35 days after sowing (DAS) with a knapsack sprayer using flat fan nozzle with a spray volume of 500 ml for spray based on 5 x 2 m area in a randomized block design. The plants that remained unsprayed with herbicide served as control. Observations were recorded on 30 DAS on weed mortality. Percentage mortality was calculated by the formula; no. of plants that survived after 30 days/ no. of plants at the time of spray x 100). The populations that showed mortality in the range of 70-100% were classified as susceptible (S), those that showed mortality in the range of 35-70% were classified as medium susceptible/medium resistant (MS/MR) and those in the range of 0-35% as resistant (R) populations .

In another experiment, six selected populations (Table 2) of *P. minor* along with wheat variety '*WH 711*' were tested for GR_{50} values against sulfosulfuron and ready mix formulation of mesosulfuron + iodosulfuron. Seedlings were raised in the same manner as described above. The dose range of sulfosulfuron sprayed was 0, 12.5, 25, 50 and 100 g/ha and dose range for mesosulfuron +

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iodosulfuron was 0, 7.2, 14.4 and 28.8 g/ha. Observations were recorded at 30 DAS on weed mortality and biomass accumulation. For plotting dose response curves and calculation of GR_{50} values were made as per methodology reported earlier (Dhawan *et al.* 2009).

In yet another experiment, effect of ready mix formulation of mesosulfuron + iodosulfuron (14.4 and 28.8 g/ha) was studied on physiological indicators like photosynthetic pigments, membrane integrity, lipid peroxidation, proline content and activity of antioxidant enzymes in six selected populations and wheat variety '*WH 711*'.Seedlings were raised in the same manner as in earlier two experiments. Leaf samples(youngest 2-3 leaves) were collected 10 days after spray of the herbicide. Chlorophyll was extracted by the method of Arnon (1949) using 80% acetone. Membrane stability was assessed by the method of vanStove and Stobbe (1977) as described earlier (Dhawan *et al.* 2010). Free proline was assessed by the method of Bates *et al.* (1973). Acid ninhydrin was prepared by dissolving 1.25 g ninhydrin in 30 ml acetic acid and 20 ml phosophoric acid with continuous stirring until dissolved and stored at room temperature before use. 200 mg of fresh tissue was homogenized in 2 ml of aqueous sulfosalicylic acid in a mortar and centrifuged at 4000 rpm for 20 minutes. The residue was re-extracted with 2 ml of 3% sulfosalicylic acid and centrifuged. The supernatants were combined and volume was made to 10 ml. One ml of this aliquot was transferred in a test tube of 1 ml each of acid- ninhydrin and acetic acid was added. The mixture was heated on a boiling water bath at $100^{O}C$ for one hour after which the reaction was terminated by placing the tubes in ice bath. The reaction mixture was shaken with 2 ml toluene and kept for several hours at room temp. Chromatograph was extracted in toluene phase and O.D. was measured at 520 nm using toluene as blank. Standard curve was prepared with graded doses of DL-proline.

For extraction of enzymes, 500 g leaf tissue was homogenized in 3 ml phosphate buffer 0.8 M pH 7.0) in a pre-chilled glass pestle mortar at $4^{O}C$. This was centrifuged at 10,000 rpm for 30 M. Pellet was discarded and supernatant was used for enzyme assay. Peroxidase was assayed by the method of Plewa *et al.* (1991). Guaiacol oxidation was monitored by reading the absorbance at 470 nm at the moment of enzyme extract addition and 1 minute later. The difference in absorbance (470 nm) was divided by the tetraguaiacol molar extinction co-efficient (25.5 m/M/cm) and the enzyme activity was expressed as mol of H_2O_2 used/min/mg protein. Peroxidase unit was calculated for the formation of 1mM tetraguaiacol for 1 M. The enzyme units were calculated by formulae given by Kokkinakis and Brooks (1999). Catalase was measured by the reduction of potassium dichromate to chromic acid by hydrogen peroxide (Sinha 1972). The reaction mixture containing 0.5 ml of 0.2 M H_2O_2, 0.8 ml of enzyme extract and 0.7 ml of 0.1M phosphate, buffer pH 7.0 was incubated at $37^{O}C$ for 30 M. After that 4.0 ml of dichromate acetic acid reagent (5% potassium dichromate + glacial acetic acid in a ratio of 1:3) was added and mixture heated in a boiling water bath for 10 M and cooled. Green colour of chromic acetate thus formed was measured at 570 nm. One unit of enzyme has been defined as amount of enzyme required to utilize 1 millimole of hydrogen peroxide under assay conditions. The specific activity has been expressed as units/min/mg protein.

To study the effect of pendimethalin, earthen pots (9" dia) filled with soil were sprayed with 0.25, 0.50 and 1.0 kg/ha pendimethalin prior to sowing. The herbicide was mixed thouroughly in the upper soil layer manually to ensure uniformity of appication. Twenty seeds of six *P. minor* populations as indicated in the Table 3 and wheat were sown 24 h after spray in four replicates. Per cent emergence was recorded 30 days after spray. In another experiment Petri-plate assay was conducted. Twenty seeds of *P. minor* populations and wheat were sown in Petri-plates lined with filter paper and soaked in different concentrations of pendimethalin (2.5, 5.0 and 25 g/ha). Number of seeds germinated, hypocotyl length and radical length was recorded after 7 days.

RESULTS AND DISCUSSION

After sulfosulfuron (25 g/ha) spray, mortality was less than 30% in 12 populations which were identified as resistant populations. These were Ambala – Jansui Head, Jind- Majra, Hisar-Nangla, Karnal-Uchana, Karnal-Sagga, Fatehbad-Badi Birthal, Jind-Raseedan, Kurukshetra-Chanarthal, Kurukshetra- Munak, Hisar- HAU farm, Kaithal-Gumthala and Hisar-Lalodha. Eight populations showed mortality in the range of 30-70% and were categorized as medium susceptible/medium resistant (MR/MS) populations. After spray with 32 g/ha sulfosulfuron + metsulfuron, 11 populations were found to be resistant, 8 populations MR/MS and one population from Hisar – Nangla was found to be susceptible. Similarly, after spray with 14.4 g/ha mesosulfuron + iodosulfuron, 12 populations were found to be resistant, 7 MS/MR and one population from Jind-Pipaltha was found to be susceptible to Atlantis (Table 1). GR_{50} values were higher than the recommended dose of sulfosulfuron *i.e.* 25 g/ha in all populations. These were in the range of 30-50 g/ha in populations from Karnal-Uchana, Kurukshetra-Neemwali, Kurukshetra-Chanarthal, Jind-Raseedan and Jind-Pipaltha. Populations from Karnal-Sagga showed GR_{50} value of 110 g/ha. Wheat showed GR_{50} value more than 200 g/ha. After spray with mesosulfuron + iodosulfuron (28.8 g/ha) per cent mortality increased in all populations and up to 75% in many populations. GR_{50} values for mesosulfuron + iodosulfuron varied between 7.2 to >84. Populations from Uchana and Sagga showed GR_{50} values higher than 84. Populations from Kurukshetra –Neemwali showed a value of 16.2 and those from Jind-Raseedan, Kurukshetra-Chanarthal and Jind-Pipaltha showed GR_{50} values of 7.8. Wheat showed a GR_{50} value of 28 (Table 2).

Table 1. Effect of sulfosulfuron, sulfosulfuron + metsulfuron and mesosulfuron + iodosulfuron on mortality in different *P. minor* populations

Population	Mortality (%) of *P. minor*			
	S	SM	M	MI
Ambala–Jansui Head	15	40	45	60
Ambala–Adumajra	35	30	30	60
Jind–Majra	20	40	45	55
Hisar–Nangla	20	70	25	60
Karnal–Uchana	15	5	40	40
Karnal–Sagga	15	15	25	10
Fatehbad–Badi Birthal	15	45	5	75
Jind–Raseedan	25	15	45	75
Kurukshetra–Chanarthal	25	50	15	75
Jind–Pipaltha	30	50	75	75
Katihal–Thana	30	15	25	55
Kurukshetra–Neemwali	30	0	15	25
Kurukshetra–Munak	25	35	20	75
Rohtak	45	25	60	75
Hisar, HAU–Farm	25	25	30	75
Hisar-Bass	45	20	15	75
Kaithal–Gumthala	15	5	20	75
Hisar–Lalodha	25	20	20	75
Hisar–Vaibhalpur	35	20	20	75
Sirsa, University Farm	30	50	5	75
LSD (P=0.05)	6.9	7.1	10.3	20.5

S - Sulfosulfuron (25 g/ha); SM - Sulfosulfuron + metsulfuron (32 g/ha); M - Mesosulfuron + iodosulfuron (14.4 g/ha); MI - Mesosulfuron + iodosulfuron (28.8 g/ha)

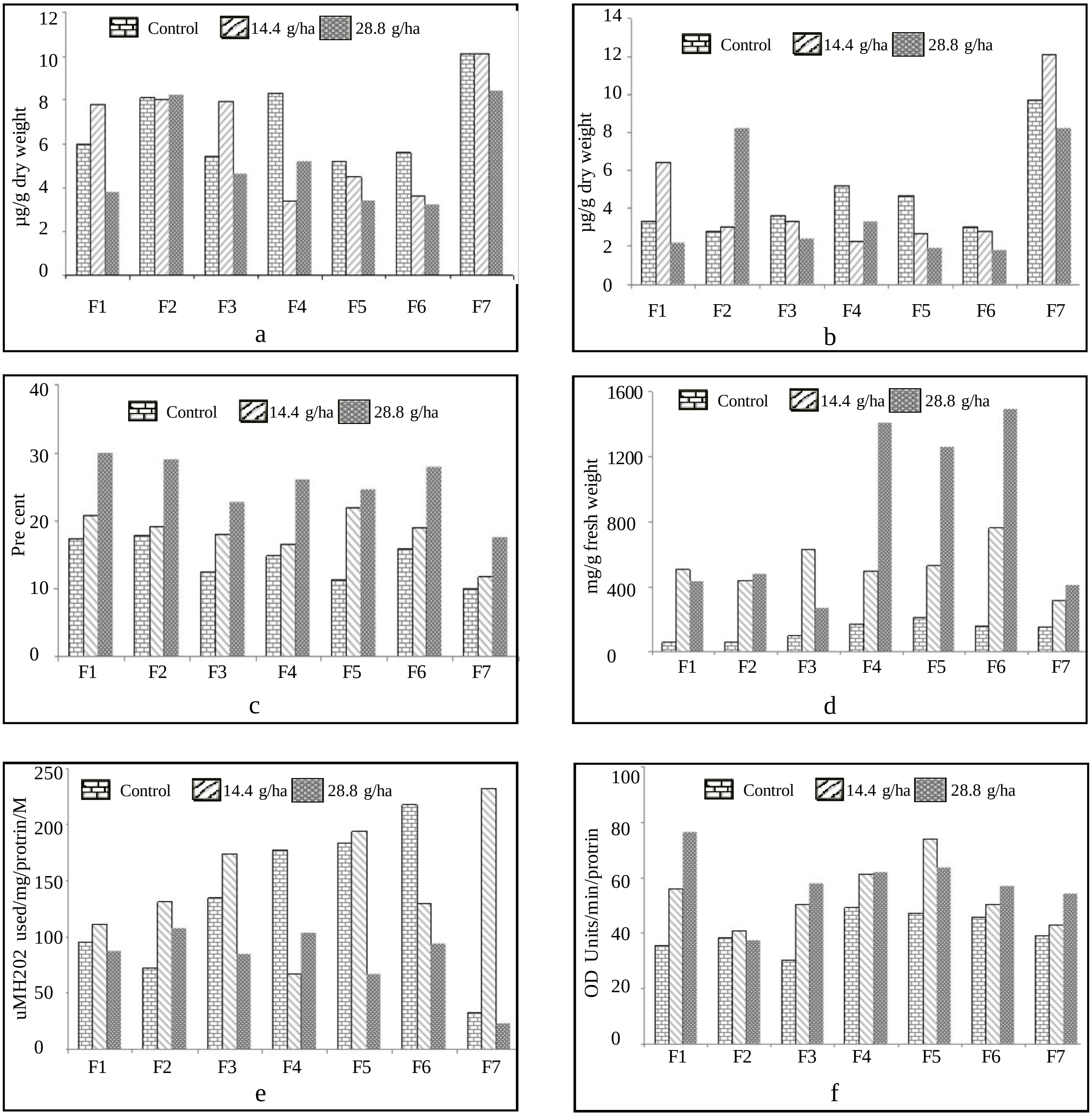
A decline in total chlorophyll content was observed 20 days after spray with 14.4 g/ha mesosulfuron + iodosulfuron in populations from Jind-Raseedan, Jind-Pipaltha and Kurukshetra-Chanarthal. An increase in chlorophyll content was observed in populations from Karnal-Uchana and Kurukshetra-Neemwali of *P. minor*. No decline was observed in populations from Karnal-Sagga and wheat. At 28.8 g/ha further decline was observed in all populations except Karnal-Sagga and Jind Raseedan (Fig. 1a). A decline in carotenoid content was also observed 20 DAS with mesosulfuron + iodosulfuron (14.4 g/ha) in populations from Jind-Raseedan and Kurukshetra-Chanarthal. A less or no decline was observed in populations from Karnal-Sagga, Kurukshetra-Neemwali and Jind-Pipaltha of *P. minor*. An increase in carotenoid content was observed with mesosulfuron + iodosulfuron (14.4g/ha) in *P. minor* population from Karnal-Uchana and wheat. After spray with 28.8 g/ha mesosulfuron + iodosulfuron carotenoid content declined in all populations except Karnal-Sagga where it showed an increase at this dose (Fig. 1b).

The ion efflux increased in all populations after spray with 14.4 g/ha of mesosulfuron + iodosulfuron. The increase being highest in Kurukshetra-Chanarthal and least

Table 2. Effect of sulfosulfuron and mesosulfuron + iodosulfuron on GR_{50} values of different *P. minor* populations

Population	GR_{50} value (g/ha)	Regression equation $Y= (a+bx+cx^2)$	R^2
Sulfosulfuron			
F_1	100	$Y= 87 + 32x-11x^2$	0.69
F_2	100	$Y= 83 + 24x-8.2x^2$	0.99
F_3	55	$Y= 127 - 17x-2.5x^2$	0.82
F_4	80	$Y= 42.2 + 105x-27.5x^2$	0.49
F_5	80	$Y= 75 + 64x-18.4x^2$	0.35
F_6	75	$Y= 104 + 8x-6.3x^2$	0.74
F_7	>200	$Y= 121 - 37x+6.9x^2$	0.13
Mesosulfuron + iodosulfuron			
F_1	>84	$Y= 134 - 40x + 5.9x^2$	1
F_2	>84	$Y= 159 -77x +17.8x^2$	1
F_3	16.2	$Y= 161 - 70x + 9.3x^2$	1
F_4	7.2	$Y= 260 - 199x + 39.8x^2$	1
F_5	7.2	$Y= 282 - 227x + 47.5x^2$	1
F_6	7.2	$Y= 271 -217x - 47x^2$	1
F_7	28.8	$Y= 54 +150x -43.6x^2$	1

F_1 - Karnal-Uchana; F_2 - Karnal-Sagga; F_3 - Kurukshetra-Neemwali; F_4 - Jind -Raseedan; F_5 - Kurukshetra-Chanarthal; F_6 - Jind-Pipaltha; F_7 - Wheat



F1 = Karnal-Uchana, F2 = Karnal-Sagga, F3 = Kurukshetra-Neemwali, F4 = Jind -Raseedan, F5 = Kurukshetra-Chanarthal, F6 = Jind-Pipaltha, F7 = Wheat

LSD (P=0.05) - Population x herbicide - total chlorophyll =1.105; carotenoid content =1.035; ion efflux=5.8; proline=123; catalase 4.4; peroxidase=8.4

Fig. 1. Effect of mesosulfuron + iodosulfuron on total chlorophyll content (a), carotenoid content (b), ion efflux(c), proline content (d) ,catalase(e) and peroxidase(f) activities

in Karnal-Sagga and wheat. This increased further after spray with 28.8 g/ha mesosulfuron + iodosulfuron (Fig. 1c). An increase in proline content was observed in all populations of *P. minor* and wheat after spray with 14.4 g/ha mesosulfuron + iodosulfuron. At 28.8 g/ha, the increase was more in populations from Jind-Raseedan, Kurukshetra-Chanarthal and Jind-Pipaltha(Fig. 1d). Catalase activity increased after spray with 14.4 g/ha mesosulfuron + iodosulfuron in populations from Karnal-Uchana, Karnal-Sagga, Kurukshetra-Neemwali. In wheat it increased to much higher levels than the *P. minor* populations. A decline in catalase activity was observed in populations from Jind Raseedan and Jind-Pipaltha. At 28.8 g/ha a further decline in catalase activity was observed in all populations (Fig. 1e). Peroxidase activity increased in all populations of *P. minor* and wheat after spray with 14.4 g/ha mesosulfuron + iodosulfuron. The enzyme activity increased with increasing dose to 28.8 g/ha except for Karnal-Sagga where it did not show this change and in Kurukshetra-Chanarthal where it declined at this dose (Fig. 1f).

None of the populations was susceptible to sulfosulfuron. All the populations tested were either resistant or medium resistant to the herbicide. GR_{50} values (herbicide dose required for 50% reduction of the growth) were in the range of 30-110 g/ha, well above the recommended dose of the herbicide. The population from Karnal-Sagga showed highest value of 110 g/ha. It is pertinent to note here that GR_{50} values of sulfosulfuron against *P. minor* populations at the time of recommendation of the herbicide was 5 g/ha (Yadav and Malik 2005). A test of other sulfonyl urea herbicides, *viz.* (sulfosulfuron + metsulfuron) and (mesosulfuron + iodosulfuron) showed similar response with most of the populations being either resistant or medium resistant to these herbicides. Brar and Walia (2009) reported significant decline in *P. minor* density after spray with mesosulfuron + iodosulfuron. Singh *et al.* (2010a) however, reported lower efficacy of mesosulfuron + iodosulfuron on some *P. minor* populations. Data on chlorophyll content after spray with 14.4 g/ha mesosulfuron + iodosulfuron indicated a decline in the 3 medium resistant populations, *viz.* Jind–Raseedan, Jind-Pipaltha and Kurukshetra-Chanarthal but an increase in the resistant populations, *viz.* Karnal-chana, Karnal-Sagga and Kurukshetra-Neemwali. No change was observed in wheat. A decline in chlorophyll content after spray with isoproturon has earlier been reported in *P.minor* in susceptible populations. A further decline was observed with a higher dose of mesosulfuron + iodosulfuron in all populations except Karnal-Sagga which is highly resistant. Carotenoid content increased in resistant population from Karnal-Uchana and wheat after spray with 14.4 g/ha with mesosulfuron + iodosulfuron. In resistant population from Karnal–Sagga it increased after spray with 28.8 g/ha mesosulfuron + iodosulfuron. Wheat showed the highest carotenoid content at 14.4 g/ha and same as *P. minor* population from Karnal-Sagga at 28.8 g/ha. The content of photosynthetic pigments provides clues for their impact on biomass accumulation (Singh *et al.* 2010b). Carotenoids in addition to their role as accessory pigments for photosynthesis are also known to act as photoprotective agents against reactive enzyme species (ROS) produced as a result of stress.

As a result of herbicide spray due to stress effects, free radicals and other active derivatives of oxygen are produced. These reduced oxygen species such as hydrogen peroxide (H_2O_2), O_2 and OH radicals inactivate enzymes and damage cellular components. Singlet oxygen produced through the triplet state of chlorophyll is highly destructive. This oxygen species initiates lipid peroxidation which results in membrane destruction and increase in membrane permeability. Data on ion efflux after spray with mesosulfuron + iodosulfuron indicates a progressive increase in permeability with increase in dose of the herbicide. The ion efflux in wheat was relatively lesser at all doses as compared to *P. minor* populations. This indicates lesser damage in wheat as compared to the *P. minor* populations. Accumulation of proline in response to various stresses has been reported in a number of plant species under water and salt stress (Hsiao 1973, Waldren and Tuare 1974) , in cold treated plants (Tantau and Dorfling 1991), as part of plant's defense reaction against abiotic and biotic stresses (Reddy and Veeragnjaneygulu 1991). It is also seen to accumulate in response to stresses caused by herbicides (Toteva *et al.* 2004). In the present investigation proline levels increased in all the populations after spray with mesosulfuron + iodosulfuron. The level remained higher in medium resistant populations as compared to the resistant ones at both the lower and higher doses. The high concentration of proline corresponds to its osmotic role but other functions including radical detoxification and regulation of cellular redox status have also been suggested (Hare and Cress 1997). Enzymes like peroxidase and catalase have antioxidant functions in crops as well as weeds after spray with herbicides (Pan *et al.* 2008). In the present investigation catalase activity increased in wheat as also in populations from Karnal-Uchana, Karnal-Sagga, Kurukshetra-Neemwali and Kurukshetra-Chanarthal. Peroxidase activity increased in all populations except one from Karnal-Sagga. Studies on

Table 3. Effect of pre-emergence application of pendimethalin in pot-culture on per cent emergence and plant height of different *P. minor* populations and wheat at 30 days after seeding

Population	Pendimethalin (kg/ha)			
	0	0.25	0.50	1.0
Emergence (%)				
F_1	52.5	7.5	0	0
F_2	50	12.5	2.5	0
F_3	52.5	15	0	0
F_4	62.5	5	0	0
F_5	55	17.5	0	0
F_6	50	10	0	0
F_7	65	67.5	57.5	22.5
Plant height (cm)				
F_1	31.2	3.7	0	0
F_2	34.2	23	7.5	0
F_3	34.5	21	0	0
F_4	26.5	3.5	0	0
F_5	23.5	17.5	0	0
F_6	28.2	8.25	0	0
F_7	42.2	29.2	29	19.5

Population details are given in Table 2

chlorosulfuron transformed plants have indicated a need for a balanced interaction of protective enzymes (Toteva *et al.* 2004).

The study on evaluation of pendimethalin in pot culture assay indicated that 50-60% emergence was observed in all *P. minor* populations and wheat in control. In pots sprayed with 0.25 kg/ha pendimethalin, emergence declined to 5-17% in *P. minor* populations but not in wheat. At 0.50 and 1.0 kg/ha⁻ pendimethalin, emergence declined further to zero except in case of population from Karnal-Sagga where it was 2.5% at 0.5 kg/ha pendimethalin. Plant height also decreased after a pre-emergence spray of 0.25 kg/ha in *P. minor* population as well as wheat. Decline was more in *P. minor* populations (Table 3). In Petri-plate assay germination percentage declined with increase in dose of pendimethalin. At a dose equivalent to 25 g/ha it was more in Kurukshetra-Chanarthal and Kurukshetra-Neemwali. Hypocotyl and radical length also declined significantly with pendimethalin (2.5 to 25 g/ha) in all *P. minor* populations.

Table 4. Germination, hypocotyl length and radical length of different *P. minor* populations and wheat at 7 days after application of different concentrations of pendimethalin in petri-plates

Population	Pendimethalin (g/ha)			
	0	2.5	5.0	25
Germination (%)				
F_1	93	93	76	76
F_2	93	96	73	80
F_3	90	93	95	63
F_4	90	96	85	80
F_5	96	75	85	45
F_6	91	88	85	83
F_7	100	100	96	93
Hypocotyl length (cm)				
F_1	2.8	0.15	0.15	0.15
F_2	2.6	0.16	0.15	0.16
F_3	2.6	0.15	0.5	0.16
F_4	2.8	0.15	0.15	0.15
F_5	2.7	0.15	0.15	0.15
F_6	3	0.15	0.15	0.15
F_7	5	4	1.5	1.5
Radical length(cm)				
F_1	2.3	0.3	0.1	0.07
F_2	2.2	0.3	0.1	0.06
F_3	1.5	0.3	0.1	0.1
F_4	2.9	0.3	0.1	0.1
F_5	2.7	0.3	0.1	0.08
F_6	2.2	0.3	0.1	0.1
F_7	6.6	6.0	2.0	1.5

Population details are given in Table 2

In wheat, however the suppression was lesser at 2.5 gha as compared to 5.0 and and 25 g/ha (Table 4).

For management of the weed species resistant or cross resistant to one or two categories of herbicides, herbicides with different mode of action are advocated to be employed. Pendimethalin belonging to Group III herbicides could completely arrest the growth of all *P. minor* populations tested in pot culture as well Petri-plate assay. Management of isoproturon resistant *P. minor* by trifluralin derivatives had been advocated earlier (Yaduraju and Ahuja 1995). With limited herbicides options available pendimethalin appears to be the best option for management of *P. minor*.

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Combination of pinoxaden with other herbicides against complex weed flora in wheat

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ABSTRACT

A field experiment was conducted during 2010-11 and 2011-12 to evaluate the efficacy of pinoxaden alone and in combination with other herbicides against complex weed flora in wheat. Pinoxaden 50 g/ha alone and as tank mixture with and before metsulfuron-methyl 4 g/ha, carfentrazone-ethyl 20 g/ha and 2,4-D 500 g/ha was compared to isoproturon + 2,4-D, clodinafop *fb* 2,4-D, weed free and weedy check for weed control and grain yield. *Phalaris minor* and *Anagallis arvensis* were the major weeds constituting 59.1 and 20.8% of the total weed population during 2010-11 and 67.6 and 16.9% during 2011-12, respectively. *Avena ludovician, Lolium temulentum, Poa annua* and *Vicia sativa* were the other important weeds found in association with wheat. Weeds reduced grain yield of wheat by 39.5%. Pinoxaden + metsulfuron-methyl (50 + 4 g/ha) and pinoxaden *fb* metsulfuron-methyl (50 *fb* 4 g/ha) were comparable to weed free treatment in reducing the density of *Phalaris minor* and *Anagallis arvensis*. Pinoxaden alone was not effective against broad-leaved weeds, while carfentrazone, metsulfuron-methyl and 2,4-D were not effective against grasses. Combined application of pinoxaden with metsulfuron-methyl/carfentrazone (as tank mixed or as followed by) resulted in significantly lower total weed density and weed biomass. Combined application of pinoxaden with metsulfuron-methyl, carfentrazone and 2,4-D resulted in significantly higher tillers, grains/spike and 1000-seed weight and grain yield as comparable to in weed free.

Key words: Carfentrazone, Chemical control, Metsulfuron-methyl, Pinoxaden, 2,4-D, Weeds, Wheat

Wheat is the second most important crop after rice in India. Among different production factors, weeds pose serious threat to the productivity of wheat. They compete with crop plants for light, water and nutrients. Isoproturon was nationwide recommended herbicide in wheat. However, continuous reliance on isoproturon resulted in a heavy build-up of *Phalaris minor* (Malik and Singh 1995) and the problem of its resistance to isoproturon. Clodinafop and sulfosulfuron were recommended as alternate herbicides against isoproturon resistant *Phalaris minor*. But resistance against these herbicides was also reported (Dhawan *et al*. 2009) necessitating the search for new herbicide molecules. Pinoxaden, belonging to phenyl-pyrazolin group with acetyl-COA-carboxylase (ACCase) has inhibiting action (Hoffer *et al*. 2006). It is a selective grass killer with foliar action. Since grass killers don't control the broad-leaved weeds, the present study was conducted to evaluate the bioefficacy of pinoxaden in combination with herbicides that were reported to be effective against broad-leaved weeds such as metsulfuron-methyl, carfentrazone and 2,4-D for managing complex weed flora in wheat.

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MATERIALS AND METHODS

Wheat variety '*HPW 155*' was sown during the first fortnight of November for two consecutive years (2010-11 and 2011-12) with recommended package of practices except weed control. The soil of experimental field was silty clay loam in texture, acidic in reaction, medium in available nitrogen, phosphorus and high in available potassium. Fifteen weed control treatments, *viz*. pinoxaden (50 g/ha), metsulfuron-methyl (4 g/ha), carfentrazone-ethyl (20 g/ha) and 2,4-D (500 g/ha) alone, pinoxaden (50 g/ha) with and before carfentrazone-ethyl (20 g/ha), metsulfuron-methyl (4 g/ha) and 2,4-D (500 g/ha), isoproturon + 2,4-D (1250 + 500 g/ha), clodinafop *fb* 2,4-D (60 *fb* 1000 g/ha), mesosulfuron + iodosulfuron (13 + 5 g/ha), weed free and weedy check were tested in a randomized block design with 3 replications. All herbicides alone and as combination were applied as post-emergence at 28-35 DAS as per treatment with knapsack power sprayer using 750 litre water per hectare. Application of the second herbicide was made two days after the first. Observations on weed density and biomass were recorded at 90 DAS and at harvest using quadrat of 0.5 x 0.5 m, placed at two random spots in each plot. Weed density and biomass data showed variation and were subjected to square root transformation ($\sqrt{x+1}$). Wheat grain yield and yield attributes were recorded at maturity. Economics of the treatments was computed based on the prevalent prices of the inputs used and outputs obtained. The crop was harvested in the first fortnight of May. The different impact indices were worked out after Walia (2003).

RESULTS AND DISCUSSION

Effect on weeds

Wheat field was infested with both grassy and broad-leaved weeds. However, the flora was dominated by grassy weeds (*Phalaris minor*, *Avena ludoviciana*, *Lolium temulentum* and *Poa annua*) constituting 70.1 and 76.1% of total weed flora during 2010-11 and 2011-12, respectively. *Phalaris minor* had the highest proportion (59.1 and 67.6%) of total weed flora in 2010-11 and 2011-12, respectively. *Avena ludoviciana* and *Lolium temulentum* have shown their occurrence during both the years, however, *Poa annua* was present only during 2010-11. Among broad-leaved weed species,viz. *Vicia sativa*, *Anagallis arvensis*, *Stellaria media*, *Ranunculus arvensis* and *Convolvulus arvensis*), *Anagallis arvensis* was the major weed constituting 20.8% during 2010-11 and 16.9% of total weed flora during 2011-12. All treatments were significantly superior to weedy check in reducing the count of *P. minor* at 90 DAS during both the years (Table 1). However, 2,4-D 500 g/ha, metsulfuron-methyl 4 g/ha and carfentrazone-ethyl 20 g/ha could not significantly re-

Table 1. Effect of weed management treatments on density (no./m^2) of grassy weeds

Treatment	Dose (g/ha)	*P. minor*				*A. ludoviciana*				*L. temulentum*			
		2010-11		2011-12		2010-11		2011-12		2010-11		2011-12	
		90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest
Pinoxaden	50	2.8 (6.7)	3.6 (12.0)	1.8 (2.6)	1.7 (2.7)	1.0 (0.0)	1.8 (2.7)	1.0 (0.0)	1.4 (1.3)	2.1 (4.0)	1.8 (2.7)	1.8 (2.6)	2.1 (4.0)
Metsulfuron methyl	4	12.4 (156.0)	6.3 (40.0)	11.3 (126.0)	6.8 (45.3)	3.4 (10.7)	3s.2 (9.3)	3.4 (10.7)	3.4 (10.7)	3.8 (13.3)	s2.5 (6.7)	3.7 (13.3)	3.4 (10.7)
Pinoxaden + carfentrazone-ethyl	50 + 20	2.5 (5.3)	4.9 (22.7)	1.4 (1.3)	2.9 (9.3)	1.0 (0.0)	2.1 (4.0)	1.0 (0.0)	2.2 (4.0)	2.3 (5.3)	1.8 (2.7)	2.6 (8.0)	1.9 (4.0)
Pinoxaden + metsulfuron-methyl	50 + 4	2.1 (4.0)	4.7 (21.3)	1.4 (1.3)	2.4 (6.6)	1.0 (0.0)	1.4 (1.3)	2.0 (5.3)	1.7 (2.7)	1.4 (1.3)	1.4 (1.3)	1.4 (1.3)	1.0 (0.0)
Pinoxaden + 2,4-D	50 + 500	2.3 (5.3)	4.2 (17.3)	2.0 (5.3)	3.4 (13.3)	1.0 (0.0)	2.2 (4.0)	1.0 (0.0)	2.9 (5.3)	2.1 (4.0)	1.7 (2.7)	2.1 (4.0)	2.3 (5.3)
Pinoxaden *fb* carfentrazone-ethyl	50 *fb* 20	2.3 (5.3)	3.7 (13.3)	1.8 (4.0)	3.2 (9.3)	1.0 (0.0)	1.8 (2.7)	1.0 (0.0)	1.7 (2.7)	1.7 (2.7)	2.3 (5.3)	1.7 (2.7)	2.5 (6.7)
Pinoxaden *fb* metsulfuron-methyl	50 *fb* 4	2.5 (6.7)	3.8 (14.7)	1.8 (4.0)	3.0 (9.3)	1.0 (0.0)	1.8 (2.7)	1.4 (1.3)	1.7 (2.7)	2.2 (4.0)	1.4 (1.3)	3.2 (9.3)	2.3 (5.3)
Pinoxaden *fb* 2,4-D	50 *fb* 500	2.3 (5.3)	3.4 (10.7)	1.4 (1.3)	1.7 (2.7)	1.0 (0.0)	1.7 (2.7)	1.0 (0.0)	1.4 (1.3)	1.9 (4.0)	1.8 (2.7)	1.9 (4.0)	1.7 (2.7)
Carfentrazone-ethyl	20	13.4 (184.0)	6.6 (44.0)	12.5 (156.0)	7.2 (52.0)	3.4 (10.7)	3.2 (9.3)	2.7 (8.0)	3.4 (10.7)	3.7 (13.3)	1.7 (2.7)	2.9 (9.3)	2.7 (8.0)
Mesosulfuron + idosulfuron	13 + 5	5.8 (33.3)	5.6 (30.7)	6.1 (37.3)	6.0 (34.7)	1.7 (2.7)	2.5 (6.7)	1.6 (2.6)	2.7 (8.0)	3.4 (10.7)	2.3 (5.3)	3.2 (9.3)	2.7 (8.0)
Isoproturon + 2,4-D	1250 + 500	3.0 (9.3)	4.0 (16.0)	2.8 (10.7)	3.7 (13.3)	2.3 (5.3)	2.5 (5.3)	1.4 (1.3)	1.7 (2.7)	2.3 (5.3)	2.2 (6.7)	2.5 (6.7)	2.5 (6.7)
Clodinafop *fb* 2,4-D	60 *fb* 1000	3.4 (10.7)	3.6 (16.0)	3.1 (8.7)	3.8 (14.7)	2.3 (5.3)	2.3 (5.3)	2.2 (4.0)	2.9 (5.3)	1.8 (2.7)	1.4 (1.3)	1.8 (2.7)	2.3 (5.3)
2,4-D	500	10.1 (108.0)	6.1 (37.3)	10.1 (101.3)	6.8 (45.3)	4.1 (16.0)	3.4 (10.7)	3.5 (12.0)	3.4 (10.7)	3.9 (14.7)	2.7 (6.7)	3.9 (14.7)	3.8 (13.3)
Weed free		1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Weedy check		16.5 (273.3)	7.1 (50.7)	15.7 (244.7)	6.4 (40.0)	4.7 (21.3)	4.0 (14.7)	4.0 (17.3)	3.4 (10.7)	4.0 (16.0)	3.0 (8.0)	3.4 (13.3)	3.4 (10.7)
LSD (P=0.05)		2.4	1.7	2.7	2.0	1.0	1.3	1.5	1.3	1.4	NS	NS	1.6

Data transformed to square root transformation ($\sqrt{x+1}$). Values given in parentheses are the means of original values, DAS= Days after sowing, *fb*= followed by; Herbicide application was made 28-35 DAS, *fb* application was made 2 DAS after the first.

Table 2. Effect of weed management treatments on density (no./m^2) of broad-leaved weeds

Treatment	*Vicia*				*Anagallis*				*Coronopus*			
	2010-11		2011-12		2010-11		2011-12		2010-11		2011-12	
	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest
Pinoxaden	3.8 (13.3)	3.2 (9.3)	3.4 (10.7)	4.0 (16.0)	7.6 (61.3)	4.7 (21.3)	10.6 (114.7)	10.0 (98.7)	2.08 (4.00)	1.67 (2.67)	2.1 (4.0)	4.1 (16.0)
Metsulfuron methyl	2.1 (4.0)	2.1 (4.0)	2.3 (5.3)	2.8 (6.7)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.67 (2.67)	1.00 (0.00)	1.7 (2.7)	1.0 (0.0)
Pinoxaden + carfentrazone-ethyl	3.4 (10.7)	2.5 (6.7)	3.4 (10.7)	3.2 (9.3)	2.9 (9.3)	3.0 (8.0)	2.9 (9.3)	2.8 (9.1)	2.33 (5.33)	1.41 (1.33)	2.3 (5.3)	2.0 (4.3)
Pinoxaden + metsulfuron-methyl	2.1 (4.0)	1.8 (2.7)	2.1 (4.0)	2.8 (6.7)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.00 (0.00)	1.00 (0.00)	1.0 (0.0)	1.0 (0.0)
Pinoxaden + 2,4-D	2.3 (5.3)	2.5 (5.3)	2.3 (5.3)	3.8 (13.3)	4.9 (24.0)	3.1 (10.7)	4.9 (24.0)	5.7 (32.0)	1.67 (2.67)	1.67 (2.67)	1.7 (2.7)	2.5 (6.7)
Pinoxaden *fb* carfentrazone-ethyl	3.2 (9.3)	3.2 (9.3)	3.6 (12.0)	3.9 (14.7)	2.9 (10.7)	2.8 (6.7)	2.9 (10.7)	2.8 (5.7)	1.82 (2.67)	1.41 (1.33)	1.8 (2.7)	2.6 (6.9)
Pinoxaden *fb* metsulfuron-methyl	2.3 (5.3)	2.5 (5.3)	2.3 (5.3)	3.7 (13.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	3.3 (13.3)	1.87 (4.00)	2.08 (4.00)	1.9 (4.0)	2.2 (6.7)
Pinoxaden *fb* 2,4-D	3.6 (12.0)	3.0 (8.0)	3.6 (12.0)	3.3 (10.7)	4.1 (21.3)	3.4 (10.7)	4.1 (21.3)	8.1 (73.3)	1.00 (0.00)	1.00 (0.00)	1.0 (0.0)	2.9 (9.3)
Carfentrazone-ethyl	2.3 (5.3)	2.1 (4.0)	2.3 (5.3)	3.7 (13.3)	1.0 (0.0)	2.1 (4.0)	1.0 (0.0)	2.9 (9.3)	1.41 (1.33)	1.00 (0.00)	1.4 (1.3)	1.7 (2.7)
Mesosulfuron + idosulfuron	2.1 (4.0)	1.8 (2.7)	1.7 (2.8)	3.2 (9.3)	2.3 (5.3)	2.2 (4.0)	1.0 (0.0)	1.0 (0.0)	1.41 (1.33)	1.41 (1.33)	1.4 (1.3)	1.0 (0.0)
Isoproturon + 2,4-D	3.0 (8.0)	1.7 (2.7)	2.3 (5.3)	3.8 (13.3)	2.9 (9.3)	2.7 (8.0)	3.1 (10.7)	4.9 (24.0)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Clodinafop *fb* 2,4-D	2.5 (6.7)	3.0 (8.0)	3.6 (12.0)	3.9 (14.7)	5.0 (24.0)	4.1 (16.0)	2.3 (5.3)	3.7 (13.3)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
2,4-D	2.3 (5.3)	1.7 (2.7)	2.3 (5.3)	3.0 (8.0)	2.8 (6.7)	3.0 (8.0)	1.4 (1.3)	2.9 (9.3)	1.00 (0.00)	1.00 (0.00)	1.0 (0.0)	1.0 (0.0)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.00 (0.00)	1.00 (0.00)	1.0 (0.0)	1.0 (0.0)
Weedy check	3.8 (13.3)	3.7 (13.3)	3.8 (13.3)	4.1 (16.0)	9.8 (96.0)	5.2 (26.7)	7.8 (61.3)	6.9 (48.0)	2.28 (5.33)	2.54 (6.67)	2.3 (5.3)	4.1 (16.0)
LSD (P=0.05)	1.5	1.3	1.5	1.1	2.3	1.4	2.29	2.3	NS	NS	NS	1.9

Data transformed to square root transformation ($\sqrt{x+1}$); Values given in parentheses are the means of original values.

duce the count of *P. minor* until harvest during both the years as these wee mainly broad-leaved herbicides. Similarly, mesosulfuron + iodosulfuron (13+5 g/ha) showed little effect on *Phalaris* during both the years. Pinoxaden 50 g/ha alone and with 2,4-D, carfentrazone-ethyl or metsulfuron-methyl (both as tank mixed combination or as sequence application) provided excellent control of *P. minor* and was comparable to weed free check. The activity of pinoxaden against *P. minor* has been well established (Chhokar *et al. 2008*, Yadav *et al.* 2009 and Kumar *et al.* 2010). Isoproturon + 2,4-D and clodinafop *fb* 2,4-D had also effectively controlled *P. minor* but pinoxaden had an edge over both of these treatments. The effectiveness of isoproturon (Chopra *et al.* 2001) and clodinafop (Jat *et al.* 2007) against *P. minor* has also been documented.

Pinoxaden alone or with other broad-leaved herbicides effectively controlled *Avena ludoviciana* and was as good as weed free until harvest during both the years. The broad-leaved herbicides 2,4-D, carfentrazone-ethyl and metsulfuron-methyl did not significantly affect the density of *A. ludoviciana* over weedy check. Isoproturon + 2,4-D and clodinafop *fb* 2,4-D were less effective against *A. ludoviciana* than pinoxaden during 2010-11. The count of *L. temulentum* was significantly affected at 90 DAS during 2010-11 and at harvest during 2011-12. The density of *P. annua* was significantly affected at 90 DAS during 2010-11. Pinoxaden alone and with other herbicides, isoproturon+ 2,4-D and clodinafop *fb* 2,4-D was comparable to weed free in reducing the density of *L. temulentum* and *P. annua* at 90 DAS during 2010-11. However, owing to withering/shedding of the weed by harvest, only weed

Table 3. Effect of treatments on total weed density (no./m^2) and weed biomass (g/m^2)

Treatment	2010-11				2011-12			
	90 DAS		At harvest		90 DAS		At harvest	
	Density	Biomass	Density	Biomass	Density	Biomass	Density	Biomass
Pinoxaden	10.8 (116.0)	2.8 (7.6)	7.7 (58.7)	8.9 (79.1)	11.8 (140.0)	2.8 (7.6)	12.8 (162.7)	11.6 (136.3)
Metsulfuron-methyl	13.8 (193.3)	4.0 (14.7)	7.8 (62.7)	11.6 (135.5)	13.6 (188.0)	4.0 (14.7)	9.2 (86.7)	13.0 (169.6)
Pinoxaden + carfentrazone-ethyl	6.3 (38.7)	1.6 (1.7)	7.0 (48.0)	7.3 (52.9)	5.9 (34.7)	1.6 (1.7)	8.6 (73.3)	6.7 (44.4)
Pinoxaden + metsulfuron methyl	3.2 (9.3)	1.2 (0.5)	5.2 (26.7)	6.5 (41.6)	4.6 (28.0)	1.2 (0.5)	6.2 (37.3)	5.9 (34.4)
Pinoxaden + 2,4-D	6.5 (41.3)	1.3 (0.9)	6.7 (44.0)	6.3 (40.3)	6.5 (41.3)	1.3 (0.9)	8.1 (72.7)	5.8 (37.6)
Pinoxaden *fb* carfentrazone-ethyl	5.5 (30.7)	1.9 (2.6)	6.4 (40.0)	6.9 (47.7)	5.6 (3)	1.9 (2.6)	8.7 (74.7)	6.5 (42.5)
Pinoxaden *fb* metsulfuron-methyl	4.9 (24.0)	1.2 (0.5)	5.5 (29.3)	4.6 (23.2)	5.5 (30.7)	1.2 (0.5)	6.6 (50.7)	4.8 (20.6)
Pinoxaden *fb* 2,4-D	6.5 (44.0)	1.4 (1.0)	6.0 (36.0)	4.0 (16.2)	6.0 (40.0)	1.4 (1.0)	10.4 (113.3)	6.5 (44.7)
Carfentrazone-ethyl	14.8 (222.7)	4.9 (24.2)	8.1 (66.7)	11.2 (125.4)	14.4 (210.7)	4.9 (1.2)	10.0 (98.7)	12.4 (155.0)
Mesosulfuron + idosulfuron	7.6 (57.3)	1.4 (1.2)	7.5 (54.7)	6.7 (53.1)	7.1 (49.3)	1.4 (1.2)	7.8 (60.0)	8.7 (77.2)
Isoproturon + 2,4-D	5.8 (34.7)	1.2 (0.5)	6.2 (38.7)	6.7 (44.7)	6.5 (44.0)	1.4 (1.0)	6.7 (44.0)	7.3 (52.9)
Clodinafop *fb* 2,4-D	7.2 (50.7)	2.0 (3.7)	7.0 (50.7)	9.8 (98.3)	6.3 (38.7)	1.6 (1.7)	7.7 (58.7)	11.6 (135.5)
2,4-D	12.4 (156.0)	4.2 (16.8)	8.4 (69.3)	10.3 (106.2)	11.8 (141.3)	4.2 (16.8)	9.4 (86.7)	14.2 (203.4)
Weed free	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Weedy check	21.0 (445.3)	5.5 (31.7)	11.3 (126.7)	13.6 (194.8)	19.7 (390.7)	5.5 (31.7)	12.6 (158.7)	15.1 (228.8)
LSD (P=0.05)	2.2	1.2	1.3	2.9	2.7	1.4	2.1	2.4

Data transformed to square root transformation ($\sqrt{x+1}$). Values given in parentheses are the means of original values.

free, pinoxaden *fb* 2,4-D and pinoxaden + metsulfuron-methyl could result in significantly lower density of *L. temulentum* over the weedy check. Metsulfuron-methyl, carfentrazone-ethyl, 2,4-D and mesosulfuron + iodosulfuron were not effective against *L. temulentum* and *P. annua*. Pinoxaden was not effective against broad-leaved weeds as their count under the treatment was not significantly different from that under weedy check (Table 2). Application of metsulfuron-methyl alone or in combination with other herbicides, 2,4-D and carfentrazone gave effective control of *A. arvensis* and other broad-leaved weeds during both the years. The effectiveness of metsulfuron-methyl alone or in combination with other herbicides (Kumar *et al*. 2010, Kumar *et al*. 2011) and carfentrazone (Singh *et al*. 2005, Jat *el al*. 2007) against *Anagallis arvensis* has been documented.

Owing to reduction in count of one or more than one species, all the weed control treatments resulted in significant lower total weed density and total weed biomass as compared to weedy check (Table 3). Pinoxaden + metsulfuron-methyl (50 + 4 g/ha) resulted in significantly lowest total weed density and total weed biomass among herbicidal treatments and was comparable to weed free. Pinoxaden + carfentrazone-ethyl (50 + 20 g/ha), pinoxaden + 2,4-D (50 + 500 g/ha), pinoxaden *fb* carfentrazone-ethyl (50 *fb* 20 g/ha), pinoxaden *fb* metsulfuron-methyl (50 *fb* 4 g/ha), pinoxaden *fb* 2,4-D (50 *fb* 500 g/ha), isoproturon + 2,4-D (1250 + 500 g/ha), mesosulfuron + iodosulfuron (13 + 5 g/ha) and clodinafop *fb* 2,4-D (60 *fb* 1000 g/ha) were other superior treatments. 2,4-D (500 g/ha), metsulfuron methyl (4 g/ha) and carfentrazone-ethyl (20 g/ha) were least effective.

Table 4. Effect of weed management treatments on yield attributes and yield of wheat

Treatment	Effective tiller/m^2		Grains/spike		Test weight (g)		Grain yield (t/ha)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Pinoxaden	204.2	194.7	42.6	50.5	43.4	43.2	3.68	3.55
Metsulfuron-methyl	179.1	167.3	42.6	48.3	42.8	42.1	3.15	3.06
Pinoxaden + carfentrazone-ethyl	200.5	180.7	43.8	49.8	43.2	43.4	3.70	3.66
Pinoxaden + metsulfuron-methyl	205.7	194.7	44.2	51.3	44.0	43.6	3.83	3.81
Pinoxaden + 2,4-D	198.3	186.7	45.1	51.8	42.1	42.8	3.66	3.59
Pinoxaden *fb* carfentrazone-ethyl	200.5	180.0	43.3	49.1	42.4	42.0	3.58	3.49
Pinoxaden *fb* metsulfuron-methyl	205.0	180.0	44.9	48.9	43.6	44.0	3.73	3.75
Pinoxaden *fb* 2,4-D	198.3	199.3	43.3	50.8	42.5	42.6	3.51	3.45
Carfentrazone-ethyl	177.6	186.2	42.5	48.8	42.0	42.4	3.06	3.15
Mesosulfuron + iodosulfuron	186.5	178.7	43.3	51.1	43.3	43.4	3.38	3.40
Isoproturon + 2,4-D	188.0	190.5	44.2	51.5	44.5	43.8	3.59	3.61
Clodinafop *fb* 2,4-D	195.4	191.6	43.6	50.4	43.4	43.3	3.57	3.54
2,4-D	174.6	198.7	42.7	49.3	42.6	42.5	3.04	2.99
Weed free	208.7	202.7	43.9	51.3	43.8	44.5	3.86	3.90
Weedy check	166.5	145.8	37.3	40.5	39.5	40.1	2.43	2.26
LSD (P=0.05)	7.4	10.5	0.8	1.1	1.8	1.9	0.43	0.46

Table 5. Effectof weed management treatments on economics and impact indices

Treatment	Cost of weed control (x10^3 ₹/ha)	Gross returns (x10^3 ₹/ha)	GR_{WC} (x10^3 ₹/ha)	NRwc (x10^3 ₹/ha)	MBCR	Weed persistence index (WPI)	Crop resistance index (CRI)	Herbicide efficiency index (HEI)
Pinoxaden	0.81	64.08	22.13	21.32	26.33	1.66	2.98	1.06
Metsulfuron methyl	0.79	55.23	13.28	12.49	15.71	1.58	1.82	0.45
Pinoxaden + carfentrazone-ethyl	1.28	64.81	22.86	21.58	16.79	2.62	6.63	2.47
Pinoxaden + metsulfuron methyl	0.88	67.13	25.18	24.29	27.46	4.02	8.77	3.50
Pinoxaden + 2, 4-D	0.94	64.11	22.16	21.22	22.53	1.86	8.21	2.97
Pinoxaden *fb* carfentrazone-ethyl	2.00	62.99	21.04	19.03	9.49	2.89	7.02	2.38
Pinoxaden *fb* metsulfuron methyl	1.60	66.34	24.40	22.79	14.20	1.58	15.17	5.75
Pinoxaden *fb* 2, 4-D	1.66	62.00	20.05	18.39	11.07	1.43	10.25	3.36
Carfentrazone-ethyl	1.19	55.77	13.82	12.62	10.57	1.28	2.02	0.49
Mesosulfuron + iodosulfuron	0.78	59.72	17.77	16.99	21.73	2.41	4.56	1.45
Isoproturon + 2, 4-D	1.33	62.74	20.79	19.46	14.67	2.45	6.32	2.32
Clodinafop *fb* 2, 4-D	1.87	62.83	20.89	19.01	10.15	5.16	2.68	0.93
2, 4-D	0.85	54.21	12.26	11.41	13.40	2.06	1.78	0.39
Weed free	9.60	68.28	26.33	16.73	1.74	-	-	-
Weedy check	-	41.94	-	-	-	1.00	1.00	0.00
LSD (P=0.05)		7.07						

GR_{WC} - Gross returns due to weed control; NRwc - Net returns due to weed control; MBCR - Marginal benefit cost ratio

Effect on crop

On an average, weeds in weedy check reduced grain yield of wheat by 39.5% over the weed free. All treatments were significantly superior to weedy check in increasing effective tillers/m^2, spikelets per spike, number of grain per spike, test weight and thereby grain yield of wheat (Table 4). The higher yield and yield attributes were owing to superior weed control both in terms of reduction in density and biomass of weeds. Grain and straw yields of wheat were negatively associated with weed biomass (r= -0.891 and -0.866, respectively) and weed count (r=0.940 and -927, respectively). With every g/m^2 increase in weed biomass, the grain yield of wheat was expected to decrease by 3.36 kg/ha (Y=3759.4 – 3.362 X, Y being yield in kg/ha and x weed biomass in g/m^2, R^2 = 0.794). With increase in one weed/m^2, the grain yield of wheat may decrease by 5.77 kg/ha (Y= 3905 – 5.744 X, X being weed number/m^2, R^2= 0.884). Weed free gave highest grain yield. However, pinoxaden + metsulfuron-methyl (50 + 4 g/ha), pinoxaden (50 g/ha), pinoxaden + carfentrazone-ethyl (50 + 20 g/ha), pinoxaden *fb* metsulfuron-methyl (50 *fb* 4 g/ha), isoproturon + 2, 4-D (1250 + 500 g/ha), clodinafop *fb* 2,4-D (60 *fb* 1000 g/ha), pinoxaden + 2,4-D (50 + 500 g/ha), pinoxaden *fb* carfentrazone-ethyl (50 *fb* 20 g/ha) and pinoxaden *fb* 2,4-D (50 *fb* 500 g/ha) were as good as weed free. 2,4-D (500 g/ha), metsulfuron-methyl (4 g/ha), carfentrazone-ethyl (20 g/ha) and mesosulfuron + iodosulfuron (13 + 5 g/ha) being statistically at par were less effective in influencing grain yield of wheat.

Impact assessment

Manual weed control is a costly proposition as evident, cost of weed control under weed free was highest (Table 5). Herbicides are the cheap alternatives under all situations. Because of higher grain and straw yields, weed free resulted in highest gross return and gross return due to weed control. However, due to lower control cost, all herbicidal treatments except 2,4-D, carfentrazone ethyl and metsulfuron-methyl alone were superior to weed free in influencing net returns due to weed control. Pinoxaden + metsulfuron methyl resulted in highest net return due to weed control (₹ 24400/ha) and was followed by pinoxaden *fb* metsulfuron-methyl, pinoxaden + carfentrazone ethyl, pinoxaden and pinoxaden + 2,4-D. Marginal benefit cost ratio (MBCR) was also highest under pinoxaden + metsuluron (27.46). This was followed by pinoxaden (26.33) and pinoxaden + 2,4-D (22.53). Weed persistence index (WPI) was highest under clodinafop *fb* 2,4-D and *fb* pinoxaden + metsulfuron-methyl, pinoxaden + carfentrazone-ethyl, and isoproturon + 2,4-D. Crop resistance index (CRI) was highest under pinoxaden *fb* metsulfuron-methyl *fb* pinoxaden *fb* 2,4-D, pinoxaden + metsulfuron-methyl and pinoxaden + 2,4-D. Herbicide efficiency index (HEI) was also highest under pinoxaden *fb* metsulfuron-methyl followed by pinoxaden + metsulfuron-methyl, pinoxaden *fb* 2,4-D, pinoxaden + 2,4-D and pinoxaden + carfentrazone ethyl.

The present investigation conclusively inferred that combined application of pinoxaden and metsulfuron-methyl/carfentrazone/2,4-D either as tank mixed or sequential was the better alternative to isoproturon + 2,4-D or clodinafop *fb*. 2,4-D in controlling weeds and achieving higher wheat yield and economic returns.

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Influence of quizalofop-ethyl on narrow-leaved weeds in blackgram and its residual effect on succeeding crops

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ABSTRACT

A field experiment was conducted at Research Farm of MPUAT, Udaipur for two consecutive years during 2008-09 and 2009-10 to evaluate the efficacy of different doses of quizalofop-ethyl as post-emergences (at 4-6 leaf stage of weeds) in blackgram and residual effect thereof on succeeding *Rabi* crops (wheat, gram and mustard). The experiment comprising five weed control treatments, *viz*. quizalofop-ethyl at 37.5 and 50 g/ha as post-emergence, pendimethalin 750 g/ha as pre-emergence, farmers practice of two hand weedings at 20 and 35 days after sowing (DAS) and weedy check, was conducted in randomized block design with four replications. To study phytotoxicity, quizalofop-ethyl 100 g/ha was also included in addition to above treatments. In the experimental field, more than 50% weeds were dominated by *Echinochloa* spp. Results revealed that among the herbicidal treatments, quizalofop-ethyl 50 g/ha recorded the lowest narrow-leaved weed density and dry weight at 30 DAS and at harvest during both the years. Quizalofop-ethyl irrespective of its doses was not effective against broad-leaved weeds. The weed control efficiency of quizalofop-ethyl 50 g/ha was 81.3% than the highest (85.6%) under two hand weedings against grassy weeds at harvest. Number of branches and pods/plant, seeds/pod and grain and stover yields of blackgram were also superior in plots treated with quizalofop-ethyl 50 g/ha or two HW. Quizalofop-ethyl was found safe to blackgram, and did not cause any residual toxicity to succeeding crops.

Key words: Blackgram, Chemical control, *Echinochloa* spp., Quizalofop-ethyl, Residual effect

Blackgram (*Vigna mungo* L.) is one of the important pulse crops grown during *Kharif* season in south Rajasthan where the average productivity is only 0.30 t/ha (Anonymous 2010) which is quite low against its potential yield. High temperature coupled with frequent rains during growing period infest the crop heavily with weeds specially *by Echinochloa* spp. besides some broad-leaved weeds which adversely affect the productivity of this crop. The weeds reduce the seed yield of blackgram as high as 80-90% (Kumar *et al*. 2000). *Echinochloa colona* alone, one of the major weeds in blackgram, may reduce the seed yield to the extent of 49% (Rao and Rao 2003). Therefore, control of weeds during critical period of crop weed competition is very important to avoid severe yield losses. Due to labour scarcity, use of manual control of weed is very difficult. In monsoon season sometimes, pre-emergence herbicides become difficult, therefore, suitable post-emergence herbicide are required. Wheat, gram and mustard are the important succeeding crops grown after blackgram therefore, study was also done on residual effect of herbicides, on these crops.

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MATERIALS AND METHODS

A field experiment was conducted during the year 2008-09 and 2009-10 at the Instructional Farm of College of Technology and Engineering, MPUAT, Udaipur. The soil of the experimental field was sandy clay loam in texture with low in available nitrogen and phosphorus and high in available potassium. Experiment consisted of five weed control treatments, *viz*. quizalofop-ethyl (Targa super 5 EC) 37.5 and 50 g/ha as post-emergence (4-6 leaf stage of weeds), pendimethalin (Stomp 30 EC) 750 g/ha as pre-emergence, farmers' practice of doing two hand weedings at 20 and 35 DAS and weedy check. For residual study, the original experimental lay out was kept undisturbed, and wheat, gram and mustard were sown across the plots. The crops were raised as per recommended package. Treatments were evaluated in randomized block design with four replications in blackgram using variety '*T-9*' with the plot size of 9 x 3 m. The herbicides were applied by knapsack sprayer fitted with flat fan nozzle using 500 litres of water per hectare. Data on major weed flora, their per cent contribution, weed density and dry biomass, growth and yield attributes as well as yield of blackgram were recorded following standard practices. Phytotoxicity of different treatments of quizalofop-ethyl on blackgram as well as on follow up *Rabi* crops were also studied. Residual effects of herbicides were studied in succeeding *Rabi* season crops in terms of germination count, plant height as well as yield of these crops.

RESULTS AND DISCUSSION

Weed flora

The major weed flora of the experimental field consisted of narrow-leaved weeds (*Echinochloa* spp. and *Cynodon dactylon*), sedges (*Cyperus rotundus)* and broad-leaved weeds (*Parthenium hysterophorus*, *Amaranthus viridis*, *Triantherma portulacastrum* and others). The mean per cent contribution of these weeds were 58.6, 0.9, 6.9, 15.8, 10.1, 4.2 and 3.5, respectively. *Echinochloa* spp. was the major narrow-leaved weed contributed 58.6% in the total weed density. In general, the density and dry biomass of weeds were comparatively higher in 2009 over 2008 which might be probably due to favourable environmental conditions leading to vigorous growth of weeds.

Weed density

All the weed control treatments significantly reduced the density of narrow-leaved weeds during both the years compared to weedy check. Quizalofop-ethyl 50 g/ha resulted into significantly less narrow-leaved weed density over all other treatments. The mean weed density in quizalofop-ethyl 50 g/ha, farmers' practice, quizalofop-ethyl 37.5 g/ha and pendimethalin 750 g/ha was 2.04, 3.45, 4.20 and 6.5/m^2, respectively as against 9.8/m^2 in weedy check. The herbicide quizalofop-ethyl at either levels of its application did not have any effect on broad-leaved weeds during both the years. However, farmers' practice of two hand weeding during both the years and pendimethalin 750 g/ha were found significant in reducing the density of broad-leaved weeds only in 2009 compared to weedy check. Better response of quizalofop-ethyl in controlling narrow-leaved weeds might be due to the fact that aryloxyphen-oxypropionates (AOPP) class to which this herbicide belongs is readily absorbed and translocated to meristematic region and exert herbicide activity. It acts by inhibiting the enzyme Acetyl Coenzyme–A carboxylase (ACCase) in susceptible species (Burton 1997). Acetyl coenzyme catalyzes, the first committed step of fatty acid biosynthesis, is adenosine triphosphate dependent carboxylation of acetyl Co A to malonyl Co A. Grass species have a eukaryotic type ACCase in the chloroplasts which is sensitive to ACCase inhibitors. Whereas most broad-leaved species have a prokaryotic type of ACCase, which is not sensitive to ACCase inhibitors (Incledon and Hall 1997).

Dry weight of weeds

It was found that the dry biomass of narrow-leaved weeds at 30 days after treatment (DAT) and at harvest was affected significantly. The mean data on dry weed biomass of narrow-leaved weeds at harvest revealed that lowest weed biomass in farmers' practice (0.53 t/ha) followed by quizalofop-ethyl 50 g/ha (0.68 t/ha), and pendimethalin (1.03 t/ha) as against 3.78 t/ha in weedy check on mean basis (Table 1). The weed control efficiency against narrow-leaved weeds at 30 DAT and at

Table 1. Weed density, their dry biomass and weed control efficiency as affected by weed control treatments

Treatment	Weed density no./m^2 at 30 DAT				Dry biomass of weeds (t/ha)						Weed control efficiency (%)					
	Narrow-leaved weeds		Broad-leaved weeds		30 DAT Narrow-leaved weeds		30 DAT Broad-leaved weeds		At harvest narrow-leaved weeds		30 DAT Narrow-leaved weeds		30 DAT Broad-leaved weeds		At harvest narrow-leaved weeds	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Quizalofop-ethyl 37.5 g/ha	4.61 (21)*	3.79 (15)	7.90 (63)	8.83 (78)	0.52	0.65	1.57	1.70	0.71	0.84	76.6	87.1	1.1	3.0	75.4	81.9
Quizalofop-ethyl 50 g/ha	1.74 (3)	2.33 (5)	7.45 (56)	9.27 (86)	0.21	0.37	1.53	1.68	0.61	0.76	90.4	92.7	3.3	4.5	78.9	83.7
Pendimethalin 750 g/ha	6.30 (40)	6.86 (47)	6.55 (43)	5.96 (36)	0.25	0.75	1.01	1.10	1.01	1.45	85.6	85.2	36.0	37.2	65.1	69.0
Farmers practice	3.22 (10)	3.67 (13)	0.71 (0)	5.49 (29)	0.09	0.19	0.46	0.29	0.46	0.60	96.0	96.2	70.7	83.3	84.2	87.2
Weedy check	8.41 (70)	11.18 (126)	7.57 (63)	9.37 (88)	2.9	5.06	1.58	1.75	2.9	4.7	-	-	-	-	-	-
LSD (P=0.05)	1.18	1.41	2.16	1.48	0.63	0.51	0.56	0.47	0.34	0.39	-	-	-	-	-	-

*Original figures in parentheses were subjected to square root transformation ($\sqrt{x+0.5}$) before statistical analysis. DAT – days after treatment harvest also depicted the same trend and the maximum of 96.08 and 85.68% was found in farmers practice, respectively on mean basis followed by quizalofop-ethyl 50 g/ha with the mean values of 91.55 and 81.30% at 30 DAT and at harvest, respectively. The results were in conformity with the findings of Singh *et al.* (2006).

Different weed control treatments had significant effect on all the growth and yield attributing characters except plant height and 1000-seed weight during both the years (Table 2). The highest number of branches/plant, pods/plant and seeds/pod were recorded in farmers' practice during both the years with mean values of 4.99, 37.48 and 6.93, respectively. However, among the herbicidal treatments, application of quizalofop-ethyl 50 g/ha recorded the maximum number of branches (4.23/plant), pods/plant (31.67) and seeds/pod (6.47) in individual years as well as on mean basis. The increase in growth and yield attributes under these treatments might be attributed due to the reduction in weed competitiveness with the crop which ultimately favoured better environment for growth and development of crop.

All the weed control treatments significantly increased both seed and stover yields of blackgram in both the years of experimentation (Table 2). It was found that the highest seed yield and stover yield of blackgram was recorded in farmers practice followed by post-emergence application of quizalofop-ethyl 50 g/ha. Mean data for two years revealed per cent increase in seed yield due to farmers' practice, quizalofop-ethyl 50 g/ha, pendimethalin 750 g/ha and quizalofop-ethyl 37.5 g/ha and was 226.1, 188.6, 141.7 and 126.5, respectively compared to weedy check. The corresponding increase in stover yield under these treatments was 249.8, 219.7, 147.9 and 129.5 % as against the lowest recorded in weedy check. The yield levels during first year under different treatments were lower compared to second year because during first year, there were continuous rains at flowering stage resulting in falling of flowers as well as shattering of pods ultimately led to poor yield of crop. The highest yield under farmers practice of two hand weedings at 20 and 35 DAS was due to the fact that this treatment controlled early as well as late flushes of weeds and provided weed free environment to the crop during critical period of crop weed competition. The results are in conformity with the findings of Rajput and Kushwah (2004). On the other hand quizalofop-ethyl 50 g/ha had significantly controlled the most dominated narrow-leaved weed *Echinochloa* spp. and saved the crop efficiently from its infestation and it reflected in terms of significant increase in growth and yield attributes which

Table 2. Growth, yield attributes and yield of blackgram as affected by weed control treatments

Treatment	Plant height at harvest (cm)		No. of pods/ plant		No. of seeds/pod		1000-seed weight (g)		Yield (t/ha)			
									Grain		Stover	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Quizalofop-ethy 37.5 g/ha	55.4	53.3	21.20	31.50	5.91	6.20	56.1	53.6	0.31	0.63	0.62	1.57
Quizalofop-ethyl 50 g/ha	53.3	50.8	24.33	39.00	6.45	6.48	57.8	54.0	0.38	0.83	0.72	2.34
Pendimethalin 750 g/ha	53.8	55.0	25.15	31.75	6.21	6.53	57.6	55.0	0.36	0.65	0.70	1.67
Farmers practice	48.1	54.6	29.70	45.25	6.87	6.98	58.7	55.7	0.41	0.96	0.80	2.54
Weedy check	55.6	60.0	18.95	21.25	5.56	5.63	54.6	53.0	0.21	0.21	0.42	0.52
LSD (P=0.05)	NS	NS	4.13	9.09	0.38	0.58	NS	NS	0.06	0.16	0.11	0.32

Table 3. Residual effect of weed control treatments on germination count, plant height and yield of succeeding crops

Treatment	Plant height (cm)						Grain/seed yield (t/ha)					
	Wheat		Mustard		Gram		Wheat		Mustard		Gram	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Quizalopof-ethyl 37.5 g/ha	80.3	82.4	181.6	179.2	42.1	42.0	3.39	4.14	1.74	1.50	1.07	0.66
Quizalopof-ethyl 50 g/ha	79.7	81.5	179.9	180.8	42.1	40.6	3.48	3.99	1.75	1.37	1.17	0.58
Pendimethalin 750 g/ha	79.1	81.8	182.9	182.2	43.9	42.6	3.37	4.12	1.78	1.45	1.19	0.63
Farmers practice	80.7	84.1	182.5	179.5	42.2	41.4	3.51	4.13	1.69	1.47	1.18	0.66
Weedy check	80.0	81.8	181.7	179.4	42.4	44.4	3.39	4.10	1.74	1.54	1.07	0.64
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

ultimately resulted into higher yield of crop. Similar findings were also reported by Khedkar *et al.* (2009) and Meena *et al.* (2009) in soybean.

Visual phytotoxicity on blackgram in terms of epinasty, hyponasty, necrosis, vein clearing and wilting at 3,5,7,10 and 15 days after quizalofop-ethyl application did not show any type of phytotoxic effects and thus, found completely safe for the crop.

Residual phytotoxicity on suceeding crops

Herbicides applied in blackgram did not show any kind of phytotoxicity on any of the succeeding crops, *viz.* wheat, mustard and gram. Post-emergence application of quizalofop-ethyl 37.5, 50.0 and 100.0 g/ha and pre-emergence application of pendimethalin 750 g/ha used in blackgram also did not show any residual effect on germination, plant height as well as seed/grain yield of these crops as evident from the data presented in (Table 3). The mean grain/seed yield of wheat, mustard and gram ranged between 3.72 and 3.77, 1.57 and1.64, and 0.86 and 0.92 t/ha, respectively.

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Integrated weed management in sesame

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ABSTRACT

A field experiment was conducted to find out the most effective control measure for weeds in sesame (*Sesamum* indicun L.) under rainfed condition. Result showed that two hand weeding (weed free) recorded lowest weed population and dry weight which was significantly superior over rest of the treatments. Application of quizalofop-ethy l0.05 kg/ha + 1 HW proved most effective and also recorded lower population and dry weight of weeds followed by trifluralin 0.75 kg/ha + 1 HW and pendimethalin 0.75 kg/ha + 1 HW. Weed control efficiency and seed yield was higher under quizalofop-ethyl 0.05 kg/ha + 1 hand weeding as compared to other weed control treatments.

Key words: Herbicides, Integrated weed management, Sesame, Weed control efficiency, Weed flora

India is the world's largest producer of sesame accounting nearly 35% of the total production but its productivity is extremely low (368 kg/ha). Inadequate weed management appears to be one of the major constraints for such low productivity of sesame. Being a slow growing crop during seedling phase, weeds affect the growth of sesame and reduced the yield. The period from 15 and 30 DAS is the most critical period of crop weed competition in sesame (Venkatakrishnan and Gnanamurthy 1998). In oil seed crops, yield loss due to weed competition varied from 16 to 68% (Varaprasad and Shanti 1993). Hand weeding is commonly practiced by the farmers as an effective method of weed control but incessant rain, high wages and timely unavailability of labourers at weeding peaks are also some of constraints. Therefore, integrated weed management (manual as well as chemical weeding) is most efficient and acceptable approach to combat with the weed control problems. Hence, present study was under taken.

MATERIALS AND METHODS

Field studies were conducted during rainy season of 2009 and 2010 at RVSKVV, College of Agriculture, Farm, Gwalior. The soil of the experimental was sandy loam with (7.97 P^H), available N 237 kg/ha, P_2O_5 23.73 kg/ha and K_2O 477.22 kg/ha. There were Ten treatments (Table 1). The experiment was laid down in randomized block design with three replications. Sesame variety '*JT 8*' was sown on 25th July during 2009 and 23rd July 2010 in row 30 cm apart, using 5 kg/ha seeds. Crop was fertilized 40 kg N, 30 kg P_2O_5 and 20 kg K_2O as basal dose. The N,P and K nutrients were applied through urea, diamolium phosphate (DAP) and muriate of potash, respectively. Trifluralin was incorporated in depth of 2-3 cm top soil layer before sowing, pendimethalin as pre-emergence and quizalofop-ethyl was applied at 20 DAS with hand knapsack sprayer fitted with flat fan nozzle at spray volume of 800 l/ha. Weed density and weed dry weight were recorded at 30, 60 DAS and harvest stage with the help of 0.5 x 0.5 m quadrate by throwing randomly at three places in each plot. Weeds were removed and counted species wise. After drying in hot air oven (60 ± 1^0C for 24 hours), weed dry weight was recorded and reported as per square meter. Weed control efficiency was also calculated as suggested by Maity and Mukherjee (2011). The economics was calculated on the basis of prevailing market rates of agriculture produced and cost of cultivation treatments wise.

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RESULTS AND DISCUSSION

Effect on weeds

Among the weed flora, *Phyllanthus niruri, Commelina benghalensis, Digera arvensis, Cyperus rotundus*, and *Echinochloa crusgalli* were recorded. All the weed control treatments proved significantly effective in reducing the population and dry weight of weeds as compared to weedy check. Two hand weeding (at 15 and 30 DAS) significantly reduced weed population at 30, 60 DAS and harvest stage over rest of treatments. Although, this treatment was found on par with quizalofop-ethyl in combination with one hand weeding in case of weed dry weight. Yadav (2004) also reported lowest weed dry matter and highest weed control efficiency under pre-emergence application of pendimethalin 0.5 kg/ha + 1 HW at 40 DAS. Among integrated weed management practices, quizalofop-ethyl + 1 HW produced lower weed population which was significantly superior over remaining treatments except trifluralin and pendimethalin with one hand weeding.Whereas, they were also on par among themselves. Among alone herbicides, quizalofop-ethyl recorded lowest value of weeds population, which was at par with trifluralin and both were significantly superior over pendimethalin. Weed control efficiency of treatments varied from 61.3 to 95.6%. Two hand weeding at 15 and 30 DAS resulted in higher value of weed control efficiency followed by quizalofop-ethyle + 1 HW, trifluralin + 1 HW and pendimethalin + 1 HW at 30 DAS. Sootrakar *et al.* (1995) also reported that HW 3 times (25, 40 and 55 DAS) resulted in the lowest weed counts and the highest weed control efficiency (98.8%).Weed control treatment may be attributed to kill and check the growth of weeds due to application of herbicides resulting in reduction in dry matter and increased weed control efficiency. Similar, finding was also reported by Chauhan and Gurjar (1998).

Effect on crop

All the weed control treatments produced significantly more capsules/plant, seed/capsule, test weight and seed yield kg/ha than weedy check. Two hand weeding at 15 and 30 DAS resulted in significantly highest value in capsules/plant, test weight and seed yield over rest of the treatments. Although this treatment was found on par with trifluralin + 1 HW and quizalofop-ethyle + 1 HW in case of seeds per capsule. Narkhede (2000) observed that cul-

Table 1. Effect of weed control treatments on weed population, weed dry matter and weed control efficiency (%) in sesame (pooled data of two years)

Treatment	Dose (kg/ha)	Weed population (no./m^2)			Weed dry weight (g/m^2)	Weed control efficiency (%)
		30 DAS	60 DAS	Harvest		
Trifluralin (PPI)	0.75	29.8	17.3	13.8	60.4	66.7
Pendimethalin (PE)	0.75	44.8	25.9	17.2	70.2	61.3
Quizalofop-ethyl at 20 DAS	0.05	28.4	17.5	13.4	63.1	65.2
Trifluralin + 1 HW at 30 DAS	0.75	6.8	8.8	5.5	34.2	81.2
Pendimethalin + 1 HW at 30 DAS	0.75	10.5	10.8	7.8	42.5	76.6
Quizalofop-ethyl + 1 HW at 30 DAS	0.05	7.5	7.2	4.2	28.5	84.3
Trifluralin + one hoeing at 30 DAS	0.75	15.4	11.7	8.2	51.16	71.9
Pendimethalin + one hoeing at 30 DAS	0.75	18.3	13.6	10.3	53.9	70.3
Weed free (2 HW at 15 and 30 DAS)	-	4.4	2.7	2.1	8.0	95.6
Weedy check	-	109.9	86.3	51.2	181.4	0.0
LSD (P=0.05)		2.25	2.14	1.37	21.0	-

Table 2. Effect of different weed control treatments on yield attributes, yields, net returns and B:C ratio of sesame (pooled data of two years)

Treatment	Dose (kg/ha)	No. of capsules/ plant	No. of seeds/ capsule	Test weight (g)	Seed yield (t/ha)	Net returns (x10^3 ₹/ha)	B:C ratio
Trifluralin (PPI)	0.75	25.4	48.8	2.46	0.65	19.50	2.90
Pendimethalin (PE)	0.75	25.5	49.8	2.39	0.61	17.02	2.59
Quizalofop-ethyl at 20 DAS	0.05	28.2	50.6	2.48	0.65	18.59	2.68
Trifluralin + 1 HW at 30 DAS	0.75	33.3	52.4	2.71	0.88	28.74	3.46
Pendimethalin + 1 HW at 30 DAS	0.75	29.4	51.4	2.65	0.81	24.70	3.04
Quizalofop-ethyl + 1 HW at 30 DAS	0.05	34.0	52.6	2.70	0.88	27.84	3.23
Trifluralin + one hoeing at 30 DAS	0.75	27.6	49.4	2.57	0.75	23.39	3.12
Pendimethalin + one hoeing at 30 DAS	0.75	28.2	48.9	2.55	0.72	21.26	2.85
Weed free (2 HW at 15 and 30 DAS)	-	38.1	54.4	2.77	0.99	31.98	3.42
Weedy check	-	20.3	41.8	2.25	0.41	9.79	2.06
LSD (P=0.05)		1.78	2.50	0.05	0.04	-	-

tural practices *i.e.* two hand weeding and hoeing in sesame significantly gave higher seed yield than rest of the integrated weed management practices. Among integrated weed management practices, quizalofop-ethyle with one HW produced higher number of capsules/plant, seeds/capsule, test weight and seed yield kg/ha which were statistically at par with trifluralin with 1 HW followed by pendimethalin + 1 HW treatments. Among herbicide alone, quizalofop-ethyle recorded significantly higher number. of capsules/plant over treatments trifluralin and pendimethalin. However, this treatment was on par with trifluralin in case of test weight and seed yield kg/ha. While in case of seeds/capsule, the affect was found to be non-significant. Application of herbicide and cultural practices resulting in reduced crop weed competition and creating good environment for better growth of the plant which gave higher yield of sesame. These results are in conformity with the findings of Sootrakar *et al.* (1995)

Monetary returns

All the weed control treatment gave higher monetary returns compared to weedy check because of reduced crop weed competition. Saharia and Bayon (1996) recorded that in sesame integrated control resulted in an increased in net return (₹ 4396/ha) as compare to no weeding. Two hand weeding at 15 and 30 DAS resulted highest net return (₹ 31980/ha) followed by trifluralin 0.75 kg/ha - + 1 HW, quizalofop-ethyl 0.05 kg/ha + 1 HW and pendimethalin 0.75 kg/ha + 1 HW While B:C ratio was higher under trifluralin 0.75 kg/ha + 1 HW (3.46) *fb* 2 HW at 15 and 30 DAS and quizalofop-ethyl 0.05 kg/ha + 1 HW at 30 DAS because cost of treatment of trifluralin + 1 HW at 30 DAS was lower as compared to 2 HW at 15 and 30 DAS treatment. Narkhede *et al.* (2000) obtained similar results.

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Relative effects of pre-treatment of ethephon, glyphosate and paraquat on glyphosate translocation and potency in control

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ABSTRACT

Experiments were conducted to standardize duration and level of senescence required to enhance translocation of glyphosate in *Cyperus rotundus*. Senescence was induced by paraquat (500 g/ha) or glyphosate (1.312 kg/ha). Decrease in total chlorophyll and membrane damage was more in herbicide treatments than ethephon. Periodic leaf RWC remained unchanged in control but decreased periodically in ethephon and paraquat. Significantly higher RWC was observed at 72 h in glyphosate than paraquat. Maintenance of membrane integrity and high RWC in glyphosate at 72 h than paraquat facilitated mobility of glyphosate. Total biomass reduction bioassay indicated that senescence induced by glyphosate (1.312 kg/ha) pre-treatment 48 hr followed by (*fb*) glyphosate (1.312 kg/ha) showed significantly more efficacy (7%) than pre-treatment with benzyl adenine (synthetic cytokinin) *fb* glyphosate which reduced efficacy by 9% compared to glyphosate alone.

Key words: Glyphosate, Herbicide translocation, Leaf senescence, Nutrient scavenge

Leaf senescence is a highly regulated process involving senescence associated genes which degrades chloroplasts followed by lipid degradation and nucleic acid. Ethephon produces ethylene, a senescence hormone. Paraquat inhibits photosynthesis, accepts electrons and transfers them to molecular oxygen, produce reactive oxygen species (ROS) leading to membrane damage. Experiments were carried out to assess the role of senescence induced by ethylene or herbicides on translocation and efficacy of glyphosate as reflected by biomass reduction bioassay, and herbicide induced senescence was compared with ethephon induced senescence on leaf physiology of *Cyperus rotundus*.

MATERIALS AND METHODS

Experiments were conducted to standardize duration and level of senescence required to enhance translocation of glyphosate and to assess role of herbicide induced senescence on leaf physiology. Medium size (2 g/tuber) single tuber of *C. rotundus* per pot were sown in pots filled with soil : sand : FYM (6:3:1) mixture. Pots were irrigated as and when required. Forty-five days old plants were used for senescence experiments. The best duration of senescence was assessed by spraying glyphosate (1.312 kg/ha) and allowed to senescence for varied durations (0, 24, 48, 72 and 15 days), *fb* different glyphosate concentration, *viz.* 0, 0.33, 0.66, 0.984 and 1.31 kg/ha for each set of varied duration of senescence. After 45 days of first spray, total biomass of *C. rotundus* response (logit) was regressed to varied concentration of glyphosate.

After identifying the best senescence induction duration (48 h), the level of glyphosate required for senescence for better control of *C. rotundus* was standardized. Senescence induced by varied glyphosate dosages (0, 0.32, 0.65, 0.98 and 1.31 kg/ha) for 48 h followed by same glyphosate dosages was sprayed to each set of varied level of senescent plant. After 45 days from second spray, the total biomass was recorded and logit response of different level of senescence to varied concentration of glyphosatewas assessed. The total numbers of pots were 75 with three replications for each treatment combination for both level and duration experiments.

Mean and standard deviation of percent biomass (g/plant) over control was computed and converted into logit value. Logit (eq. 1) response was regressed with logarithmic concentration of glyphosate. Thus, dose-response regression lines were obtained with goodness of fitness (Devendra *et al.* 1997). Based on shift of regression line best duration and level of senescence has been estimated.

Logit Y = a + b ($\log_e$(X)) –(1), where Logit Y = {(D-Y/Y-C)}, D and C indicate maximum (100) and minimum (0) per cent response over control, Y denotes percentage of observed biomass over control while a and b represent intercept and slope of regression line and X is the $\log_e$ concentration of glyphosate (g/ha).

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To 45 days old *C. rotundus* induced senescence by spraying glyphosate (1.312 kg/ha), or paraquat (500 g/ha) and ethephon (5000 ppm) leaf chlorophyll content, membrane integrity and RWC was assessed at Periodic 24, 48 and 72 h.

Fresh leaf samples were collected and kept immersed in acetone and dimethyl sulphoxide (DMSO) of 1:1 proportion for 24 h in vacuum, filtered and optical density of the extract was measured at 652 nm (Hiscox and Israelstam 1979) and expressed as mg/g (eq.1).

Total chlorophyll (mg/g) = OD at 652 x (volume made up/1000) x 1/fresh weight (g) .... (1)

Cell membrane integrity was measured by leakage of electrolyte (Sullivan and Ross 1979). Ten leaf dishes from periodic fresh leaf samples were incubated in 10 ml of distilled water for 2 h. Leakage of electrolyte into decanted water was measured at 273 nm (initial OD). Water was transferred back and respective leaf discs was boiled for 7 M, cooled and filtered and leakage of electrolyte into decanted water was measured at 273 nm (final OD) and expressed as per cent (eq. 2).

Per cent leakage = (initial OD/final OD) x 100 .... (2)

Periodic fresh leaves were collected and fresh weight was recorded, then leaves were transferred to petri-dish containing water. leaves were allowed to imbibe water for 4 h and than recorded turgid weight. The leaves were oven dried at 80°C for 48 h, weighted and RWC were estimated using eq. 3 (Barrs and Weatherly 1962).

RWC = (fresh weight - dry weight)/(turgid weight - dry weight) x 100 .... (3)

RESULTS AND DISCUSSION

Regression analysis showed that glyphosate induced senescence at 48 h had logit biomass to glyphosate and response regression line drastically reduced compared to other duration of senescence (Fig. 1). The slope between different durations regression lines was not same and biomass was drastically reduced for all glyphosate induced regressions compared to non-senescent (0 glyphosate regression). Highest slope of 1.08 was noticed by glyphosate (1.31 kg/ha) induced senescence.

The logit biomass - glyphosate (1.31 kg/ha) at 48 h level of senescence regression line separated out with other levels of glyphosate regression lines (Fig. 2) and the shift was non-parallel, indicating that senescence induced 48 h period responded drastic reduction of biomass for glyphosate of 1.31 kg/ha and more superior to lower dose of glyphosate.

Total chlorophyll content drastically reduced in herbicidest than ethephon - natural senescence inducer (Fig. 3). Total chlorophyll content at 24 h of ethephon treated leaf was on par with control and 72 h later less than control but more than glyphosate and paraquat. This indicateed that ethephon induced senescence was superior to glyphosate and paraquat with intact chlorophyll thus has higher energy for scavenging.

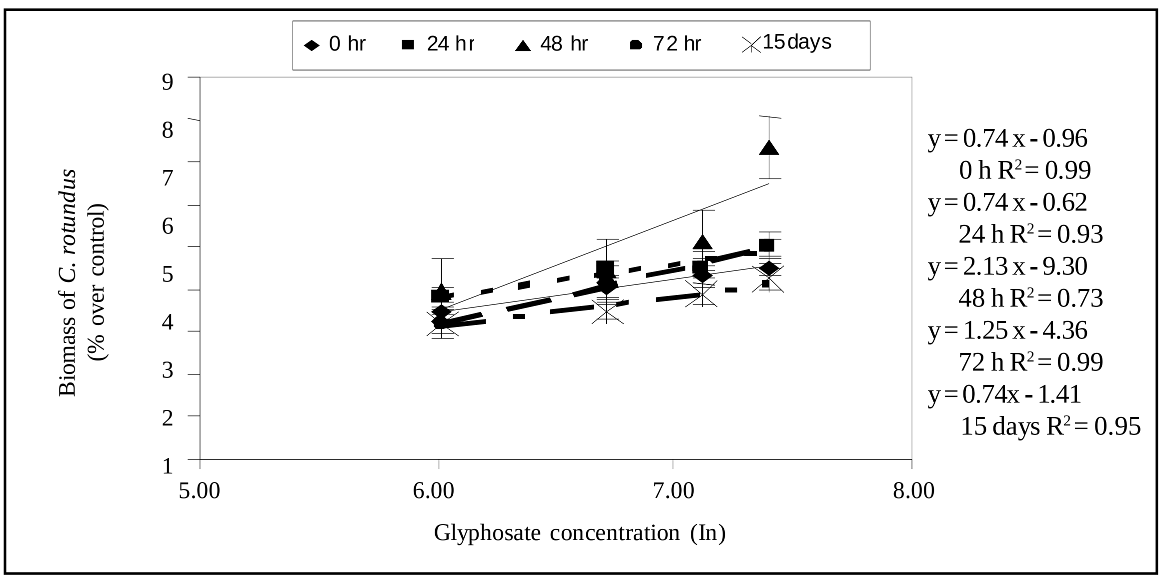

Fig. 1. Effect of varied period of senescence by glyphosate on biomass of *Cyperus rotundus* (error bar indicates replication variation)

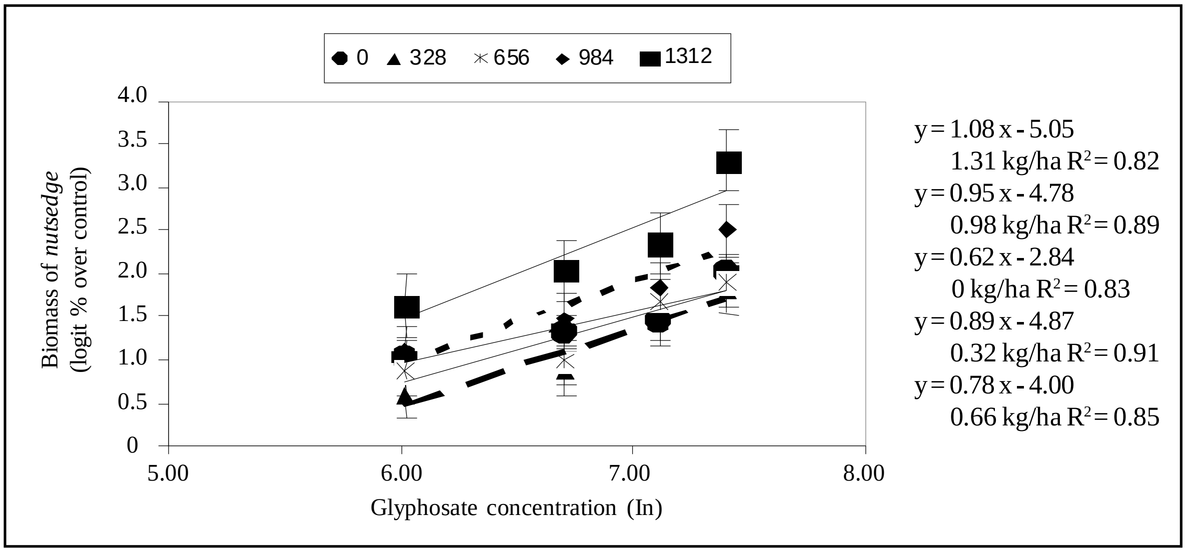

Fig. 2. Effect of level of glyphosate induced senescence for 48 h on biomass of *Cyperus rotundus* (error bar indicates replication variation)

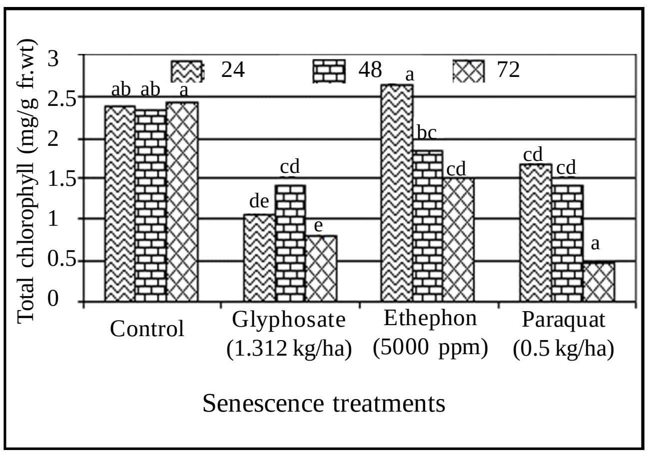

Fig. 3. Effect of glyphosate, paraquat and ethephon on total chlorophyll content in *Cyperus rotundus*

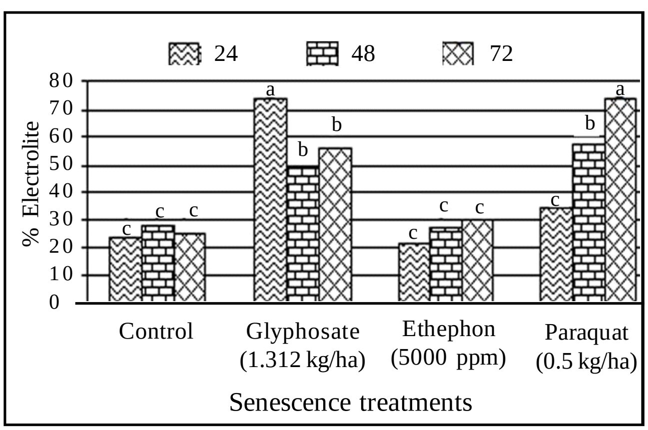

Fig. 4. Effect of glyphosate, paraquat and ethephon on membrane integrity in *Cyperus rotundus*

Membrane damage was much higher in case of paraquat and glyphosate than ethephon and control (Fig. 4). Initial membrane damage 24 h was more in glyphosate than paraquat, but later at 72 h significantly less damage compared to paraquat. Thus glyphosate induced senescence was better than paraquat but both were inferior to ethephon in membrane damage. Membrane intactness played an important role in efflux of herbicide into phloem depends on plasma membrane transporter (phPT1). Phosphate transporters are up-regulated during leaf senescence.

Leaf RWC in control treatment remained same and superior to herbicides and ethylene. Leaf RWC of glyphosate was on par with ethephon at all stages of senescence but had higher RWA than paraquat especially at 72 h glyphosate (Fig. 5). Thus glyphosate maintained RWC on par with ethephon which helped in enhanced phloem loading, translocation at 48 h after glyphosate application.

Biomass reduction over control was 96.5, 90.0 and 88% in 1.312+1.312, 3.28 and 1.312 kg/ha, respectively (Table 1). These data suggest that senescence induced by glyphosate at 48 h, *fb* glyphosate application enhanced the glyphosate efficacy. Exposure to ethylen eaccelerates leaf senescence whereas BA delays senescence (Grbic and Bleecker 1995). Total biomass reduction was assessed with anti-senescence BA (10 µm) pre-treatment 48 h, *fb* glyphosate application. BA treatment reduced glyphosate efficacy by nine per cent compared to glyphosate (1.312 kg/ha). Thus, glyphosate induced leaves senescence at 48 h contribute 9% more to glyphosate efficacy by enhanced translocation owing to phosphate transporters are up-regulated during leaf senescence. During fall season (Novem-

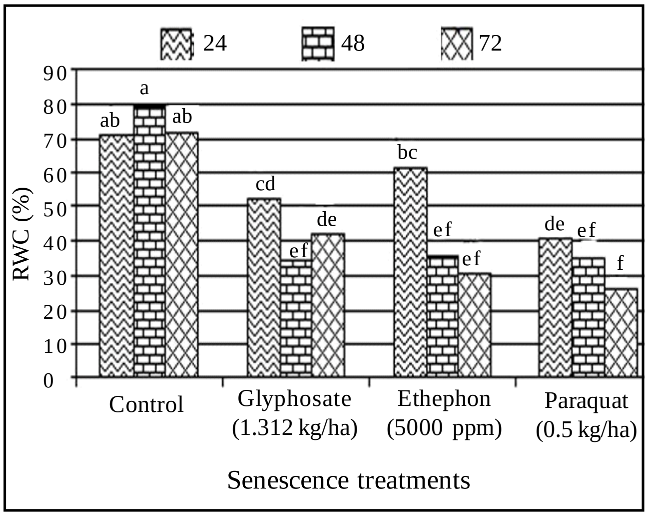

Fig. 5. Effect of glyphosate, ethephon and paraquat on relative water content in *Cyperus rotundus*

Table 1. Effect of herbicide induced senescence on biomass of *C. rotundus*

Treatment	Total biomass (g)
Control	111.0[a]
Glyphosate 3.28 kg/ha	10.9[cd]
Glyphosate 1.312 kg/ha	13.2[c]
Glyphosate 1.312 kg/ha + after 48 h 1.312 kg/ha	3.9[d]
BA 10 µm + glyphosate 1.312 kg/ha	22.7[b]
LSD (P=0.05)	8.5

ber to February), glyphosate had lowest ED_{75} for control of *C. rotundus* (142 g/ha) than other growing seasons (329-1699 g/ha) due to scavenging of nutrients from senescent foliage (Devendra *et al.* 2005).Translocation of ^{14}C-glyphosate out of fed leaf was 10 and 5.8% during February and June, respectively (Chandranaik *et al.* 2004). Glyphosate (1.3 kg/ha) induced senescence maintained membrane integrity and high RWC than paraquat, which helped in enhanced phloem loading, translocation of glyphosate.

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Adsorption of oxadiargyl and butachlor on soil particle size separates

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ABSTRACT

Study on adsorption of oxadiargyl and butachlor was carried out on soil particle size separates of four type of soils from different agroclimatic zones of Andhra Pradesh using batch equilibration technique. Irrespective of the particle size, the per cent adsorption was more in vertisols than alfisols. Among four soils studied, maximum adsorption (59.7 µg/g) was observed in 0.05 mm soil separate of vertisol-2, whereas minimum adsorption of 4.5 µg/g was observed in 2 mm soil of alfisol-1. The amount adsorbed increased with increase in initial concentration and reached a plateau. The isotherms were mainly parabolic in nature with 'S' shaped tendency. The S-shape reflected the initial resistance to the adsorption of herbicides, to overcome later by the cooperative effect of adsorbed molecules. Soil low to medium in organic carbon, has a tendency to give S-shaped isotherms on account of their hydrophilic nature as compared to soil high in organic carbon which tend to be hydrophobic. The adsorption maxima was positively and significantly correlated with organic carbon content. Freundlich 'K_f' values which indicate the extent of binding of herbicide to the soil constituents were positively and significantly correlated with organic carbon, clay content and clay + organic carbon.

Kew words: Adsorbtion, Butachlor, Herbicide, Oxadiargil, Soil particle size

Adsorption is an important process for determining the ultimate fate of organic chemicals in soils because detoxification mechanism such as degradation, metabolism, microbial uptake and mobilization are operative only on the non-sorbed fraction of the molecules. Pesticide sorption refers to the bonding of the chemical to sites on mineral or organic surfaces which controls the quantity of herbicides in soil solution and thus determines its bioavailability and mobility in soil. Pesticide removal through run off is another pathway of removal from crop lands. During runoff events, the clay and silt sized fractions of soil are relatively carried off the field along with the runoff water resulting in the enrichment of these fine sized fractions at the edge of the field. These fine sized fractions are characterized by high specific area and organic carbon content. Pesticide sorption coefficient for these fractions are expected to be much higher than the whole soil.

It has been shown that it is possible to estimate the sorption capacity of different particle size fractions from the knowledge of their organic carbon content and Freundlich constant in a single or limited number of fractions (Karichkoff 1981, Nked-Kizza *et al.* 1983, Shanti *et al.* 1997). Therefore, it is necessary to characterize herbicide sorption not only on whole soil but also on various soil separates. The present investigation was undertaken to characterize the adsorption of technical grade herbicides oxadiargyl (5-tert-butyl-3-[2,4- dichloro- 5-(prop-2-ynyloxy)phenyl]-1,3,4-oxadiazol-2(3H)-one) and butachlor(N-(butoxymethyl)-2-chloro-N-2,6-(diethylphenyl) (acetamide) on various size particles of four selected soils from the different agro-climatic zones of Andhra Pradesh.

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MATERIALS AND METHODS

Experiment was conducted at All India Coordinated Research Programme on Weed Control, Acharya N G Ranga Agricultural University, Hyderabad, with two alfisols (A1: ARS, Anantarajupeta and A2: Karimnagar) and two vertisols (V1: RARS, Lam and V2: Kurnool) of Andhra Pradesh during 2007-2008. Representative soil samples were collected from the surface horizon with no background of oxadiargyl and butachlor application. The soils were air dried and passed through a 2 mm sieve. The physico-chemical properties of these soils were analysed by using standard procedures (Jackson 1973).

The soil samples were fractioned to 1 mm, 0.5 mm and 0.25 mm by dry sieving sieves. The < 50 m fraction consisting of silt plus clay was fractionated from these soils by wet sieving method (Jackson 1956). Suitable quantity of soil was suspended in distilled water for 24 h and then stirred on a mechanical stirrer for 30 minutes. The suspension was sieved through 50 micro sieve and the residue was again sieved with fresh amount of distilled water till the filtrate was free of silt plus clay. The filtered suspension was transferred to reagent bottles and allowed to stand overnight for settling of silt plus clay and was air dried under shade, pounded and stored for further studies. The procedure used for studying adsorption on soil particle size separates ensured minimal destruction of chemical nature of soil and this procedure was earlier used by Shanti *et al.* (1997) and Nagamadhuri (2003).

Technical grade oxadiargyl (98% purity) and butachlor (86.87% purity) obtained from M/S Bayer Crop Science, Mumbay and from M/s Hyderabad Chemicals Balanagar, Hyderabad, respectively were used for the present study. Adsorption studies were conducted using the batch equilibration technique.

Two of each 1 mm, 0.5 mm, 0.25 mm and 0.5 mm sieved soils of two selected vertisols and alfisols were equilibrated with 20 ml of oxadiargyl solutions of various concentrations ranging from 0,5,10,15,20,25,30 and 35 µg/ml and 0, 10, 20,30, 40, 50, 60, 70, 80 and 90 µg/ml concentrations of butachlor, respectively in 20 ml capacity bottles for 24 h with intermittent shaking at 27 ± 2^{o}C. Ionic strength was maintained at 0.01 M $CaCl_2$. After 24 h, the slurry was centrifuged at 5000 rpm for 15 minutes. In all the adsorption studies 0.01 M $CaCl_2$ was used as background electrolyte to suppress non-specific adsorption and to simulate natural conditions found in many soils. Further more, it facilitated the separation of solid material from aqueous solution after equilibration (Borggaard Striebig 1998). Identical soil blanks minus the herbicides were maintained. The absorbance for each treatment and the corresponding blank were measured at 226 nm for oxadiargyl and 410 nm for butachlor. The difference was taken as the actual equilibrium absorbance for which the concentration was calculated with reference to the calibration curve. The amount of herbicide adsorbed per gm of soil was calculated from the difference in the initial and equilibrium concentrations. The supernatant was drawn and the oxadiargyl and butachlor concentrations were determined using UV spectrophotometer at 226 and 410 nm and the quantity adsorbed was calculated.

RESULTS AND DISCUSSION

Physico-chemical properties of of vertisol and alfisol revealed low content of organic content in respect of whole soil,which was 0.45 and 0.85 g/ka in alfisol and vetisole, respectively (Table 1). Results revealed that the organic carbon content of 2 mm fraction varied from 3.13 (V_1) to 8.51 g/kg (A_1), 1 mm fractions varied from 4.65 g/kg (A_1) to 9.32 g/kg (V_1); whereas in 0.5 mm fractions organic carbon content varied from 7.12 g/kg (A_1) to 10.86 g/kg (V_1) 0.25 mm fractions 8.86 g/kg (A_1) 11.24 g/kg (V_1) and in 0.05 mm fractions 9.46 g/kg (A_1) to 12.61 g/kg (V_1) (Table 2).

Adsorption of oxadiargyl on soil separates

The adsorption isotherms for various sized fractions were parabolic in nature with S-shaped character indicated a stronger initial competition of water molecules to the surface as compared with the herbicide (Fig. 1 to 4). The extent of adsorption of oxadiargyl (varied in 2 mm sieved soil to 0.05 mm sieved soil in each sample studied) was 4.5 to 11.34 µg/g (V_1); 21.25 to 59.71 µg/g (V_2); 15.36 to 27.65 µg/g (A_2) and 12.04 to 30.34 µg/g (A_1). Among four soils studied, maximum adsorption (59.71 µg/g) was observed in 0.05 mm soil separate of vertisol-2, whereas lowest adsorption of 4.5 µg/g was observed in 2 mm soil of alfisol-1. The amount adsorbed increased with increase in initial concentration and reached a plateau. The isotherms were mainly parabolic in nature with 'S' shaped tendency to reach surface saturation in the concentration range studied (Fig. 1 and 2). The data was fitted to Freundlich equation.

Freundlich constants K_f, n and K_{foc} were increased with decreasing particle size fraction. The K_{foc} values for 2 mm sieved soils was less than the obtained for individual soil fractions, while n values were almost similar for all separates. K_f values varied for different size fractions, while n values were quite similar. Similar results were reported by Shanti *et al*. (1997) and Nagamadhuri (2003).

Adsorption of butachlor on soil separates

The extent of adsorption of butachlor was varied in 2 mm sieved soil to 0.05 mm sieved soil in each sample studied was 32.86 to 62.43 µg/g (V_1); 61.63 to 98.61 µg/g (V_2); 57.60 to 99.07 µg/g (A_2); and 35.20 to 59.84 µg/g (A_1). The adsorption isotherms were 'S' shaped (Fig. 3 and 4) confined mainly to the initial stages of adsorption and followed Freundlich adsorption equation.

Freundlich constants K_f,n and K_{foc} were increased with decreasing particle size fraction. The K_{foc} values for 2 mm sieved soils was less than the obtained for individual soil fractions, while n values were almost similar for all separates. The K_f values in 1 mm fractions varied from 0.48 (A_1) to 3.16 (V_1); in 0.5 mm fractions 0.72 (A_1) to 3.81 (V_1); in 0.25 mm fractions 0.91 (A_1) to 4.11 (V_1) and in 0.05 mm fractions 1.16 (A_1) to 4.68 (A_4). The K_{foc} values were also followed the same trend of an increase in the K_{foc} with decrease in soil particle size fraction.

When the amount of herbicide adsorbed per gram of organic carbon was plotted for all the fractions, a single coalesced isotherm was obtained. These values were much closer to K_{foc} and 1/n values of the individual fractions, suggesting that organic matter content of soil separates is

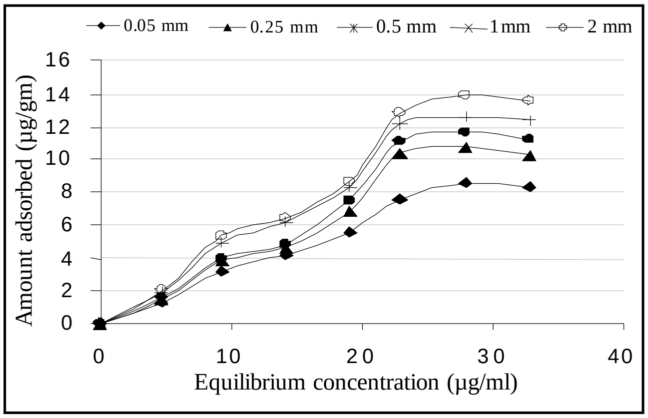

Fig. 1. Adsorption of oxadiargyl in Alfisol-1

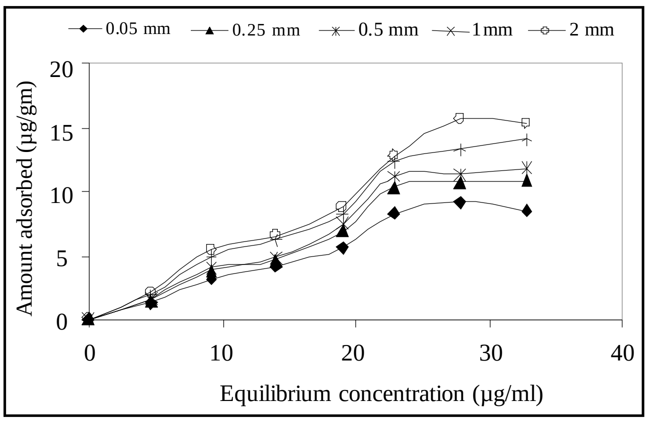

Fig. 2. Adsorption of oxadiargyl in Vertisol-1

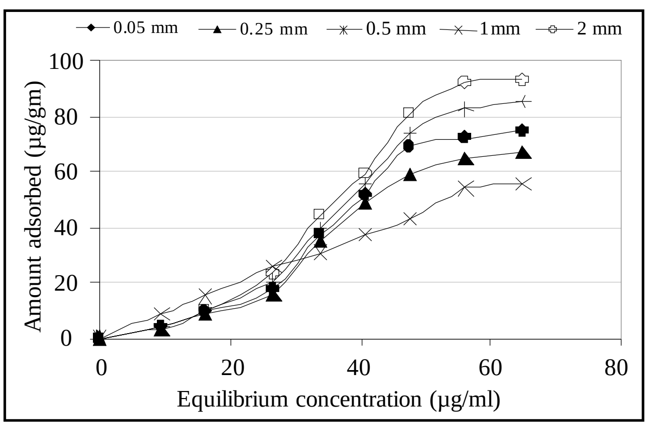

Fig. 3. Adsorption of butachlor in Alfisol-2

responsible for the adsorption of oxadiargyl and butachlor on soils and their particle size separates (Shanthi *et al.* 1997, Nagamadhuri 2003).

Further, it has been shown that it is possible to estimate sorption capacity of different particle size fractions from the knowledge of organic carbon content in a limited or a number of fractions. Similar studies were conducted by Shanti *et al.* (1997) for adsorption of metaxuron and isoproturon; Nagamadhuri (2003) for atrazine and isoproturon, Nkedi- kizza *et al.* (1983) for the adsorption of 2,4,5–T and diuron. The organic carbon content increased with decrease in particle size (Table 2). Similar observations were made by Rai *et al.* (2000). It has been shown that herbicides can be removed through run off process, during which the finer sized colloidal fractions are selectively carried off the field with the stream off water. These fine size fractions of soils are characterized by high surface area and organic carbon content. Hence, it is expected that the extent of adsorption on these fractions to be higher than those for whole soils. It is, therefore essen-

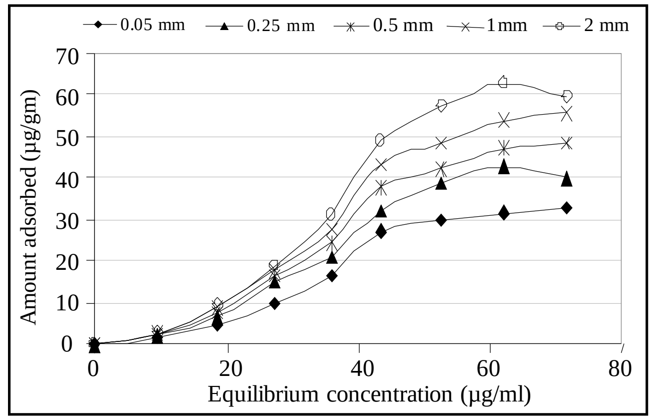

Fig. 4. Adsorption of butachlor in Vertisol-2

Table 1. Physico-chemical and textural characteristics of four selected soils of Andhra Pradesh

Soil	pH	EC (dS/m)	OC (g/kg)	Texture (%)		
				Sand	Silt	Clay
Vertisol						
V1: RARS, Lam	7.82	0.22	0.85	55.8	11.0	33.2
V2: Kurnool	8.65	0.29	0.45	84.4	2.00	13.60
Alfisol						
A1: ARS, Anantarajpeta	7.71	0.24	0.67	74.4	3.00	12.60
A2: Karimnagar	6.57	0.16	1.06	76.0	0.4	23.6

Table 2. Organic carbon content (g/kg) in soil separates of selected alfisol and vertisol

Soil/size fraction	2 mm	1 mm	0.5 mm	0.25 mm	0.05 mm
Vertisol					
V1: RARS, Lam	3.13	4.65	7.12	8.86	9.46
V2: Kurnool	5.30	6.60	8.40	9.10	10.30
Alfisol					
A1: ARS, Anantarajpeta	8.51	9.32	10.86	11.24	12.61
A2: Karimnagar	4.53	5.86	7.35	9.64	10.82

Table 3. Correlation coefficients between soil parameters and adsorption of herbicides

Soil parameter	Vertisols		
	K_f	n	K_{foc}
Oxadiargyl			
pH	-0.643	0.204	0.016
OC	0.322	-0.197	-0.070
Clay	0.632*	0.083	0.008
Clay+OC	0.623*	0.076	0.003
Butachlor			
PH	0.829	0.364	0.622
OC	0.099	0.522	0.455
Clay	0.902	0.277	0.565*
Clay+OC	0.901	0.296	0.543*
	Alfisols		
	K_f	n	K_{foc}
Oxadiargyl			
pH	0.122	0.124	0.006
OC	0.290	0.249	-0.136
Clay	0.450	0.044	0.183
Clay+OC	0.460*	0.050	0.182
Butachlor			
PH	-0.385	0.2.19	-0.401
OC	-0.240	0.283	0.593
Clay	0.886	0.418	0.670
Clay+OC	0.889*	0.416	0.666

tial not only to characterize the extent of adsorption on whole soils but also on various particle size separates of soil.

Correlation coefficients

Simple correlations were worked out between the extent of adsorption, Freundlich constant K_f and k with soil properties. The adsorption maxima (k) was positively and significantly correlated with organic carbon content. The positive and significant correlation between adsorption parameters and clay content indicated the importance of clay content to the adsorption of oxadiargyl and butachlor (Table 3). Another important finding that could be observed was a highly significant and positive correlation between adsorption parameter and clay + OC, indicating that the clay intimated some modifications of their adsorption capacity and they may complement one another on the role of pesticide adsorption beyond that observed in pure inorganic clay systems. Similar results were reported by Raman and Reddy (1993) and Arvind *et al.* (2000). The role of organic carbon in the adsorption of oxadiargyl and butachlor is consistent with reduced biological activity of these herbicides in soils with high organic carbon content. Organic carbon content has been shown to be the first critical parameter positively and significantly correlated with adsorption of above herbicides in soils (Johnson and Sims 1993, Moreau and Mouvet 1997). Clay content of soil is said to be another critical parameter in adsorption of oxadiargyl and butachlor in soils and its role is often masked by that of organic matter and this can become a significant factor when organic carbon content decreases (Arvind *et al*. 2000, Scrano *et al*. 2004). Hitherto, it was opined that organic matter plays an important role in the adsorption of pesticides in soil, where organic matter content exceeds 6 per cent. But in the case of tropical and sub tropical soils, where organic mater content seldom exceeds 2 per cent, clays have been found to be the predominant factor in the adsorption of soil applied herbicides. However, present study revealed that in soils clay and organic matter exists together in the form of clay organo-complexes and these complexes have an important role to play in the adsorption of soil applied herbicides. Raman and Rao (1984) demonstrated that the adsorption of herbicides on model clay-organo complexes was much higher than the corresponding homoionic clays suggesting that the naturally occurring clay-organo complexes in soils play a very significant role in the adsorption of soil applied herbicides. Thus it is possible to obtain significant and positive correlations of adsorption parameters with clay + organic carbon.

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Presence of heavy metals in medicinal weed species grown at contaminated sites

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ABSTRACT

Concentration of heavy metals like Cd, Pb, Ni, Co, Zn, Mn and Fe were tested in medicinal weeds growing at heavy metal contaminated site around Jabalpur during winter season of 2008. Except *Vicia sativa,* higher concentration of Cd was observed in weeds like *Sonchus arvensis* (3.07 µg/g), *Alternanthera viridis* (1.56 µg/g), *Anagalis arvensis* (1.5 µg/g), *Melilotus indica* (1.30 µg/g), *Eclipta alba* (1.14 µg/g), *Chenopodium album* (1.15 µg/g), *Cichorium intybus* (1.05 µg/g), *Lathyrus sativa* (0.77 µg/g). Copper concentrations in plant was higher than prescribed standard limit, *viz. Amaranthus viridis* (*46* µg/g), *Ageratum conyzoides* (22 µg/g), *Polygonum persicaria* (37 µg/g), *Commelina communis* (30 µg/g), *Alternanthera sessilis* (22 µg/g), *Solanum nigrum* (22 µg/g) and *Ipomoea aquatica* (21 µg/g) . Ni and Zn contents exceeded the permissible limit in shoots of *Polygonum persicaria* (19,265 µg/g), *Commelina communis* (17,192 µg/g), *Alternanthera sessilis* (14,216 µg/g), *Amaranthus viridis* (17,488 µg/g), *Ipomoea aquatic* (15,238 µg/g), *Heliotropicum indicum* (16,89 µg/g), *Ageratum conyzoides* (15,127 µg/g), *Blumea lacera* (3,218 µg/g), *Solanum nigrum* (16, 191 µg/g), *Convolvulus arvensis* (15,125 µg/g) and *Cyperus iria* (15,177 µg/g) respectively. *Calotropis procera* (21 µg/g) exhibited higher Pb concentration exceeding prescribed standard limit. Conversely, Co content was found within prescribed limit in *Melilotus indica, Lathyrus sativa, Heliotropicum indicum, Cyperus iria, Convolvulus arvensis, Blumea lacera,* Pb below standard limit in *Hyptis suaveolens, Cichorium intybus, Lantana camara and Datura stramonium*, and no Pb was detected in *Alternanthera sessilis, Abutilon indicum, Xanthium strumarium, Anagalis arvensis.*

Key words: Contamination, Heavy metals, Standard limit, Weed species

Herbal medicines are in great demand in both developed and developing countries in primary health care because of their great efficacy having little or no side effects. The weeds prevailing abundantly in nature have been used since time immemorial as an indispensable basic raw material in the ayurvedic medicines. *Datura stramonium* is commonly used for the preparation of 'Kanaka taila' by many industries indigenously and for skeletal muscle relaxant in the western system of medicine respectively. This plant has contributed various pharmacological activities in Indian system of medicine like analgesic and antiasthmatic activities (Soni *et al.* 2012). However, indiscriminate collection of such weeds from the contaminated sites has deteriorated the quality of medicines. Saper (2004) reported that one out of five ayurvedic formulations from South Asian countries contains heavy metals. A single dose of 0.1-0.2 mg Cu/kg body weight can cause gastrointestinal disturbances in sensitive persons (Bosshard and Zimmerli 1994). Ingestion of Zn in large amount cause vomiting and diarrhea and neurological damages.

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World Health Organization (WHO) recommended that medicinal plants which form the raw materials for the finished products may be checked for the presence of heavy metals. WHO prescribed maximum permissible limits of toxic metals like Ar, Cd and Pb, which amount to be1.0, 0.3 and 10 ppm, respectively WHO (1998). Weeds species having medicinal value are indiscriminately grown at contaminated sites pose risk in the herbal products of theuraptic use. Their use may disturb the normal functions of central nervous system, liver, lungs, heart, kidney and brain, leading to hypertension, abdominal pain, skin eruptions, intestinal ulcer and different types of cancers.

An investigation was made to study the status of heavy metals (Ni, Co, Pb and Zn) in weedy plants grown in drains carrying waste water and along the roads in Jabalpur and adjoining areas.

MATERIALS AND METHODS

Out of 20 weed species of medicinal value, 11 from drains and 9 from the road sites were selected for the heavy metal uptake study in their shoot part. The weed samples were collected from the various drains including

Omati, Urdhana, Panagar, Pariyet and Karonda and road sites of National highway (Nagpur bypass), Adhartal, Khamaria, Mandla and Mazoli in Jabalpur city and its adjoining area during the winter season of 2008. Plants were washed in fresh running water to eliminate dust, dirt and possible parasites and then treated with deionized water and were dried in shade at 25-30°C. During sample preparation for analysis, necessary measures were taken in order to avoid any loss or contamination of heavy metals. For each species, 10-15 plants were collected randomly at maturity stage. The plant samples were thoroughly washed and dried at 70^{0}C for 48 h, ground and mixed thoroughly for metal analysis. Weed samples (1 g) were digested in concentrated nitric and perchloric acid (5:1) till a clear solution was obtained. The solution was filtered, reconstituted to the desired volume and analysed with atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Medicinal weeds observed in heavy metal contaminated soils along drains and roads were; *Vicia sativa, Chenopodium album, Melilotus indica, Lathyrus sativa, Anagallis arvensis, Alternanthera viridis, Sonchus arvensis, Eclipta alba, Cichorium intybus, Calotropis procera, Hyptis suaveolens, Cichorium intybus, Lantana camara, Alternanthera sessilis, Abutilon indicum, Xanthium strumarium, Anagalis arvensis, Datura stramonium.* Aquatic weeds including *Polygonum persicaria, Commelina communis, Alternanthera sessilis, Amaranthus viridis, Ipomoea aquatica, Heliotropicum indicum, Ageratum conyzoides, Blumea lacera, Solanum nigrum, Convolvulus arvensis and Cyperus iria* were observed in the waste water carrying drains in Jabalpur and adjoining areas.

The concentration of Cu, Ni, Zn, Mn, Cd and Pb in selected medicinal unmetals plants are depicted (Table 1 and 2). Higher concentration of Co (Table 1 and 2) was found in *Amaranthus viridis* (46 µg/g) followed by *Polygonum persicaria* (37 µg/g), *Ageratum conyzoide* (37 µg/g), *Commelina communis* (30 µg/g), *Alternanthera sessilis* (22 µg/g), *Solanum nigrum* (22 µg/g) and *Ipomoea aguatica* (21µg/g) grown in waste water carrying drain whereas *Vicia sativa* (78.4 µg/g), *Chenopodium album*, (31.8 µg/g) *Anagalis arvensis,* (20.5 µg/g), *Alternanthera viridis,* (22.6 µg/g) *Sonchus arvensis,* (41.4 µg/g) *Eclipta alba,* (48.9 µg/g), *Cichorium intybus* (28.2 µg/g) grown in contaminated field soil irrigated with waste water which was beyond the prescribed limit (20 µg/ g) as suggested by European Union. Conversely, the Co content was found within prescribed limit in weeds growing along the drain including *Heliotropicum indicum, Cyperus iria, Convolvulus arvensis, Blumea lacera* and in weeds growing in field including *Melilotus indica, Lathyrus sativa* respectively. High levels Cu may cause metal fumes fever with flue like symptoms, hair and skin decoloration, dermatitis, irritation of the upper respiratory tract, metallic taste in the mouth and nausea. FDA 1993 has recommended the lower limit of the acceptable range of Cu as 20 IJg/mg body weight per day (FDA 1993). Co deficiency results in anemia and congenital inability to excrete resulting in Wilson's disease (Bull and Cox *1994*).

The concentrationof Ni in different plants was higher in weed species, *Polygonum persicaria* (19 µg/g), *Commelina communis* (17 µg/g), *Alternanthera sessilis* (14 µg/g), *Amaranthus viridis* (17 µg/g), *Ipomoea aquatica* (15 µg/g), *Heliotropicum indicum* (16 µg/g), *Ageratum conyzoides* (15 µg/g), *Blumea lacera* (3 µg/g), *Solanum nigrum* (16 µg/ g), *Convolvulus arvensis* (15µg/g) and *Cyperus iria* (15 µg/g). The most common ailment arising from Ni is an allergic dermatitis known as Ni itch, which usually occurs when skin is moist. Further Ni has been identified as a suspected carcinogen and adversely affects lungs and nasal cavities. Although Ni is required in minute quantity for body as it is mostly present in the pancreas and hence plays an important role in the production of insulin. Its deficiency results in the disorder of liver (Pendias and Pendias 1992). EPA has recommended daily intake of Ni below be <1 mg beyond which it is toxic (McGrath and Smith 1990).

High concentration of Zn was found in *Amaranthus viridis* (488 µg/g) followed by *Polygonum persicaria* (265 µg/g. *Ipomoea aquatica* (238 µg/g), *Blumea lacera* (218 µg/g), *Alternanthera sessilis,* (216 µg/g). *Commelina communis* (192 µg/g), *Solanum nigrum* (191 ppm), *Cyperus iria* (177 ppm) and *Ageratum conyzoides* (127 ppm), *Convolvulus* arvensis (125 µg/g) and *Heliotropicum indicum* (89 µg/g) (Table 1). Zn is an essential trace element for plant growth and also plays an important role in various cell processes including normal growth, brain development, behavioural response, bone formation and wound healing. Zn deficient patients fail to improve their power of perception and also causes loss of sense of touch and smell (Hunt 1994). The dietary limit of Zn is 100 µg/g.

Maximum concentration of Mn was found in *Alternanthera sessilis* (124 ppm), *Hyptis suaveolens* (93.9 ppm), *Calotropis procera* (76.6 µg/g), *Lantana camara* (74.5µg/g), *Cichorium intybus* (68.8 µg/g) , *Datura stramonium* (65.4 µg/g), *Abutilon indicum,* (27.8 µg/g) which

Table 1. Heavy metal uptake by weed species grown in contaminated soils in Jabalpur

Medicinal weeds grown in contaminated soils along drains	Heavy metals (µg/g dry weight)			Medicinal weeds grown at contamminted soils along roads	Heavy metals (µg/g dry weight)	
	Cu	Cd	Fe		Pb	Mn
Vicia sativa	78.4	ND*	3485	*Calotropis procera*	21.0	76.6
Chenopodium album	31.8	1.11	547.5	*Hyptis suaveolens*	6.25	93.9
Melilotus indica	Nd	1.30	ND	*Cichorium intybus*	3.00	68.8
Lathyrus sativa	Nd	0.77	ND	*Lantana camara*	5.5	74.5
Anagalis arvensis	20.5	1.55	1060	*Alternanthera sessilis*	ND	124
Alternanthera viridis	22.6	1.56	621	*Abutilon indicum*	ND	27.8
Sonchus arvensis	41.4	3.07	923	*Xanthium strumarium*	ND	ND
Eclipta alba	48.9	1.14	962	*Anagalis arvensis*	ND	ND
Cichorium intybus	28.2	1.05	646	*Datura stramonium*	2.15	65.4
EU[1], PFA[2] limit, critical concentration of Mn[3]	<20[1]/30[2]	0.2[1]/1.5[2]	-	WHO[3] Limit	10[3]	300-500[3]

ND - Not detected

Table 2. Heavy metals concentrations in aquatic weeds grown in drains carrying waste water

Weed species grown in drains	Heavy metals (µg/g dry weight)			
	Co	Ni	Zn	Fe
Amaranthus viridis	46	17	488	420
Commelina communis	30	17	192	1257
Alternanthera sessilis	22	14	216	345
Ipomoea auatica	21	15	238	510
Heliotropicum indicum	9	16	89	550
Polygonum persicaria	37	19	265	1240
Ageratum conyzoides	37	15	127	818
Blumea lacera	17	3	218	574
Solanum nigrum	22	16	191	400
Convolvulus arvensis	13	15	125	1900
Cyperus iria	7	15	177	513
Range	7-46	3-19	89-488	345-1900
EU[1], PFA[2] limit	<20[1]	<1.5[1]	< 50[2]	-

was within normal background level (300-500 µg/g), whereas no Mn was detected in *Xanthium strumarium* and *Anagallis arvensis*. Mn deficiency in plants causes chlorosis. The estimated safe and adequate daily dietary intake in adults is 11 mg/day (Pendias and Pendias 1992). Deficiency of Mn in beings human causes myocardial infarction and other cardiovascular diseases, also disorder of bony cartilaginous growth in infants and children (Smith 1990, Barceloux 1999).

High Fe concentration was recorded in *Convolvulus arvensis* (1900 µg/g dry weight) followed by *Commelina communis* (1257 µg/g), *Polygonum persicaria* (1240 µg/g), *Ageratum conyzoide* (818 µg/g), *Blumea lacera* (574 µg/g), *Heliotropicum indicum* (550 µg/g), *Ipomoea auatica* (510 µg/g), *Cyperus iria* (513 µg/g), *Amaranthus viridis* (420 µg/g), *Solanum nigrum* (400 µg/g) and *Alternanthera sessilis* (345 µg/g) grown along the drain and *Vicia sativa* (3485 µg/g), *Anagallis arvensis* (1060 µg/g), *Eclipta alba* (962 µg/g), *Sonchus arvensis* (923 µg/g), *Cichorium intybus* (646 µg/g), *Alternanthera viridis* (621µg/g) and *Chenopodium album* (547.5 µg/g), was beyond the prescribed limit (20 µg/g) as suggested by EU. Conversely, no Fe content was found in weeds *viz.*, *Melilotus indica* and *Lathyrus sativa*. The dietary limit of Fe in the food is 10-60 mg/day (Kaplan *et al.* 1993). Low Fe content causes gastrointestinal infection, nose bleeding and myocardial infarction (Hunt 1994).

Cd accumulates in human body and damages mainly kidneys and liver. Except *Vicia sativa*, Cd contents were observed in field weeds like *Sonchus arvensis* (3.07 µg/g), *Alternanthera viridis* (1.56 µg/g), *Anagallis arvensis* (1.55 µg/g), *Melilotus indica* (1.30 µg/g), *Eclipta alba* (1.14 µg/g), *Chenopodium album* (1.11 µg/g), *Cichorium intybus* (1.05 µg/g) and *Lathyrus sativa* (0.77 µg/g). The maximum acceptable concentration of Cd for food stuff is around 0.2 ppm (EU limit), 1 ppm (Neil 1993). *Calotropis procera* (21 ppm) accumulated higher concentration of Pb which exceeded the prescribed standard limit (Table 2), whereas *Hyptis suaveolens* (6.25 µg/g), *Cichorium intybus* (3.00 µg/g), *Lantana camara* (5.5 µg/g) and *Datura stramonium* (2.15 µg/g) absorbed Pb below the prescribed standard limit. However, no Pb was detected in *Alternanthera sessilis, Abutilon indicum, Xanthium* *strumarium, Anagallis arvensis* grown in soils along roads. The typical symptoms of Pb poisoning are colic, anemia, headache, convulsions and chronic nephritis of the kidneys, brain damage and central nervous system disorders. WHO (1998) prescribed limit for Pb contents in herbal medicine is 10 ppm.

Indiscriminate use of medicinal weeds grown in waste water carrying drain or soils irrigated with untreated waste water and soils contaminated along the roads roses great risk of metal entry into food chain. Heavy metal contents in most of the weeds with medicinal values exceeded the prescribed stringent EU limit as well as the PFA Indian limit. Higher concentration of Co (78.4 µg/g) in *Vicia sativa*, Pb (22 µg/g) in *Calotropis procera*, cadmium (3.07 ppm) in *Sonchus arvensis*, Ni (19 ppm) in *Polygonum persicaria*, Zn (488 µg/g) in *Amaranthus viridis*, Mn (232 µg/g) in *Alternanthera sessilis,* Fe (1900 µg/g) in *Convolvulus arvensis* were above the detection limits. These findings may be taken into consideration while using herbs for human consumption. Medicinal plants used for human consumption or for preparation of herbal products and standardized extracts should be collected from an unpolluted natural habitat.

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Weed control through smothering crops and use of plant extracts as bioherbicides

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ABSTRACT

A field experiment was conducted at BCKV, Mohanpur during the pre-*Kharif* season of 2010 and 2011 to observe the weed smothering ability of different crops and also to evaluate the bio-herbicidal potential of plant extracts on weeds. The study revealed that among the crops, significantly lowest population of different categories of weeds were found under black gram while highest population was recorded under sesame. Among the weed management practices, hand weeding at 20 DAS resulted in lowest population of all categories of weeds at 30 DAS. Among the botanical plant extracts, *Ageratum conyzoides* extract 5% (w/v) recorded lowest sedge and broad-leaved weed population while lowest grassy weed population was recorded under *Ocimum sanctum* extract 5% (w/v). The highest weed control efficiency was recorded under hand weeding treatment followed by fenoxaprop-p-ethyl while among the botanical plant extract, *Ageratum conyzoides* recorded the highest.

Key words: Bioherbicids, Herbicides, Plant extracts, Smoothering effect, Weed control

Synthetic herbicides continue to be a key component in most weed management strategies, but, the indiscriminate use of chemical herbicides for weed control in the last 50 years has resulted in serious ecological and environmental problems and developed resistance to herbicide in weeds and to challenge these problems, research has increased its effort to find out alternative strategies. The negative effects of commercial herbicide use on environmental contamination and human health make necessary to diversify weed management options (Duke 1986). The increasing concern about the toxicity of synthetic herbicides has boosted the search for eco-friendly and sustainable weed management practices. Plants offer an excellent source of biologically active natural products and have enormous potential to inspire and influence modern agrochemical research. Natural compounds from plants provide potential for new herbicidal solutions, or lead compounds for new herbicides (Duke *et al*. 2000, Vyvyan 2002). A number of classes of allelochemicals causing inhibition of germination and growth of weeds have been identified (Wu *et al*. 1999). Plant extracts (compound mixtures) potentially possess multiple phytotoxic compounds and hence multiple modes of simultaneous herbicidal attack, making it more difficult for weeds to develop herbicide resistance and most products show wide windows of crop safety. Present study was undertaken to observe the weed smothering ability of different crops (sesame, greengram and blackgram) and to test the bio-herbicidal properties of some commonly available plants on the weeds of different crops for their management.

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MATERIALS AND METHODS

The field experiment was conducted at the Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal having medium land topography during pre-*Kharif* season of 2010 and 2011. The experimental soil was Gangetic new alluvial (inceptisol) with sandy clay loam texture, having good irrigation cum drainage facility and medium soil fertility status with neutral soil pH. The experiment was conducted in split plot design replicated thrice, keeping the crops (C) under the main plot treatment, sesame, greengram, black gram and nine weed management treatments allocated in the subplot treatments, *viz*. untreated control, hand weeding at 20 DAS, 5% (w/v) *Ageratum conyzoides* aqueous extract, W_4: 5% (w/v) *Blumea lacera* aqueous extract, W_5: 5% (w/v) *Ocimum sanctum* aqueous extract, W_6: 5% (w/v) *Physalis minima* aqueous extract, W_7: 5% (w/v) *Amaranthus tricolor* aqueous extract, W_8: Quizalofop-p-ethyl 5 EC 50 g/ha at 20 DAS, W_9: Fenoxaprop-p-ethyl 9 EC 30 g/ha at 20 DAS. All the botanical extract treatments were applied as pre-emergence at 1 DAS and added with surfactant Tween 80 0.25%. The net plot area was 3 × 2 m. The varieties of crops used were: Sesame- *Rama (Improved Selection-5)*, Greengram- *Bireswar (WBM – 34-1-1)* and Blackgram- *Sarada (WBU-108)*. A spacing of 30 ×

10 cm from row to row and plant to plant respectively for all the crops was maintained. The recommended dose of fertilizer to each crop was applied.

The plant extracts and herbicides were sprayed as per the necessary treatments with a knap sack sprayer with flood jet deflector nozzle size WFN 0.040 with great care to ensure uniform spraying after proper calibration. Data on weeds were recorded in a quadrat (0.5 × 0.5 m) per plot and converted to 1 m^2. Weeds were counted and removed for recording their dry weights. These data were subjected to square root transformation

The data collected were subjected to statistical analysis appropriate to the design by following the procedure laid out by Gomez and Gomez 1984. The significance of different sources of variations was tested by Fisher's and Snedecor's F-test at probability level of 0.05. For the determination of critical difference at 5% level of significance, the statistical tables formulated by Fisher and Yates (1979) tables were consulted. The values wherever necessary were transformed into square root values as applicable for respective statistical analyses (Panse and Sukhatme 1978).

Aqueous extracts were prepared by following the procedure of Cheema and Khaliq (2000). Leaves of plants (*A. conyzoides, B. lacera* and *P. minima*) were collected from BCKV campus whereas that of *O. sanctum* and *A.tricolor* from Jaguli area. After collection, leaves were dried in shade at room temperature for a week and later dried at 40^0C in oven for 48 h and grounded to powder. The dried powder material was soaked in water in the ratio 1:5 (w/v) for 24 hours. Then the water extracts were collected by passing through sieves. The filtrates were boiled at 100^0C for reducing the volume (3 litres). The final extract was left to stand at 4^0C for 30 M and then filtered. The concentrated extract was collected for spraying in the specific treatment plots.

RESULTS AND DISCUSSION

Major weed species observed in the experimental field were: *Cynodon dactylon*, *Echinochloa colona*, *Eleusine indica, Digitaria sanguinalis, Dactyloctenium aegyptium, Cyperus rotundus, Euphorbia hirta*, *Alternanthera philoxeroides*, *Trianthema portulacastrum*, *Cleome viscosa*, *Blainvillea latifolia* and *Digera arvensis*.

At 15 DAS, the weeds (grass, sedge and broad-leaved weed) did not vary significantly under different crops which might be attributed to the fact that at this stage the crops did not have the ability of smothering the weeds due to the initial establishment of the crops, particularly the canopy structure of the crop. At 30 DAS, the weeds (grass, sedge and broad-leaved) vary significantly under different crops. The population of weeds were found lowest under blackgram followed by greengram while highest was obtained in sesame treatment, having lowest weed control efficiency of 27.72%. Blackgram recorded highest weed control efficiency of 36.22% followed by greengram with 32.36%. This might be due to the weed smothering ability of the legumes due to profuse canopy which also resulted in higher weed control efficiency. Ghosh *et al*. (2007) also expressed similar opinions, where legumes with good canopy were more efficient than sesame for weed control. Among the two legume crops, though the difference was not so large, population of weeds were found to be lower in black gram than green gram. The reason might be due to more branched stature of this crop compared to greengram resulting in denser canopy which resulted in higher suppression of weeds. Ali (1988) also expressed the weed smothering potential of black gram where the crop has been reported to smother weed flora appreciably by 20-45%.

Under different weed management, the grassy weed at 15 DAS treatments varied significantly where *Ocimum sanctum* extract recorded least grassy weed population followed by *Ageratum conyzoides* extract which did not vary significantly with each other. Sharma and Singh (2004) and Souza *et al.* (2009) also revealed the bioherbicidal property of *Ocimum sanctum* extracts. In case of sedge, weed population at 15 DAS, maximum control was found in *Ageratum conyzoides* extract followed by *Blumea lacera* extract. The maximum control of broad leaved weed at 15 DAS was recorded in *Ageratum conyzoides* extract. Kato *et al*. (2001) also reported the herbicidal effect of the shoot extracts of *Ageratum conyzoides.* Trand *et al*. (2004) also gave similar views in field conditions. At 15 DAS, there was no control of weeds in hand weeding and chemical herbicide plots since the treatments were implemented at 20 DAS.

The lower density of weeds in the plant extract treatments might be due to the presence of suppressive water soluble allelochemicals associated with the respective plant extracts. The biochemical interactions might have occurred when the water soluble chemicals present in the botanical extracts came in contact with the embryo of the weed seeds after application which influenced the germination, survival, growth and development of weeds. The inhibition of weeds might have occurred through different toxic mechanism such as reduction in germination or lengthening of germination process or slowing seedling growth which was also reported by Ercoli *et al*. (2007).

Table 1. Effect of treatments on weed population (no./m^2) at 15 DAS and 30 DAS and weed control efficiency (pooled data)

Treatment	At 15 DAS			At 30 DAS			Weed control efficiency (%) at 30 DAS
	Grass	Sedge	Broad-leaved weeds	Grass	Sedge	Broad-leaved weeds	
Crops							
Sesame	4.85 (23.69)	4.69 (21.81)	4.56 (20.69)	6.28 (41.76)	7.76 (61.41)	5.18 (27.69)	27.72
Greengram	4.62 (21.33)	4.75 (22.37)	4.71 (21.83)	5.91 (36.41)	7.30 (54.41)	5.02 (25.63)	32.36
Blackgram	4.43 (19.91)	4.65 (21.57)	4.59 (20.96)	5.26 (29.56)	6.42 (43.59)	4.65 (22.31)	36.22
LSD (P=0.05)	NS	NS	NS	0.315	0.339	0.069	-
Weed management							
Untreated control	5.38 (29.28)	5.03 (24.94)	4.78 (22.44)	7.40 (56.39)	8.81 (77.28)	5.85 (34.00)	-
Hand weeding at 20 DAS	4.85 (23.72)	4.80 (22.72)	4.53 (20.22)	3.27 (10.50)	4.06 (17.33)	2.55 (6.78)	69.73
5% (w/v) *Ageratum conyzoides* aqueous extract	4.27 (18.11)	3.91 (14.94)	4.09 (16.44)	6.38 (40.44)	6.91 (47.89)	5.07 (25.50)	32.59
5% (w/v) *Blumea lacera* aqueous extract	4.37 (19.06)	4.13 (16.78)	4.35 (18.61)	6.60 (43.33)	7.61 (57.78)	5.20 (26.83)	23.29
5% (w/v) *Ocimum sanctum* aqueous extract	4.00 (15.78)	4.27 (17.94)	4.47 (19.78)	6.09 (36.78)	7.20 (51.94)	5.37 (28.72)	28.67
5% (w/v) *Physalis minima* aqueous extract	4.43 (19.44)	4.78 (22.44)	4.65 (21.33)	6.66 (44.22)	7.98 (63.78)	5.54 (30.44)	15.14
5% (w/v) *Amaranthus tricolor* aqueous extract	4.56 (20.56)	4.97 (24.33)	4.85 (23.22)	7.32 (53.61)	8.46 (71.94)	5.73 (32.50)	9.44
Quizalofop-p-ethyl 50g/ha	4.81 (23.28)	5.22 (27.06)	4.95 (24.56)	4.42 (20.00)	6.80 (46.22)	4.68 (21.72)	52.14
Fenoxaprop-p-ethyl 30g/ha	5.07 (25.56)	5.14 (26.11)	4.91 (23.83)	4.20 (17.89)	6.63 (44.06)	4.55 (20.39)	57.87
LSD (P=0.05)	0.347	0.179	0.195	0.379	0.381	0.281	-

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

At 30 DAS, highest population of all categories of weeds was recorded in untreated control treatment while lowest population was found in hand weeding treatment, which was followed by chemical herbicide treatments which were statistically ont par with each other. Among the plant extracts, *Ocimum sanctum* extract recorded lowest population of grassy weed which was followed by *Ageratum conyzoides* extract which did not vary significantly with each other. In case of sedge and broad-leaved weed, *Ageratum conyzoides* extract recorded lowest sedge weed population and it was statistically at par with fenoxaprop-p-ethyl treatment.

After the application of chemical herbicide treatments at 20 DAS, there was reduction in the population of weeds at 30 DAS, where the reduction was more pronounced in grassy weed. Chin and Pandey, (1991) also obtained similar results where application of fenoxaprop-ethyl resulted in a significant reduction in monocotyledon weeds. Among the two herbicides used in the experiment, though the results obtained from both the treatments were statistically at par, fenoxaprop-p-ethyl exhibited more suppression of all categories of weeds than quizalofop-p-ethyl, which might be due to the contact as well as systemic action of the former herbicide while quizalofop-p-ethyl exhibited only systemic action. Fenoxaprop-p-ethyl treatment recorded higher weed control efficiency of 57.9% than Quizalofop-p-ethyl treatment which recorded 52.1%. Similar type of observations were also reported by Sitangshu (2006) while working in jute in West Bengal where fenoxaprop-p-ethyl showed highest WCE (86.6%), closely followed by quizalofop-p-ethyl (79%). Result showed that at 30 DAS, highest weed control efficiency of 69.7% was recorded by hand weeding treatment while among the plant extract treatments *Ageratum conyzoides* extract recorded highest weed control efficiency (32.6%).

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Effect of herbicides on weed control and yield of sugarcane

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Weeds constitute one of the most important problems faced in crop cultivation because of its negative effect on the quality and quantity (Mehra *et al*. 1995). The competition between crop and weed is one of the important limiting factors in successful raising of plants of commercial value. Use of herbicides is one of the methods currently used to control weeds. The application of these herbicides at early stages of crop growth checks the competition between weeds and the crop during initial stages while weeds emerging later cause weak competition and do not cause any damage to crop plants.

Richard (1997) used paraquata 2.24 kg/ha in sugarcane to control Johnson grass (S*orghum halepense*), which led an increase in the yield to the extent of 16%. Agrawal *et al.* (1986) found that use of paraquat 600 g/ha led to killing of all weeds and continued to respond in controlling weeds until 4 weeks from the date of application. Fluazifop-butyl is used to control grass weeds in sugarcane. Like glyphosate and paraquat, it is applied by directed spray on weeds without making any contact with the crop plants. Chevalier, a herbicide mixture of mesosulfuron + iodosulfuron is also effective against broad-leaved annual weeds in grassy crops in Iraq (Anonymous 2001). However, it has not been tested in sugarcane in Iraq. This study was conducted to identify the most effective herbicides against weeds in sugarcane crop in Iraq.

A field experiment was conducted at the research farm of the General Company for industrial crops in province of Tikrit (Dhuluiya), Iraq. The experiment was laid out in randomized complete block design and replicated four times. The treatments included four herbicides, *viz.* fluazifop-butyl, Chevalier (mesosulfuron + iodosulfuron), glyphosate and paraquat, and weedy check (control). The soil of the experimental site was clay loam having low organic content (0.23%) and available N,P,K (157.4, 17.5 and 174.0 kg/ha, respectively) and slightly alkaline in reaction (pH 7.7). The experimental unit (plot) area was 36 m^2 and distance between the experimental units was 1.0 m. Application of 200 kg N/ha was made in the experimental field with urea (46% N) in two equal parts. One half of the urea was applied at the time of planting and the remaining half was applied after three months of planting. Triple superphosphate 120 kg P_2O_5/ha was applied once at the time of planting. Irrigation was provided upto mid October at an interval of 7-12 days. Sugarcane crop was harvested in the month of January. Herbicides glyphosate 5.76 kg/ha, paraquat 0.80 kg/ha and fluaziphop-butyl 0.75 kg/ha were sprayed directly on the weeds at the beginning of tillering stage in sugarcane, while Chevalier 0.30 kg/ha was sprayed as blanket spray.

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A quadrant of one m^2 was thrown randomly in each experimental unit three times and green weed plants not affected by herbicides were counted and averaged for calculating weed density. Green weed plants were cut at the soil surface from the same site (quadrant) in the experimental unit. The weeds samples were air dried followed by oven dried at 65^0C for 48 h and weighed.

Ten sugarcane plants in two rows in the middle of each experimental unit were tagged used to record the number of green leaves, cane height and stem diameter. Stem diameter of cane was measured at five centimeters above the soil surface by using Vernier caliper. Number of millable and unmillable canes were sorted and counted from one line in midlle of the each plot.

Two leaves from middle of each tagged plant were taken to measure length and maximum width and single leaf area was calculated using the equation given by Tejera *et al.* (2007). The canes were collected from middle lines of each experimental unit and after topping, cane were weighed to obtain cane yield. The data recorded from the experiment were analyzed using standard methods of statistical analysis.

Weed species present in the sugarcane field were: *Aster tripolium* L, *Alhagi maurorum* Medic, *Convolvulus arvensis* L, *Sesbania aegyptica* Pers., *Sonchus oleraceus* L, *Imperata cylindrica* (L) P. Beauv and *Avena fatua* L.

(Table 1). Among these, the prominent weed species were the broad-leaved annual weeds,*viz. Sesbania aegypticapers* and *Sonchus oleraceus* which occupied 51.1% share in total weed population (Table 2). The broad-leaved perennial weeds *i.e. Aster tripolium, Alhagi maurorum* and *Convolvulus arvensis* were few and constituted 7.5% of the total weed population. The grasses including perennial grasses like *Imperata cylindrica* and annual grasses such as *Avena fatua* constituted 41.4% of total weed density. The application of herbicides affected the weed type and density but the response of different types of weeds varied to different herbicides.

Application of paraquat controlled almost all types of weeds. The weed density was least under this treatment at all the growth stages of the crop till harvest. The effect of this herbicide in controlling weeds was quick because of its nature (contact herbicide). As a result the weed density decreased to 12.3 plant/m² compared with 24.5 and 67.2 plants/m² under glyphosate and fluaziphop-butyl, respectively. Weed growth was restored in the plots treated with glyphosate and fluaziphp-butyl led to a decrease in proportion of weed control compared to paraquat. The weed density under weedy check plot was 93.5 plants/m². Thus, in herbicide treatments, crop growth was better leading to higher number of millable cane at harvest.

The weeds in paraquat treated plots belonged to seven plant species, five of them were broad-leaved species, *viz. Aster tripolium*, *Alhagi maurorum*, *Convolvulus arvensis, Sesbania aegyptica* and *Sonchus oleraceus* that formed 71.4% of total weeds, and two species of grasses weeds, *viz. Imperata cylindrica* and *Avena fatua* accounted for

Table 1. Major weed species in experimental field

Scientific name	Life cycle	Weed type	Population (no./m^2)
Aster tripolium	Peremnial	Broad-leaved	2.8
Alhagi maurorum	Peremnial	Broad-leaved	2.3
Convolvulus arvensis	Peremnial	Broad-leaved	1.9
Sesbania aegyptica	Annual	Broad-leaved	4.9
Sonchus oleraceus	Annual	Broad-leaved	42.9
Imperata cylindrica	Peremnial	Grass	13.6
Avena fatua	Annual	Grass	25.1
Total			93.5

28.6% of the total weeds. However, the ratio of weed control under paraquat was higher. The control of weeds in the early growth stage encouraged sugarcane plants to produce new tillers and provided the principle factors for composition of the tillers specially space and light followed by water and food.

The weeds in glyphosate treatment were of five plant species, all broad-leaved species, *viz. Aster tripolium, Alhagi maurorum, Convolvulus arvensis, Sesbania aegyptica* and *Sonchus oleraceus* formed 100% of the total weeds. Although glyphosate being non-selective kills all plant species, the ratio of weed control achieved by using glyphosate was less than paraquat. Glyphosate being systemic in nature, has ability to move and go to the underground parts, and the symptoms appear after a longer or shorter period depending on the conditions surrounding the plant. In this period, weeds compete with the crop for space and light as well as water, which negatively affected the growth of the tillers. As a result of high temperature that exceeds 30ºC until the start of boom growth stage of the crop, the physiological influence of herbicide

Table 2. Effect of herbicides on density and dry weight of weed species in sugarcane

Treatment	*Aster tripolium*	*Alhagi maurorum*	*Convolvulus arvensiss*	*Sesbania aegyptica*	*Sonchus oleraceus*	*Imperata cylindrica*	*Avena fatua*	Total
Weed density (no./m²)								
Glyphosate	3.0	2.2	2.0	6.0	11.3	0.0	0.0	24.5
Fluaziphop-butyl	18.6	16.3	0.0	0.0	24.2	0.0	6.1	65.2
Paraquat	1.9	1.4	1.3	1.2	3.8	1.5	1.2	12.3
Chevalier	1	0.0	0.0	1.3	1.7	21.7	15.6	41.3
Control	2.8	2.3	1.9	4.9	42.9	13.6	25.1	93.5
LSD (P=0.05)								16.0
Dry weight of weeds (g/m^2)								
Glyphosate	2.1	5	3.0	10	14	0.0	0.0	34.1
Fluaziphop-butyl	3.1	20.0	0.0	0.0	18.0	0.0	10.1	51.2
Paraquat	1.0	2.6	1.7	1.9	4.5	1.8	2.0	15.5
Chevalier	3.0	0.0	0.0	6.2	3.1	17.1	12.8	42.2
Control	5.4	4.2	4.7	9.7	60.2	22.0	20	126.2
LSD (P= 0.05)								22.2

may reduce dramatically in controlling weeds and might encourage emergence of new weeds later.

Weeds in fluaziphop-butyl treatment belonged to four plant species, including three species of broad-leaved, *viz. Aster tripolium*, *Alhagi maurorum* and *Sonchus oleraceus* collectively constituted 75% of the total density of weeds, and one species of grasses, *i.e Avena fatua* accounted for 25% of the total density of weeds. The control achieved by using fluaziphop-butyl was less than glyphosate due to the fact that fluaziphop-butyl is selective systemic herbicide that affects grasses (perennials and annuals) only.

All the herbicide treatments were found effective in significantly reducing the dry weight in weeds compared to the control (126.2 g/m²) (Table 2). The dry matter accumulation in weeds was lowest (15.5 g/m²) in paraquat treatment. The decrease in dry weight of green weeds under paraquate may be due to control of most types of weeds because of its use in the early stages of crop growth. The use of glyphosate in sugarcane significantly reduced the dry weight of green weed to the level of 34.1 g/m² compared to control (126.2 g/m²). The reduction in dry weight of green weeds in glyphosate may be due to low density of weed plants especially the weeds like *Sesbania aegyptica* and *Aster tripolium* that has profuse vegetative growth. The effect of paraquat and glyphosate was more pronounced as compared to fluaziphop-butyl in reducing the dry weight of green weeds. Fluaziphop-butyl being a selective herbicide controled grasses only and in the absence of grasses, the growth of broad-leaved weeds was higher, thus, recording higher dry weight of weeds compared to paraquat and glyphosate.

Herbicides application in sugarcane to control weeds registered significant effect on cane height (Table 3). Application of glyphosate increased the cane height to the highest level of 153.7 cm, but did not differ significantly from fluaziphop-butyl treatment (149.0 cm). Chevalier could not exert its significant effect on cane height compared to control (145.3 cm). While, the use of paraquat decreased the cane height amounted to 138.4 cm because it being a contact herbicide, killed green tissues of weeds after a few hours from the time of spray causing wilting and drying quickly in the weeds, which might helped suffcient light to reach sugarcane in early tillering stage, causing retardant in elongation of crop plants. Reziq and Ali (1981) showed that sugarcane plants in appropriate lighting conditions reduce concentration or activity of certain growth regulators of polar motion to bottom of the plants causing retardant in stem elongation.

There was significant increase in number of canes by using paraquat and glyphosate over control. Chevalier and fluaziphop-butyl did not significantly influence number of canes. The increase in number of tillers by use of paraquat at the beginning of tillering stage was due to light penetration resulting in high density of tillers. Abdul *et al.* (1982) indicated that there was a relationship between light intensity and activity of growth substances in plants. In the case of increasing light intensity, the speed of movement of growth regulators from the top of the plant to the base becomes less causing an increase in number of tillers on the one hand and reduced weed density on the other hand with high percentage of weed control.

Cane stem diameter (Table 3) was not significantly affected by use of various herbicides. There was significant effect of herbicide application on average number of green leaves in sugarcane. Paraquat registered the highest increase of green leaves per cane (11 leaves/cane) that didn't differ significantly from glyphosate and fluazifop-butyl treatment (9 leaves/cane in both the treatments). However, all the herbicides helped to produce significantly higher number of green leaves per plant compared to control (7 leaves/cane).

The use of herbicides helped sugarcane to produce significantly higher leaf area over control (Table 3). The highest leaf area (57.4 cm²) was recorded with paraquat treatment followed by glyphosate (50.8 cm²) while, other herbicides could not have a significant influence on leaf

Table 3. Effect of herbicides on growth and yield of sugarcane

Treatment	Cane height (cm)	Canes/5 m row length	Stem diameter (mm)	Leaves/ plant	Single leaf area (cm^2)	Cane yield (t/ha)
Glyphosate	153.7	58.5	33.8	9.2	527	50.8
Fluaziphop-butyl	149.0	56.1	34.1	9.6	500	46.9
Paraquat	138.4	62.3	35.3	11.2	574	54.5
Chevalier	146.7	54.9	34.3	8.8	469	41.1
Control	145.3	51.7	35.0	7.6	483	37.6
LSD (P= 0.05)	2.81	5.33	NS	1.18	26.1	3.24

area over control (48.3 cm^2). The increase in leaf area by using paraquat and glyphosate may be due to the positive role of these herbicides to increase light interception by controlling a large proportion of weeds in early stages of crop growth.

Use of herbicides to control weeds in sugarcane significantly enhanced the cane yield. Paraquat registered the highest cane yield (54.5 t/ha) which was significantly higher (44.9%) over control. Glyphosate and fluazifop-butyl also proved significantly superior to control in respect of cane yield, which was 50.8 and 46.0 t/ha, respectively. The increase in cane yield by use of glyphosate and fluazifop-butyl was 35.2 and 24.9%, respectively. The increase in cane yield with Chevalier did not reach the level of significance, which registered cane yield of 41.0 t/ha compared to control (37.6 t/ha). The increase in sugarcane yield by using paraquat might be due to increase in number of tillers in the early stages of crop growth and production of high amount of photosynthetic products. Also the improved sink capacity on account of increase in number of canes may be related to weakened growth of weeds under herbicide treatment. Therefore, the stage of tillers composition must be accompanied by absence of weeds that compete with crop (Thakur *et al*. 1996). These results are consistent with findings of Agrawal *et al.* (1986).

SUMMARY

A field experiment was conducted at the research farm of the General Company for industrial crops in the province of Tikrit (Dhuluiya), Iraq to evaluate chemical herbicides, *viz*. fluazifop-butyl, glyphosate, paraquat and Chevalier in sugarcane variety '*QD12*'. Results showed that use of paraquat helped in controlling weeds to the extent of 86.8% over weedy check. As a result, weed density was very less and reduction in dry weight of green weeds was up to 87.7%. The number of canes increased by 20.5%, green leaves by 56% and leaf area by 45%, which was reflected in the highest increase in cane yield (44.9%). Cane length and diameter were not significantly affected by herbicide application.

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Evaluation of post-emergence herbicides in soybean

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Soybean (*Glycine max* L.) is one of the important oilseed crop grown all over India. In Maharashtra crop is grown during *kharif* season on an area of 30.65 lakh ha with production of 18.40 tones. As crop is grown during *Kharif* season faces heavy competition of weeds particularly during early crop growth period, poor weed management during this period is one of the most important yield limiting factor . Soybean productivity is adversely affected up to 35-80% depending on the weed infestation (Gupta *et al.* 2006). The weed control in soybean was generally done through weeding and hoeing but with unavailability of labour and increased labour cost, timely inter culture becomes a very difficult task in soybean. Recently some of the post-emergence herbicides have been found effective in controlling weeds in soybean (Khope *et al.* 2011). Hence, present investigation has been carried out to find out the performance of post emergence herbicides for weed control in soybean.

A field experiment was carried out at weed science research center, MKV, Parbhani during 2011 and 2012 to evaluate the performance of post emergence herbicides for weed control in soybean. The soil of experimental plot was black cotton soil with alkaline in reaction (pH 7.8), low in N ,medium in P_2O_5 and high in K_2O.

The experiment was land out in randomized block design comprising of 6 treatments, *viz.* T_1 - Imazethapyr 0.1 kg/ha as PoE, T_2 - Fusilade 0.125 kg/ha as PoE, T_3 - Chlorimuron 12.8/ha as PoE, T_4 - Imazethapyr (50%) + imazimox 50% 30 g/ha as PoE, T_5 - 2 HW at 20 and 40 DAS and T_6 - weedy check and replicated thrice. soybean JS-335 was sown on 26 June 2012 by drilling seeds 60 kg/ha seed rate at 45 cm row spacing. Fertilizer was applied as 25 kg N + 50 kg P/ha at the time of sowing. The density and dry weed weight were recorded at 30 and 60 DAS and yield at harvest.

The dominant weed species in grassy weeds were *Cynadon dactalon, Dinebra retraflexa, Bracheria eruciformis* and *Eragotis minor*; whereas the dominant broad-leaved weed species were: *Euphorbia hirta, Abutilon indicum, Parthenium hysterophorus, Acalypha indica* and *Alternethera sessilis*.

Two Hand weeding at 20 and 40 DAS significantly reduced weed density and dry weed weight at 30 DAS and 60 DAS respectively over weedy check, except imazethapyr + imazimox 30 g/ha and imazethapyr 0.1 kg/ha as PoE at 20 DAS. Weed control efficiency was maximum with 2 HW and hoeing at both 30 DAS and 60 DAS among all the treatments.Application of imazethapyr + imazimox 30 g/ha recorded the maximum WCE during both the years of experiment at 30 DAS as well as 60 DAS. Similar reports were also reported by Singh (2007).

Soybean grain and straw yield was significantly influenced with different treatments (Table 1). Grain yield as well as straw yield was highest with 2 hand weeding treatments, which and was on par with T_4 and T1and significantly higher than rest of the treatments during both

Table 1. Weed count (no./m^2) as influenced by various treatments

Treatment	30 DAS				60 DAS			
	Monocot		Dicot		Monocot		Dicot	
	2011	2012	2011	2012	2011	2012	2011	2012
Imazethapyr 0.1 kg/ha PoE	24.1	30.0	32.7	41.6	48.5	61.3	42.3	48.0
Fusilade 0.125 kg/ha	23.2	16.0	28.1	30.0	28.4	34.0	45.4	50.6
Chlorimuron 12 g/ha	28.6	44.6	26.2	21.3	32.3	57.3	25.3	10.6
Imazethapyr (50%) + imazimox (50%) 30 g/ha	14.1	18.6	20.8	26.0	36.3	40.0	32.3	36.0
2 HW at 20 and 40 DAS	27.6	46.0	18.3	16.0	22.4	16.0	21.8	16.0
Weedy check	25.0	68.0	60.3	86.0	65.3	118.0	94.3	184.

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Table 2. Dry weed weight, weed control wfficiency, weed yield and straw yield as influenced by various treatments

Treatment	Dry weed weight (g/m^2) 30 DAS				Dry weed weight (g/m^2) 60 DAS				WCE (%)				Seed yield (t/ha)		Straw yield (t/ha)	
	Monocot		Dicot		Monocot		Dicot		30 DAS		60 DAS					
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
T_1	5.1	4.6	6.4	6.7	5.1	14.1	9.16	24.1	65.0	71.8	67.0	54.2	2.44	2.19	2.54	2.78
T_2	9.7	4.6	10.6	6.5	9.9	16.6	15.2	26.4	54.0	72.3	64.2	64.1	2.11	1.67	2.41	2.34
T_3	3.9	9.6	9.3	6.6	10.2	29.3	17.3	18.4	60.0	59.6	41.0	72.0	1.21	1.56	1.98	2.11
T_4	2.8	4.3	4.3	6.3	4.3	12.6	8.6	13.2	64.3	73.5	67.8	71.7	3.02	2.36	2.86	2.97
T_5	2.5	0.9	4.5	2.2	5.1	03.7	8.4	06.5	66.6	92.2	69.7	90.5	3.24	2.46	2.71	3.00
T_6	16.4	11.9	19.6	28.2	24.2	34.6	22.4	84.5	-	-	-	-	1.05	1.26	2.04	2.27
LSD (P=0.05)	3.5	3.4	4.7	3.3	4.1	3.7	4.7	5.2	-	-	-	-	0.90	0.39	0.24	0.33

the years of experimentation. Similar results were also reported by Meena *et al.* (2009).

SUMMARY

A field experiment was carried out at weed science research center, MKV, Parbhani during 2011 and 2012 to evaluate the performance of post emergence herbicides for weed control in soybean showed that Grain yield as well as straw yield was highest with 2 Hand weeding and hoeing treatments, which was on par with T4 and T1 and significantly higher than rest of the treatments during both the years of experimentation. Two hand weedings at 20 and 40 DAS significantly reduced weed density and dry weed weight at 30 DAS and 60 DAS respectively over weedy check, and was at par with imazethapyr + imazimox 30 g/ha and imazethapyr 0.1 kg/ha as PoE at 20 DAS.

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Short communication

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Bioefficacy of post-emergence herbicides in soybean

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In soybean, weeds are controled by cultural, mechanical and chemical methods either alone or in combination of more than one methods. Weed management through manual weeding or hoeing although effective in reducing weed competition but it is not free from several limitations such as non-availability of sufficient manpower during peak periods, high labour cost, time consuming and not feasible under heavy soils and high rainfall areas. Moreover, mechanical weeding disturbs the physical conditions of the soil and cause mechanical injury to roots and shoots. To overcome these problems, weed control in soybean by chemicals is preferred, which is effective, cheaper and many times faster than the conventional methods.

A field experiment was conducted during rainy season of 2009-10 at Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh). The soil of the experimental field was sandy clay loam in texture, neutral in reaction having 0.68 per cent organic carbon. The soil was low in available N (215 kg/ha), P (9.20 kg/ha) and medium in K (318.0 kg/ha). Nine treatments, *viz.* imazethapyr (75 g/ha), imazethapyr (100 g/ha) imazethapyr + adjuvant (75 g + 1 l/ha) imazethapyr + adjuvant + ammonium sulphate (100 g + 750 ml + 1 kg/ha), chlorimuron-ethyl (9.7 g/ha), fenoxoprop-ethyl (67.5 g/ha), weed free (HW at 30 DAS) and weedy check were tested in randomized block design with three replications. Healthy seeds (70 kg/ha) of soybean cv. '*JS 97.52*' were treated before sowing with thiram at the rate of 3 g/kg and sown in furrows opened manually at 30 cm apart rows. The soybean crop fertilized with 20 kg N (urea) : 60 kg P_2O_5 (single super phosphate) and 20 kg K_2O (muriate of potash) at the time of sowing. The total rainfall received during the period of experimentation was 1339.3 mm. The quadrate of 0.25 m^2 was used to count the weeds in each plot. The data were transformed and expressed in per square meter. The percentage of weed flora was estimated from weedy check. Weed control efficiency (WCE) was estimated by the formula given by Mani *et al.* (1973).

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The weed flora of the experimental field consisted of both grassy weeds, *viz. Cyperus rotundus, Digitaria sanguinallis* and *Eleusine Indica* and broad-leaved weeds, *viz. Portulaca oleracea* and *Eclipta alba*.

Density and relative density of monocot weeds were higher than the dicot weeds both at 40 and harvest growth stages (Table 1). In weedy check, total weed population was significantly higher than all the herbicidal treatments including weed free treatments. Among herbicidal treatments, imazethapyr + adjuvant + ammonium sulphate (100 g + 750 ml + 1 kg/ha) was most effective in reducing most of the weeds and was almost similar to hand weeding. But, if imazethapyr was applied without adjuvant and ammonium sulpate, its effect on weeds was not appreciable. Weedy check had the highest weed biomass and it had reduced significantly when weeds were controlled either by the use of herbicides or hand weeding. The lowest weed biomass was recorded under weed free treatment (Table 2), closely followed by imazethapyr + adjuvant + ammonium sulphate (100 g + 750 ml + 1 kg/ha). Application of imazethapyr at 75 and 100 g/ha with adjuvant found significant to reduced the weed biomass than the application of imazethapyr alone and other herbicides (Kushwah and Vyas 2009).

Table 1. Weed flora in control at 40 DAS and harvest

Weed species	Density (no./m^2)		Relative density (%)	
	40 DAS	Harvest	40 DAS	Harvest
Monocot weeds				
Grasees				
Digitaria sangunallis	8.2	8.8	18.6	18.2
Eleusine indica	10.2	11.2	24.6	24.8
Sedges				
Cyperus rotundus	11.1	10.9	25.2	24.1
Dicot weeds				
Partulaca oleracea	3.5	4.0	8.1	7.8
Eclipta alba	5.3	5.8	12.1	12.8
Other weeds	5.1	5.5		
Total	44.2	45.2		

Table 2. Species-wise dry weight of weeds at 40 DAS and harvest as influenced by different weed control treatments (g/m^2)

Treatment	*Digitaria sanguinallis*		*Eleusine indica*		*Cyperus rotundus*		*Partulaca oleracea*		*Eclipta alba*		Others	
	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest
Imazethapyr (75 g/ha)	4.75 (22.05)	3.72 (13.32)	4.17 (16.86)	3.73 (13.41)	2.79 (7.27)	2.00 (3.52)	3.32 (10.53)	2.57 (6.13)	2.51 (5.80)	1.64 (2.20)	2.02 (3.60)	1.39 (1.43)
Imazethapyr (100 g/ha)	4.34 (18.33)	3.35 (10.73)	3.73 (13.40)	3.27 (10.20)	2.76 (7.13)	1.89 (3.07)	3.02 (8.60)	2.44 (5.47)	2.39 (5.20)	1.62 (2.13)	1.99 (3.47)	1.31 (1.23)
Imazethapyr + adjuvant (75 + 1/ha)	4.18 (16.97)	2.98 (8.40)	3.47 (11.53)	2.63 (6.40)	2.63 (6.40)	1.68 (2.33)	2.75 (7.07)	2.17 (4.20)	2.27 (4.67)	1.46 (1.64)	1.65 (2.22)	1.18 (0.90)
Imazethapyr + adjuvant (100 g + 1/ha)	3.11 (9.16)	2.52 (5.87)	2.91 (7.97)	2.15 (4.13)	2.53 (5.93)	1.60 (2.07)	2.42 (5.36)	2.03 (3.64)	2.22 (4.43)	1.37 (1.37)	1.56 (1.94)	1.18 (0.90)
Imazethapyr + adjuvant + AS (100 g +750 ml + 1 kg/ha)	2.60 (6.27)	2.11 (3.94)	2.61 (6.33)	1.99 (3.47)	2.49 (5.70)	1.50 (1.77)	2.32 (4.87)	1.95 (3.29)	2.08 (3.82)	1.30 (1.20)	1.52 (1.82)	1.11 (0.73)
Chlorimuron-ethyl (9.7 g/ha)	5.42 (28.85)	4.36 (18.50)	4.89 (23.43)	4.42 (19.07)	3.23 (9.97)	2.17 (4.2)	3.69 (13.15)	2.68 (6.70)	2.43 (5.42)	1.68 (2.33)	2.04 (3.67)	1.70 (2.40)
Fenoxoprop-ethyl (67.5 g/ha)	4.87 (23.24)	3.85 (14.34)	4.41 (18.98)	3.41 (11.13)	2.93 (8.10)	1.93 (3.22)	4.00 (15.49)	2.92 (8.03)	2.53 (5.93)	1.75 (2.58)	1.95 (3.29)	1.53 (1.83)
Hand weeding once at 30 DAS	2.01 (3.53)	1.38 (1.40)	1.66 (2.27)	1.66 (2.26)	1.47 (1.67)	1.21 (0.97)	0.71 (0.00)	0.71 (0.00)	1.31 (1.21)	1.28 (1.13)	1.30 (1.20)	0.98 (0.47)
Weedy check	5.86 (33.80)	6.12 (37.00)	9.24 (84.86)	9.84 (96.33)	4.12 (16.50)	4.39 (18.80)	5.19 (26.4)	5.97 (35.20)	3.13 (9.33)	3.77 (13.75)	4.08 (16.15)	8.42 (70.49)
LSD (P=0.05)	0.55	0.38	0.60	0.49	0.45	0.30	0.47	0.87	0.39	0.55	0.25	0.40

Table 3. Weed control efficiency (WCE%) and weed index of different weed control treatments over weedy check

Treatment	WCE at 40 DAS	WCE at harvest (%)	Weed index
Imazethapyr (75 g/ha)	64.7	85.3	30.3
Imazethapyr (100 g/ha)	70.0	87.9	22.9
Imazethapyr + adjuvent (75 g/ha + 1 liter)	73.9	91.2	17.8
Imazethapyr + adjuvant (100 g/ha + 1 l/ha)	81.4	93.4	5.9
Imazethapyr + adjuvent + AS (100 g/ha + 750 ml/ha + 1 kg/ha)	84.6	94.7	3.1
Chlorimuron-ethyl (9.7 g/ha)	54.8	80.4	35.2
Fenoxoprop-ethyl (67.5 g/ha)	59.9	84.9	32.1
Hand weeding at 30 DAS	94.7	97.7	00.0
Weedy check	0.0	0.0	52.9

Weed-free treatment registered maximum weed control efficiency than all other treatments because of least dry matter production of the weeds over weedy checks (Table 3). The next best treatment was imazethapyr + adjuvant + ammonium sulphate (100 g + 750 ml + 1 kg/ ha). These findings were in agreement with Shete *et al.* (2007).

All yield attributing characters, *viz.* branches/plant, leaf area index (LAI), dry matter productions were significantly different due to different treatments. Significantly maximum number of branches/plant (3.67), LAI (9.25), dry matter production (1.2 kg/m^2) was recorded under weed free condition followed by imazethapyr + adjuvant + ammonium sulpate (100 g +750 ml + 1 kg/ha). This may be because of effective control of weeds which promoted the better growth and development of plants and ultimately produced higher yield attributing traits than the weedy check and other herbicidal treatments. These results are in confirmation with findings of Mishra *et al.* (2001) and Dhane *et al.* (2009).

Pods/plant and seed yield were significantly higher under weed free treatment closely followed by imazethapyr + adjuvant + ammonium sulphate (100 g +750 ml + 1 kg/ ha). Excellent growth and development of soybean plants under weed free conditions and imazethapyr applied along with adjuvant and ammonium sulpate were noted. Because,

Table 4. Effect of herbicdes on yield and economics of soybean

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Gross monetary returns (x10^3 ₹/ha)	Total cost of cultivation (x10^3₹/ha)	Net monetary returns (x10^3₹/ha)	B:C ratio
Imazethapyr (75 g/ha)	1.96	4.78	41.1	16.9	24.5	2.43
Imazethapyr (100 g/ha)	2.19	5.29	48.1	17.2	31.2	2.79
Imazethapyr + adjuvant (75 g/ha + 1 l/ha)	2.24	5.64	49.2	17.3	32.2	2.85
Imazethapyr + adjuvant (100 g/ha + 1l/ha)	2.52	6.45	54.6	17.6	37.3	3.10
Imazethapyr + adjuvant + AS (100 g/ha +750 ml/ha + 1 kg/ha)	2.56	6.65	56.4	17.6	39.1	3.20
Chlorimuron-ethyl (9.7 g/ha)	1.64	4.45	36.3	16.1	20.6	2.27
Fenoxoprop-ethyl (67.5 g/ha)	1.81	4.65	39.5	17.1	22.9	2.33
Hand weeding at 30 DAS	2.65	6.86	58.5	18.7	39.9	3.14
Weedy check	1.25	3.23	27.6	15.6	11.9	-

both these treatments provided congenial environment at critical period of crop- weed competition than the weedy check, resulted in most inferior seed yield (1.3 t/ha). These results are in close conformity with the findings of Pandya *et al.* (2005).

The minimum gross monetary returns (₹ 25,577/ha), net monetary returns (₹11,937/ha) and B:C ratio (1:1) was recorded under weedy check treatments than the other treatments. The maximum gross returns (₹58,533/ha) and net monetary returns (₹39,893/ha) was observed under weed free conditions closely followed by imazethapyr (₹ 56,419 and 38,809/ha) + adjuvant + ammonium sulphate (100 g +750 ml + 1 kg/ha). The benefit : cost ratio represents the profitability of the treatments with each rupee investment. It is remarkable (Table 4) to note that the application of imazethapyr + adjuvant + ammonium sulphate (100 g + 750 ml + 1 kg/ha) was more remunerable (3.20) than rest of the treatments including weed free treatment (3.14). While weedy check was not advantageous as there was loss of almost 100 paise per rupee investment. Similar findings have also been reported by Bhan and Kewat (2003).

SUMMARY

A field experiment was conducted during rainy season of 2009-10 at Research Farm, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur to study the bio-efficacy of post-emergence herbicides on weeds in soybean. Early post-emergence applications of imazethapyr with adjuvant and ammonium sulphate (100 g + 750 ml + 1 kg/ha) was most effective in paralyzing the weed growth and producing significantly higher yield attributing characters and seed yield (2.6 t/ha). The same treatment recorded the maximum net monetary returns (₹ 39,109/ha) and B:C ratio (3.20). The minimum seed yield (1.3 t/ha) was recorded under weedy check.

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Short communication

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Weed management in rainy season onion

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Onion (*Allium cepa* L.) is an important bulbous vegetable crop grown in India from the ancient times. The crop is grown for green vegetable as well as mature bulbs. *Kharif* onion which is 20% of total onion production, plays crucial role in filling supply gap from October to Februrary. The productivity of *Kharif* onion is very low as compared to other seasons, because it is affected by diseases, pests and weeds. The integrated methods of weed control offer the possibilities of increasing crop production. Keeping abreast with the above facts, the present investigation was undertaken to evaluate the different weedicides for controlling weeds in *Kharif* onion.

An experiment was conducted at All India Coordinated Research Project on Vegetable crops, MPKV, Rahuri during *Kharif* season of 2011. The six treatments were tested in randomized block design with four replications in a plot size of 2 x 2 m^2. The seeds of onion cultivar '*Phule Samarth*' was sown for nursery raising on 25 June, 2011 and the transplanting was done on 23 August, 2011 on flat beds by adopting spacing of 15 x 10 cm. The six treatments consist of T_1-Oxyflourfen (425 ml/ha) application before planting and second application at 15 days after transplanting, T_2-Oxyflourfen 23.5% EC (638 ml/ha) application before planting and second application at 30 days after transplanting, T_3-Oxyflourfen (870 ml/ha) application 15 days after transplanting and second application at 30 days after transplanting, T_4-Oxyflourfen 23.5% EC (870 ml/ha) application before planting and second application at 15 days after transplanting and third application at 30 days after transplanting, T_5-Oxyflourfen (625 ml/ha) application at 15 days after transplanting and one hand weeding at 45 days after transplanting and T_6-Weedy check.

Eight week old healthy and uniform seedlings were used for transplanting. Upper one third portions of seedlings were removed at the time of transplanting to reduce the transpiration losses and better establishment of crop. All package of practices to raise good crop was done in the experiment and weed control treatments applied as per the treatments. Weed population counts were taken from an area of 0.50 m^2. from the net plot of each treatment and in each replication at 60 days after transplanting. Species wise weed count was recorded by using 0.50 m^2 quadrant in centre place in each plot and number of weeds per quadrant was worked out and weed control efficiency (WCE) was calculated.

The weed dry matter production (WDMP) was recorded after counting of weeds and removing all weeds from quadrant and sun dried for few days and then weight of each dried sample was recorded. The data recorded on weed population, weed control efficiency, weed dry matter production, kinds of weeds and yield was depicted (Table 1). The yield was influenced by different treatments of weedicide application and its frequency. The maximum yield (29.62 t/ha) was recorded in the treatment $T_{6,}$ *i.e.* oxyflourfen 23.5% EC (625 ml/ha) at 15 days after transplanting and one hand weeding at 45 days after transplanting while it was minimum in treatment weedy check (17.97 t/ha). The second best treatment was $T_{1,}$ *i.e.* oxyfluorfen (425 ml/ha) application before planting and second application at 15 days after transplanting. The above findings confirmed the results of Vashi *et al.* (2011).

The maximum weed population was recorded in weedy check treatment, *i.e.* T_5 (28.50) while it was minimum in T_1 (3.75) followed by T_2 (4.0) and T_6 - (4.50). Similar trend was observed for weed dry matter production (Table 1). All kinds of weeds were observed in weedy check treatment. Similar results were also reported by Vashi *et al.* (2011) in onion.

The maximum weed control efficiency (WCE) (87%) was noticed in treatment $T_{1,}$ *i.e.* oxyflourfen (425 ml/ha) before planting and second application at 15 days after transplanting followed by treatment T_2 (86%) *i.e.* oxyflourfen (638 ml/ha) application before planting and second application at 30 days after transplanting and treatment T_6 *i.e.* oxyfluorfen 23.5% EC (625 ml/ha) (84% WCE) at 15 days after transplanting and one hand weeding at 45 days after transplanting (Table 1). Similar results were also reported by Patel *et al.* (1983) and Kumar *et.al.* (1992).

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Table 1. Effect of different herbicides on yield and weed growth in onion

Treatment	Yield (t/ha)	Weed population (no./0.5 m^2	WCE (%)	WDMP (g/0.5 cm^2)
T_1-Oxyflourfen (425 ml/ha) application before planting and second application at 15 days after transplanting.	29.30	3.75	87.00	2.80
T_2-Oxyflurofen (638 ml/ha) application before planting and second application at 30 days after transplanting.	27.17	4.00	86.00	3.00
T_3-Oxyflourfen (870 ml/ha) application 15 days after transplanting and second application at 30 days after transplanting.	26.10	4.75	83.00	3.70
T_4-Oxyflourfen (870 ml/ha) application before planting and second application at 15 days after transplanting and third application after 30 days after transplanting.	28.05	4.50	84.00	3.35
T_5-Oxyflourfen (625 ml/ha) at 15 days after transplanting and one hand weeding at 45 days after transplanting.	29.62	4.50	84.00	3.40
T_6-Weedy check	17.97	28.50	--	220.0
LSD (P=0.05)	28.25	-	-	-

Table 2. Effect of different treatments on growth characters of onion

Treatment	Polar diameter (cm)	Equatorial diameter (cm)	Average weight of bulb (g)	TSS %	A grade bulb (%)	B grade bulb (%)	C grade bulb (%)	Small bulb (%)	Double (%)
T_1	4.60	5.30	62.37	10.2	32.8	18.8	29.9	18.3	0.69
T_2	4.65	5.90	64.87	10.7	25.2	23.3	25.8	24.9	0.93
T_3	4.70	5.80	60.37	10.6	20.1	20.9	36.6	21.2	0.71
T_4	4.50	5.65	60.31	10.5	10.4	35.2	38.3	16.8	0.27
T_5	4.60	5.60	61.30	10.6	32.2	24.5	23.5	19.5	0.35
T_6	3.80	4.10	48.20	10.0	25.2	18.3	20.8	34.9	0.93

Growth and yield attributing components, *viz.* plant height (55.6 to 65.9 cm), number of leaves (9.1 to 11.4), neck thickness (1.2 to 1.7 cm), polar diameter (3.80 to 4.70 cm), equatorial diameter (4.10 to 5.90 cm), average weight of bulb (48.20 to 64.87g), TSS% (10.2 to 10.7) were influenced by different treatments of weedicide application along with weedy check (Table 2). Similar trend of growth and yield attributing components was also reported by Vashi *et al.* (2011). The per cent of A grade bulb size was ranged between 10.4 to 32.8, B grade bulbs was between 18.28 to 35.18 and C grade bulb was between 20.76 to 38.15%. The small bulb per cent was maximum in weedy check (34.87%), while it was minimum in T_4 (16.82), T_1 (18.3) and T_6 (19.5). This indicateed the effectiveness of weedicides in controlling the weeds and subsequently increasing the production of onion in the treatments. Similar results were also reported by Kumar *et al.* (1992).

It can be concluded that for controlling the weed flora in *Kharif* onion, the application of oxyfluorfen 23.5% EC (625 ml/ha) at 15 days after transplanting and one hand weeding at 45 days after transplanting was found effective followed by oxyfluorfen (425 ml/ha) application before planting and second application at 15 days after transplanting. These herbicides were helpful in controlling the weeds and enhancing the productivity of *Kharif* onion provided its time of application and quantity of herbicides should have followed accurately.

SUMMERY

A study was undertaken at AICRP (VC), MPKV., Rahuri during *Kharif* season of 2011 using different herbicides and their time of application. It was found that the maximum weed control efficiency (87%) was recorded in oxyfluorfen (425 ml/ha) application before planting and second application at 15 days after transplanting. For controlling weed flora in *Kharif* onion, the oxyflourfen (625 ml/ha) at 15 days after transplanting and one hand weeding at 45 days after transplanting was found effective followed by oxyflourfen (425 ml/ha) application before planting and second application at 15 days after transplanting.

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Short communication

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Integrated approach for controlling water hyacinth

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Water hyacinth (*Eichhornia crassipes* (Mart.) Solms-Laubach: Pontederiaceae) is an erect, free floating, stoloniferous and perennial herb. The leaves of *E. crassipes* transpire more water into the atmosphere than normal evaporation (Bosman 1999). It affects the water quality and makes water unfit for human or livestock use. Water hyacinth infestation causes fish mortality and may serve as host for vectors of diseases (Rai and Datta 1979). In the state of Tamilnadu, India, the Veeranum lake and its distributaries form the major irrigation source that covers a large proportion of the rice tract of the state with a command area of 18,000 ha. This lake and its distributaries have been infested with *Eichhornia crassipes*. Hence there was an immediate need for its control. Manual or mechanical methods of its control are not cost effective. Use of herbicides is effective and economical but may pose potential risk on non-target organisms and water quality. Biological control using insect agents, though accepted to be the only sustainable option, does not completerly control water hyacinth. Biological control requires several years, usually 3 to 5 years, for insect population to increase to a density that could bring down the weed stand to a substantial decline (Harley *et al*. 1996).

An Indian medicinal herb, *Coleus amboinicus/ aromaticus* Benth showed remarkable allelopathic inhibition of *E. crassipes* when applied as water suspension 30 g/l of water, within 24 h and near cent per cent reduction in fresh weight with in one week was achieved. However, the botanical herbicide showed remarkable activity even at minute doses over cut leaves of the weed. Kathiresan (2000) advocted to use this plant for the control of water hyacienth. This offered a clue that there exists ample scope for applying the plant product on the weed as foliar spray with lesser quantity, if integrated with other approach that will leave the weed canopy pre disposed. Based on the above facts, present study was under taken to find out the synergistic interaction between the botanical herbicide and insect agents for integrated and sustainable control of *E. crassipes.*

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The experiments were conducted during 2002-03 at Department of Agronomy, Annamalai University, India (located at 11° 24’ N latitude and 79°41’E longitude at an altitude of 5.79 meters above mean sea level), to explore the possibility of the interaction between the insect bioagent *Neochetina* spp. and botanical herbicide *Coelus* spp. for control of water hyacinth. Different inoculation loads of biocontrol agents *Neochetina* spp. with spray of *Coleus* leaf powder extract were compared in a pot culture study. These inoculation loads comprised three, two and one insect/plant. The studies were conducted in a split plot design separately for each inoculation load with varying concentrations of aqueous extract of leaf powder of *Coleus, viz.* 5, 10, 15, 20 and 25% included, different length of interlude or time lag, *viz.* 10, 20 and 30 days between the release of insect agents and spraying of plant product on weed. These treatments were replicated five times.

The medium growth stage of the water hyacinth with fresh weight of 100-120 g, leaf area of 500-520 cm^2 and plant height of 20 - 24 cm was selected for this experiment. The observations were recorded for reduction in fresh weight and chlorophyll content at 10 days interval, insect migration and mortality rate at 1, 2, 3, 4, 7, 14 DAS (days after spraying). The reduction in fresh weight was recorded at 10 days intervals (in comparison with initial fresh weight of plants in the same treatment). Chlorophyll content of *E. crassipes* was estimated at 10 days interval by extracting the leaf tissue using dimethyl sulphoxide (DMSO) (Hiscox and Israelstam 1979).

The mortality rates of insects was calculated based on the number of insects died per pot. In order to trace the migrational behaviour of bioagentgent, each treatment container was accompanied by another container with untreated *E. crassipes* plants (without plant product or insect) and both these containers were covered by fish net stretched over steel frames of dimension 35 x 30 x 30 cm. Each pot accommodated five plants of water hyacinth. A white marking was made on the back of the insect prior to release into plants. The number of insects,

Table 1. Per cent reduction in fresh weight of *E. crassipes* at different days after insect release (DAIR)

Treatment	3 insects/plant				2 insects/plant			
	20	40	60	80	20	40	60	80
Main treatment								
25% leaf powder extract	38.8	61.1	90.0	90.0	34.39	50.9	90.0	90.0
20% leaf powder extract	37.8	50.2	74.8	90.0	32.4	44.9	68.3	90.0
15% leaf powder extract	35.0	43.8	52.9	90.0	29.1	40.9	49.2	68.1
10% leaf powder extract	34.9	42.9	50.1	72.8	28.4	36.6	39.4	40.6
5% leaf powder extract	33.3	40.1	43.7	47.0	26.4	36.0	38.9	40.1
Control (insect alone)	32.3	39.2	42.9	45.3	25.7	35.0	38.5	38.6
LSD (P=0.05)	1.9	2.5	3.2	2.6	1.9	3.0	3.6	2.7
Sub-treatment								
10 DAIR	39.8	49.8	57.2	66.7	35.5	43.3	52.9	56.9
20 DAIR	32.8	45.2	56.5	66.2	26.4	40.4	50.0	55.2
30 DAIR	33.3	43.3	53.3	63.0	25.9	38.4	49.1	54.7
LSD (P=0.05)	2.24	3.43	3.28	3.34	2.01	3.23	3.72	2.94

Figures are angular transformed values

Table 2. Per cent reduction in chlorophyll content of *E. crassipes* at different days after insect release (DAIR)

Treatment	3 insects/plant					2 insects/plant				
	20	30	40	50	60	20	30	40	50	60
Main treatment										
25% leaf powder extract	39.2	59.4	79.5	90.0	90.0	33.9	58.0	71.9	79.2	90.0
20% leaf powder extract	37.9	57.1	75.6	90.0	90.0	31.9	52.4	63.4	75.6	90.0
15% leaf powder extract	36.5	53.6	62.3	73.6	90.0	30.5	47.2	58.2	61.1	90.0
10% leaf powder extract	35.2	48.9	51.9	71.1	90.0	25.6	33.3	36.5	39.9	43.9
5% leaf powder extract	31.7	37.6	39.8	44.4	45.7	25.2	32.4	35.4	37.8	41.9
Control (insect alone)	29.6	32.2	34.7	37.7	40.9	24.1	31.6	34.4	36.1	38.5
LSD (P=0.05)	2.6	2.6	2.8	2.5	1.5	3.2	2.9	3.0	3.6	1.4
Sub-treatment										
10 DAIR	44.0	55.5	58.5	64.1	65.8	36.4	48.9	51.9	54.9	58.1
20 DAIR	30.5	51.9	56.8	63.0	65.3	24.2	44.89	49.5	53.9	57.9
30 DAIR	30.0	36.9	50.4	59.0	64.4	24.5	33.9	46.1	50.0	57.9
LSD (P=0.05)	2.4	2.9	3.1	2.3	2.0	3.4	3.2	3.0	3.7	1.8

Figures are angular transformed values

moved to untreated plants was counted at regular intervals and were considered insect migrated from the pots.

The experimental data were statistically analyzed as described by Panse and Sukhatme (1978). The data on percentage values were transformed by angular transformation, before analysis.

All the treatments registered significant reduction over fresh weight and chlorophyll content, insect migration rate and weed nutrient content. Among the different inoculation load of bioagents, three insects/plant was found most effective in reducing 100% fresh weight and chlorophyll content by 60 days, while bioagents (three/plant) followed by spraying of extract of *Coleus* leaf powder at 25% proved significantly superior in reducing the fresh weight and chlorophyll content by 100% on 50 days (Table 1 and 2). Reduction in nutrient contents in weed also recorded in three insects/plant treatment. Reduced concentration of leaf powder extract, *viz.* 20, 15 and 10% with insects also cause 100% mortality of water hyacienth but over a prolonged period. Inoculation load of two in sects/plant controlled the weed by 90 days at 25, 20 and 15% concentration of leaf powder extract.

Two insects/plant were found sufficient to cause injury in the plant to absorb aquaous extract readealy. However, one insect/plant could not offer adequate leaf scrapings to favour absorption of the leaf powder extract. Biochemi-

Table 3. Insect migration rate at different days after spray (DAS) of aquaous extract

Treatment	3 insects/plant						2 insects/plant					
	1	2	3	4	7	14	1	2	3	4	7	14
Main treatment												
25% leaf powder extract	44.4	50.8	57.5	58.9	75.0	90.0	45.0	52.7	61.1	61.1	79.5	90.0
20% leaf powder extract	43.1	49.4	54.7	57.5	72.7	90.0	43.1	52.7	54.7	61.1	75.0	90.0
15% leaf powder extract	37.9	43.1	49.5	52.1	68.6	90.0	39.2	45.0	52.7	52.7	68.6	90.0
10% leaf powder extract	36.6	39.2	46.9	49.5	58.9	90.0	39.2	43.1	48.8	52.7	56.8	58.9
5% leaf powder extract	33.9	37.9	46.2	44.4	49.5	48.2	33.2	43.1	45.0	46.9	50.8	50.8
Control (insect alone)	32.5	36.6	44.4	40.5	44.4	48.2	28.9	37.3	39.2	41.2	43.1	50.8
LSD (P=0.05)	2.4	2.4	2.5	4.0	5.1	1.6	2.0	2.6	3.5	3.8	5.0	2.0
Sub-treatment												
10 DAIR	25.8	31.1	41.2	42.5	56.1	66.8	26.6	34.2	42.1	45.0	57.8	64.7
20 DAIR	35.9	43.7	54.1	54.7	57.5	67.7	41.4	47.9	50.8	52.7	62.3	64.7
30 DAIR	51.4	53.4	54.7	58.2	67.7	67.7	49.8	54.7	57.8	60.0	64.7	65.9
LSD (P=0.05)	2.5	3.2	3.3	3.4	4.2	1.8	2.4	3.0	4.0	3.6	4.0	2.2

Figures are angular transformed values

cal constituents like a-humulene, carvacrol, thymol, a-pinene and a-terpenein in leaf powder were esponsible for its herbicidal functions (Vasquez *et al.* 1999). All the four concentration (25, 20, 15 and 10%) recorded 100% insect migration from the treated plant to untreated plants by 14 days after spraying the extract (Table 3). No insect mortality was observed in any of the concentration of the extract.

Among the different interludes or time lags of insect release, *viz.* 10, 20 and 30 days, 10 days proved more effective in reducing the fresh weight and chlorophyll content of the weed with all the concentration of leaf powder extract. Minimum migration rate and weed nutrient content were also recorded with shorter interlude of 10 days.

SUMMARY

The experiment was conducted at Annamalai University, Tamilnadu, India to study the possibility of interaction between botanical herbicide *Coleus amboinicus/ aromaticus* with insect agents *Neochetina eichhorniae/ bruchi.* Single control options was found inefficient for managing the worlds worst aquatic weed water hyacinth. The integrated approach of releasing the insect agents *Neochetina* spp. onto the weed and spraying the aqueous extract of leaf powder of *Coleus* spp. showed synergistic interaction in reducing the fresh weight and chlorophyll content of water hyacinth. Among the three inoculation loads of insect agents,*viz*. three, two and one insects/plant, three/plant followed by spraying the extract of *Coleus* spp. leaf powder at 25% proved significantly superior in reducing the fresh weight and chlorophyll content to on 60 and 50 days after releasing the insects, respectively. Among the different interludes or time lag compared for evolving a standardized method of integrating foliar spray of leaf powder extract, *viz.* 10, 20 and 30 days, 10 days performed superior by achieving fresh weight and chlorophyll content reduction and least weed nutrient content of water hyacinth. No insect mortality was observed in any of the treatments.

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Short communication

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Weed management for enhanced production of aerobic rice

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Increasing scarcity of fresh water for agriculture particularly for rice cultivation due to demand of water to industries and other sectors, has threatened the sustainability of the irrigated rice ecosystem (Tuong and Bouman 2003). In this context, aerobic rice cultivation offers an opportunity to produce rice with less water. Aerobic rice system production saved irrigation water by more than half compared to flooded system and can possibly mitigate water scarcity in the future (Epino 2004). However, direct-seeded aerobic rice is subjected to more severe weed infestation than transplanted rice because in aerobic rice system, weeds germinate simultaneously with rice and there is no water layer to suppress the weed growth. *Cynodon dactylon, Chloris barbata, Dactyloctenium aegyptium, Digitaria sangunalis, Echinochloa colona, Eleusine indica* and *Panicum repens* among the grasses; *Alternanthra pungens, Cleome viscosa, Cleome chelidoni, Eclipta alba, Euphorbia hirta, Ludwigia parviflora, Parthenium hysterophorus, Phyllanthus niruri, Portulaca olerace* and *Tridax procumbens* among the broad-leaved weeds; *Cyperus rotundus* and *Cyperus iria* among the sedges were reported to be the major weed flora of aerobic rice from different parts of India (Musthafa and Potty 2001, Moorthy and Sanjoy Saha 2002, Ramesh *et al.* 2009). Weeds are the greatest constraint to yield in upland or aerobic rice systems, resulting in yield losses between 30 and 98% (Oerke and Dehne 2004). Considering the above facts, a field experiment was conducted to evaluate the efficacy of different weed management practices in managing weeds of aerobic rice in the coastal region of Karaikal, Puducherry.

A field experiment was conducted during *kharif* 2011 at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puducherry. The soil of the experimental site was loamy sand in texture and pH was slightly acidic (6.1). The fertility status of the soil was low in available nitrogen (78.4 kg/ha) and phosphorus (16.2 kg/ha) and medium in available potassium (138 kg/ha). The organic carbon content was medium (0.76%). A early maturing (107 to 117 days) rice cv. '*PMK(R) 3*' with medium fine grain quantity, was sown in June at a spacing of 20×10 cm. The experiment consisted of 11 treatments, *viz.* pendimethalin 0.75 kg/ha + hand hoeing (HH) at 40 days after seeding (DAS), cyhalofop 0.10 kg/ha + HH at 40 DAS, pretilachlor + safener 0.50 kg/ha + HH at 40 DAS, pyrazosulfuron ethyl 0.20 kg/ha + HH at 40 DAS, butachlor 1.00 kg/ha+ HH at 40 DAS, anilophos0.40 kg/ha + HH at 40 DAS, metamifop 0.075 kg/ha + HH at 40 DAS, metamifop 0.100 kg/ha + HH at 40 DAS, hand hoeing at 20 and 40 DAS, and unweeded control. The aerobic rice under these treatments was compared with transplanted rice given two hand weedings at 20 and 40 days after transplanting (DAT). The experiment was laid out in a randomized block design with three replications. Pre-emergence herbicides were applied at three days after sowing and early post-emergence herbicides were applied at twelve days after sowing. A quadrat of size 0.25 m^2 was placed in the sampling area of each plot and weeds falling within the frames of quadrat were counted and recorded. These weeds were removed, washed free of soil and oven dried at 70°C for 72 hours and the weed biomass was recorded at 30, 60 and 90 DAS and at harvest. Weed index was caluculated using the formula given by Gill and Vijaykumar (1969). The weed control efficiency was calculated using the following formula (Mani *et al.* 1973). The plant height (cm) at harvest was measured from the bese to tip of fully emerged leaf. At harvest, rice plants from randomly selected five hills in the sampling area were uprooted, washed free of soil and shade dried. Later they were oven dried at 70°C for 72 hours and the rice biomass was recorded. The yield attributes of rice such as number of productive tillers/hill, panicle weight, grians/panicle and test weight were also recorded. Since the data on weed density and weed biomass showed high variation, the data were subjected to square root transformation using.

The predominant weed flora included grasses *Echinochloa colona, Cynodon dactylon*; *Panicum repens*

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and broad-leaved weeds such as *Trianthema portulacastrum, Cleome viscosa, Aeschynomene indica* and *Eclipta alba*. *Cyperus rotundus* was the only sedge noticed. The grasses constituted major portion (74.8 %) of the weed flora.

The weed management practices significantly influenced the weed density and dry weight at different stages of aerobic rice (Tables 1 and 2). Pre-emergence application of pendimethalin 0.75 kg/ha + HH at 40 DAS recorded the lower weed density and weed dry weight at 30 DAS. This could be attributed to the reason that pendimethalin is effective against *Trianthema portulacastrum* which was the predominant weed at initial stages of the crop growth. Anilophos 0.40 kg/ha + HH at 40 DAS recorded lowest weed density at later stages as anilophos controlled *Echinochloa colona* which predominated the experimental field at later stages of crop growth.

Weed control efficiency varied with different weed management practices in aerobic rice. At 30 DAS, weed control efficiency ranged from 27.8% in metamifop 0.075 kg/ha + HH at 40 DAS to 77.4% in pendimethalin 0.75 kg/ha + HH at 40 DAS (Table 3) indicating the superiority of pendimethalin 0.75 kg/ha + HH during critical period of crop weed competition. Similar observations were made by Ramesh *et al.* (2009) in aerobic rice.

Uncontrolled weeds reduced aerobic rice yield by 90.3%. All the weed control treatments substantially reduced the competition by weeds for various resources resulting in lower weed index. Anilophos 0.40 kg/ha+ HH recorded the least weed index (4.1) followed by butachlor 1.00 kg/ha + HH (21.0) and hand hoeing at 20 and 40 DAS (22.7).

Pendimethalin 0.75 kg/ha + HH at 40 DAS recorded higher plant height, leaf area and biomass of rice (Table 4). Among the weed control treatments, pendimethalin 0.75 kg/ha + HH at 40 DAS followed by anilophos 0.40 kg/ha + one hand hoeing at 20 and 40 DAS and butachlor 1.00 kg/ha+ one HH, recorded higher rice yield components like productive tillers per hill, panicle weight, number of grains/panicle and test weight. These treatments were on par with each other for almost all yield attributes (Table 4), since the degree of weed control achieved by these treatments were more or less similar (Table 3). The unweeded control recorded the lowest values for all yield components.

Among different weed control treatments, pendimethalin 0.75 kg/ha + HH at 40 DAS registered significantly higher grain (1.53 t/ha) and straw yields (2.74 t/ha). It was observed that in aerobic rice, the grain yield could be increased by 5.5 to 10.4 times and the straw yield by 2.0 to 3.4 times when weeds were effectively controlled. This may be attributed to enhanced availability of nutrients, soil moisture and other resources due to effective weed control by herbicides during early stages as reported by Singh *et al.* (2005). It was also observed that transplanted rice recorded 28% higher grain yield than the best treatment in aerobic rice *i.e.* pendimethalin 0.75 kg/ha + HH at 40 DAS.

Table 1. Total weed density (no./m^2) at various growth stages of aerobic rice as influenced by different weed control treatments

Treatment	Seedling stage (30 DAS)	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Harvest stage
T_1 - Pendimethalin 0.75 kg/ha + HH at 40 DAS	6.9 (47.7)	6.0 (35.0)	6.2 (37.7)	6.4 (40.3)
T_2 - Cyhalofop 0.10 kg/ha + HH at 40 DAS	14.3 (205.3)	7.4 (54.3)	7.8 (61.0)	5.7 (32.3)
T_3 - Pretilachlor + safener 0.50 kg/ha + HH at 40 DAS	13.9 (195.0)	5.8 (33.3)	7.8 (61.0)	6.8 (46.3)
T_4 - Pyrazosulfuron ethyl 0.20 kg/ha + HH at 40 DAS	15.5 (240.7)	7.3 (53.3)	8.9 (78.3)	5.2 (26.3)
T_5 - Butachlor 1.00 kg/ha + HH at 40 DAS	12.2 (147.3)	7.0 (43.0)	7.4 (54.3)	8.5 (72.0)
T_6 - Anilophos 0.4 kg/ha + HH at 40 DAS	13.9 (192.0)	5.2 (27.0)	6.0 (35.3)	6.4 (41.0)
T_7 - Metamifop 0.075 kg/ha + HH at 40 DAS	15.0 (224.3)	6.0 (35.0)	7.4 (55.0)	6.4 (40.0)
T_8 - Metamifop 0.10 kg/ha + HH at 40 DAS	13.5 (181.0)	6.2 (38.3)	7.4 (54.3)	7.0 (48.0)
T_9 - Hand hoeing at 20 and 40 DAS	14.1 (199.3)	6.7 (44.3)	6.3 (39.0)	7.0 (48.0)
T_{10} - Unweeded Control	17.1 (299.4)	17.8 (315.7)	14.4 (207.3)	12.7(161.0)
T_{11} - Transplanted rice with HW at 20 and 40 DAT	4.0 (10.3)	3.5 (11.7)	3.5 (11.7)	2.3 (5.0)
LSD (P=0.05)	0.98	0.76	0.81	0.55

Figures in parentheses indicate original values

Table 2. Total weed biomass (g/m²) at various growth stages of aerobic rice as influenced by different weed control treatments

Treatment	Seedling stage (30 DAS)	Vegetative stage (60 DAS)	Flowering stage (90 DAS)	Harvest stage
T_1	4.2 (24.9)	3.3 (10.7)	5.2 (26.9)	6.3 (39.9)
T_2	8.5 (72.0)	3.8 (13.9)	6.1 (37.1)	7.1 (50.5)
T_3	8.1 (65.1)	3.1 (9.0)	5.1 (25.4)	5.9 (34.6)
T_4	8.4 (69.7)	3.1 (9.2)	5.3 (27.3)	8.3 (69.1)
T_5	7.7 (59.6)	3.7 (13.3)	6.8 (45.7)	8.1 (65.9)
T_6	7.1 (50.3)	2.8 (7.4)	6.0 (36.1)	8.1 (65.1)
T_7	9.1 (79.6)	3.4 (11.1)	5.9 (33.8)	6.2 (28.4)
T_8	8.4 (70.0)	3.4 (11.9)	6.8 (45.4)	6.1 (38.4)
T_9	5.6 (30.6)	2.8 (7.4)	5.6 (30.8)	6.6 (37.3)
T_{10}	10.5 (110.3)	12.1 (144.7)	13.0 (170.6)	13.7 (187.9)
T_{11}	2.7 (6.7)	2.0 (3.7)	1.9 (3.0)	1.6 (2.1)
LSD (P=0.05)	0.91	0.46	0.55	0.77

Figures in parentheses indicate original values; Treatment details are given in Table 1

Pre-emergence application of pendimethalin at 0.75 kg/ha followed by one hand hoeing at 40 DAS was found most suitable weed management practice for achieving higher weed control efficiency and grain yield of aerobic rice in Karaikal region of Puducherry.

Table 3. Weed control efficiency at various growth stages and weed index as influenced by different weed control treatments in aerobic rice

Treatment	Weed control efficiency+				Weed Index+
	30 DAS	60 DAS	90 DAS	Harvest stage	
T_1	77.4	92.6	84.2	78.8	-
T_2	34.7	90.4	78.2	73.1	37.2
T_3	41.0	93.4	85.1	81.6	36.0
T_4	36.8	93.6	84.0	63.2	28.7
T_5	46.0	90.8	73.2	64.9	21.0
T_6	54.4	94.9	78.8	65.4	4.1
T_7	27.8	92.8	80.1	84.9	43.2
T_8	36.5	91.8	73.4	79.4	47.1
T_9	72.3	94.9	81.9	80.1	22.7
T_{10}	-	-	-	-	90.3
T_{11}	93.9	97.4	98.2	98.9	-28.0

+ Data statistically not analysed; Treatment details are given in Table 1

SUMMARY

A field experiment was conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, Puducherry to evaluate the efficacy of different weed management practices in managing weeds of aerobic rice in the coastal areas of Karaikal. The experiment involved eleven weed management treatments laid out in randomized block design with three replications. Treatments included: four pre-emergence (pendimethalin 0.75 kg/ha, pretilachlor + safener 0.50 kg/ha, Butachlor 1.00 kg/ha and anilophos 0.40 kg/ha) and three early post-emergence herbicides (cyhalofop 0.10 kg/ha, pyrazosulfuron ethyl 0.20 kg/ha, metamifop 0.075 kg/ha, metamifop 0.100 kg/ha) followed by one hand hoeing

Table 4. Aerobic rice growth parameters, yield components and yield as influenced by different weed control treatments

Treatment	Plant height (cm)	Leaf area index	Rice biomass (g/plant)	No of productive tillers/hill	Panicle weight (g)	No of grains/ panicle	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1	137.7	7.25	25.95	11.9	3.9	128.0	25.5	1533	2741
T_2	108.3	6.16	18.16	6.9	2.8	87.3	21.5	963	1778
T_3	126.9	5.55	22.48	8.1	3.0	98.3	22.1	981	1778
T_4	121.8	6.01	24.04	8.3	3.1	101.3	22.2	1093	2111
T_5	122.5	5.45	25.32	9.4	3.2	106.7	22.7	1211	1963
T_6	133.5	6.53	25.60	10.5	3.3	113.7	23.5	1470	2778
T_7	108.8	4.52	18.30	7.9	3.0	95.7	21.9	870	1611
T_8	100.1	5.04	15.21	5.9	2.8	71.0	21.3	811	1415
T_9	113.6	6.85	25.11	9.0	3.1	103.0	22.6	1185	2389
T_{10}	96.7	4.40	10.92	3.1	2.6	65.0	16.8	148	815
T_{11}	145.7	7.53	36.49	13.8	4.0	161.3	26	1963	4185
LSD (P=0.05)	13.5	1.13	3.75	1.5	0.5	17.5	4.2	162	344

at 40 DAS. Aerobic rice under these treatments was compared with transplanted rice given two hand weeding at 20 and 40 days after transplanting. The predominant weed flora observed in the experimental field were *Echinochloa colona, Cynodon dactylon, Panicum repens, Cyperus rotundus, Trianthema portulacastrum, Cleome viscosa, Aeschynomene indica* and *Eclipta alba.* Herbicides tested were effective in reducing the weed density and biomass and increasing the rice grain yield significantly. Pre-emergence application of pendimethalin 0.75 kg/ha + HH at 40 DAS recorded significantly higher grain and straw yields with lower weed density, weed biomass and higher weed control efficiency.

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