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Mixed weed flora management by bispyribac-sodium in transplanted rice

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ABSTRACT

Different doses of bispyribac-sodium 20, 25 and 30 g/ha were evaluated against mixed weed flora in transplanted rice under mid-hill conditions of Himachal Pradesh during 2010 and 2011. Major associated weeds were *Echinochloa colona* (31.1%) and *Commelina benghalensis* (7.3%) among grasses, *Cyperus iria* (26.9%) and *Scripus* (9.3%) among sedges and *Ammania baccifera* (8.8%) among broad-leaved weeds. Bispyribac-sodium 20-30 g/ha effectively controlled *E. colona*. Cyhalofop-butyl/butachlor *fb* metsulfuron-methyl was comparable to bispyribac-sodium in controlling *C. benghalensis*. Bispyribac-sodium brought about significant reduction in the count of *Cyperus* sp. up to 60 days after transplanting (DAT). Bispyribac-sodium 30 g/ha behaving statistically similar with bispyribac-sodium 20 and 25 g/ha resulted in significantly lower total weed count and total weed dry weight. There was no phytotoxicity of bispyribac-sodium on rice and no residual toxicity on succeeding crop of wheat. Bispyribac-sodium, farmer's practice, cyhalofop-butyl *fb* metsulfuron-methyl and cyhalofop-butyl *fb* 2,4-D were comparable in influencing rice grain yield. Rice grain yield was positively associated with plant height, panicle length, effective tillers and spikelets/panicle and was negatively associated with weed count and weed biomass. With one weed per m^2 increase up to harvest, grain yield of rice was expected to decrease by 15.3 kg/ha. Bispyribac-sodium at 30 kg/ha was the best in terms of net returns due to weed management. Cyhalofop-butyl *fb* metsulfuron-methyl gave the highest net profit/rupee invested. Herbicide efficiency index (HEI) was highest and weed index was lowest under bispyribac-sodium 30 g/ha. Weed management index (WMI) and agronomic management index (AMI) were highest under cyhalofop-butyl *fb* metsulfuron-methyl.

Key words: Bispyribac-sodium, Impact assessment, Transplanted rice, Weeds

Rice is an important cereal crop of Himachal Pradesh occupying an area of 81 thousand hectares with a production of 115.3 thousand tonnes. Among various factors responsible for low production of rice in Himachal Pradesh, inadequate weed control is the major one. Weeds cause 28-45% yield losses in transplanted rice (Singh *et al*. 2003, Kumar *et al*. 2008, Yadav *et al*. 2009). In recent past, a number of pre and post-emergence herbicides have been recommended for controlling weeds in rice. Butachlor and cyhalofop-butyl are popular among farmers. But these herbicides are less effective against sedges and broad leaved weeds. Therefore 2,4-D is recommended as a followed by application. It makes the weed control technology cumbersome and costly. This situation warrants for initiating research efforts to evaluate and identify suitable post-emergence herbicide against complex weed flora in transplanted rice. Bispyribac-sodium, is a post-emergence broad spectrum herbicide. It is effective against grasses, sedges and broad-leaved weeds in rice fields (Schmidt *et al*. 1999, Walia *et al*. 2008, Yadav *et al*. 2009). Bispyribac-sodium applied mid to late post-emergence at 20 to 23 g/ha has been reported to control barnyard grass 98%, however, when applied late post-emergence to three-tiller barnyard grass, the control was reduced to 70% (Williams 1999). Therefore, the present study was undertaken to standardize its dose against complex weed flora in transplanted rice under mid-hill conditions of Himachal Pradesh.

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MATERIALS AND METHODS

The efficacy of bispyribac-sodium with other herbicides were evaluated during the rainy season (*Kharif*) 2010 and 2011 at Palampur. The area represents the mid-hill wet temperate zone of Himachal Pradesh. The soil was silty clay loam in texture, acidic in reaction) (pH 5.7), medium in organic carbon (0.7%), available N (380 kg/ha) and available P (20.4 kg/ha) and high in available K (256 kg/ha). The experiment was laid out in randomized block design with 3 replications. The treatments consisted of three doses of bispyribac-sodium (20, 25 and 30 g /ha) at 25 days after sowing, cyhalofop-butyl 90 g/ha (15 DAT) and butachlor 1.5 kg/ha (pre.) *fb*. 2,4-D 1.0 kg/ha and metsulfuron-methyl 4 g/ha at 30 DAS, farmer's practice and unweeded check. Rice variety '*HPR-2143*' was transplanted on July11, 2010 and July 4, 2011 with recommended package of practices except treatments. Herbicides were applied with knapsack power sprayer using 600 L water per hectare. Data on density and dry weight of weeds was recorded on 60 days after transplanting (DAT) and at harvest and was subjected to square root transformation. Data on crop phyto-toxicity were recorded at 15 and 30 DAT. The crop was harvested on October 20, 2010 and October 15, 2011. Residual toxicity of bispyribac-sodium was also recorded on succeeding crop of wheat. Economics of the treatments was computed based on prevalent market prices. Impact assessment was carried out as per Walia (2003).

RESULTS AND DISCUSSION

Effect on weeds

The major weed flora of the experimental field was consisted of *Echinochloa colona* (31.1%) and *Commelina benghalensis* (7.3%) among grasses, *Cyperus iria* (26.9%) and *Scripus* (9.3%) among sedges, and *Ammania baccifera* (8.8%) among broad-leaved weeds. *Aeschynomene indica, Monochoria vaginallis* and *Bulbostylis barbata* were the other broad-leaf weeds as a whole constituted 16.6% of the total weed flora.

Weed control treatments brought about significantly variation in the count of *E. colona* (Table 1). Bispyribac-sodium-S 20-30 g/ha has effectively controlled *E. colona* upto harvest during 2010 and upto 60 DAT during 2011. Effective control of barnyard grass (*Echinochloa* sp) with bispyribac-sodium has been reported (Williams 1999). Application of cyhalofop/butachlor *fb* 2,4-D/metsulfuron was as good as bispyribac-sodium in influencing the count of *E. colona* at harvest during 2011. All treatments were significantly superior to weedy check in reducing the count of *C. benghalensis* at 60 DAT during 2010. Excepting butachlor + 2,4-D all the other treatments were comparable to each other in influencing the count of *Commelina benghalensis.* There was significant variation in the count of *Cyperus iria*. Bispyribac-sodium brought about significant reduction in its count upto 60 DAT during both the years. Count of *Cyperus* sp. under cyhalofop *fb* metsulfuron-methyl and butachlor *fb* 2,4-D at 60 DAT during 2010 was not significantly different from that under weedy check. Count of *Scripus* sp. and *Ammania baccifera* was not significantly affected (data not given). Bispyribac-sodium also significantly reduced the count of other broad-leaved weeds (*Aeschynomene indica, Monochoria vaginallis, Bulbostylis barbata*) during 2011. Other treatments except farmer's practice could not bring down the count of other broad-leaved weeds over weedy check upto 60 DAT.

Table 1. Effect of treatments on weed count (no./m²) in transplanted rice

Treatment	Dose (g/ha)	*Echinochloa*				*Commelina*		*Cyperus*				Broad-leaved		
		60 DAT		60 DAT		60 DAT		60 DAT		Harvest		60 DAT	Harvest	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2011	2010	2011
Bispyribac-sodium	20	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	2.7 (6.7)	1.7 (2.7)	1.0 (0.0)	1.0 (0.0)	2.7 (6.7)	2.9 (9.3)	3.4 (10.7)	2.3 (4.3)	2.2 (6.7)	2.9 (9.3)
Bispyribac-sodium	25	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	2.5 (5.3)	1.0 (0.0)	1.0 (0.0)	1.7 (2.7)	2.2 (4.0)	2.3 (5.3)	3.2 (9.3)	1.4 (1.3)	2.5 (6.7)	2.4 (6.0)
Bispyribac-sodium	30	1.0 (0.0)	1.0 (0.0)	1.8 (2.7)	1.8 (2.7)	1.0 (0.0)	1.0 (0.0)	1.4 (1.3)	1.8 (2.7)	1.7 (2.7)	2.7 (6.7)	1.4 (1.3)	1.0 (0.0)	2.5 (6.7)
Cyhalofop-butyl *fb* 2, 4-D	90 *fb* 1000	2.3 (5.3)	2.0 (5.3)	3.4 (10.7)	3.0 (8.0)	2.1 (4.0)	1.0 (0.0)	2.1 (4.0)	2.5 (5.3)	1.0 (0.0)	3.9 (14.7)	2.3 (5.3)	1.0 (0.0)	5.4 (28.0)
Cyhalofop-butyl *fb* metsulfuron-methyl	90 *fb* 4	3.6 (12.0)	2.1 (4.0)	2.5 (6.7)	3.2 (9.3)	1.0 (0.0)	1.4 (1.3)	3.5 (14.7)	2.7 (6.7)	3.2 (9.3)	4.1 (16.0)	2.3 (5.3)	1.7 (2.7)	5.7 (32.0)
Butachlor*fb* 2, 4-D	1500 + 1000	3.1 10.7)	2.3 (5.3)	3.2 (9.3)	3.2 (9.3)	2.5 (6.7)	1.0 (0.0)	3.1 (10.7)	3.0 (8.0)	1.0 (0.0)	4.0 (15.3)	2.3 (5.3)	1.0 (0.0)	3.4 (13.3)
Butachlor *fb* metsulfuron-methyl	1500 *fb* 4	2.9 (8.0)	1.9 (4.0)	3.0 (8.0)	3.4 (10.7)	1.0 (0.0)	1.0 (0.0)	2.1 (4.0)	3.0 (8.0)	1.4 (1.3)	4.1 (16.0)	2.3 (5.3)	1.0 (0.0)	4.8 (22.7)
Farmer's practice		1.0 (0.0)	1.4 (1.3)	2.5 (5.3)	3.4 (10.7)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	3.0 (8.0)	2.5 (6.7)	4.7 (21.3)	3.2 (9.3)	1.9 (4.0)	2.8 (13.3)
Unweeded check		4.1 (16.0)	3.8 (13.3)	5.4 (28.0.)	5.2 (26.7)	4.6 (20.0)	1.0 (0.0)	3.4 (10.7)	3.8 (13.3)	3.4 (10.7)	6.3 (38.7)	4.1 (16.0)	1.0 (0.0)	5.5 (29.3)
LSD (P=0.05)		1.2	1.6	1.1	1.9	1.2	NS	0.8	0.7	1.6	0.9	1.5	NS	2.4

Values in the parentheses are the original in means, *fb* - Followed by, DAT - Days after transplanting

All the weed control treatments recorded significantly lower total weed count and total weed dry weight as compared to unweeded check (Table 2). Owing to species-wise reduction in the count of weeds, bispyribac-sodium 30 g/ha behaving statistically similar with bispyribac-sodium 20 and 25 g/ha resulted in significantly lower total weed count and total weed dry weight. The effective control of grasses, sedges and broad-leaved weeds with bispyribac-sodium in rice fields has been reported (Schmidt *et al.* 1999, Walia *et al.* 2008, Yadav *et al*. 2009). However, bispyribac-sodium was also statistically similar with cyhalofop-butyl/butachlor *fb* metsulfuron-methyl/2,4-D.

Effect on crop

There was no phytotoxicity of bispyribac-sodium on rice. Also, there was no residual toxicity on succeeding crop of wheat during both the years of experimentation (data not given). Plant height was significantly influenced during 2010 (Table 3). Bispyribac-sodium 30 g/ha behaving statistically similar with bispyribac-sodium 20 and 25 g/ha and farmer's practice resulted in significantly taller plants as compared to other weed control treatments. Effective tillers and spikelets per panicle were also significantly influenced during 2010. Panicle length of rice was significantly influenced during 2011. Bispyribac-sodium 20-30 g/ha produced effective tillers statistically similar to cyhalofop- butyl *fb* metsulfuron methyl. Bispyribac-sodium 30 g/ha behaving statistically similar with bispyribac-sodium 20 and 25 g/ha, butachlor *fb* 2,4-D, butachlor *fb* metsulfuron-methyl and farmer's practice produced significantly more spikelet's per panicle as compared to other weed control treatments.

Weeds when allowed to grow throughout the crop season caused 48.1% yield reduction. Bispyribac-sodium 30 g/ha behaving statistically alike with bispyribac-sodium 20 and 25 g/ha and farmer's practice during both the years, cyhalofop-butyl *fb* metsulfuron-methyl during 2010 and cyhalofop-butyl *fb* 2,4-D during 2011, resulted in significantly higher rice grain yield as compared to other weed control treatments. The increased yield in these treatments was due to significant reduction in dry matter accumulation by the weeds and higher number of effective tillers, panicle length and plant height when compared to other treatments. These results are in close conformity with the findings of Walia *et al*. (2008). Rice grain yield was positively associated with plant height (r= 0.759), panicle length (r = 0.664), effective tillers (r = 0.715) and spikelets/panicle (r = 0.844). Whereas, it was negatively associated with weed count (r= -0.750 to -0.967) and weed bio mass (r= -0.684 to -0.994). With one weed/m^2 increase until harvest, grain yield of rice was expected to

Table 2. Effect of treatments on total weed count and dry weight in transplanted rice

Treatment	Dose (g/ha)	Total weed count (no./m^2)				Total weed dry weight (g/m^2)			
		60 DAT		At harvest		60 DAT		At harvest	
		2010	2011	2010	2011	2010	2011	2010	2011
Bispyribac-sodium	20	5.0 (24.3)	4.7 (21.7)	6.6 (44.0)	6.2 (37.3)	1.9 (2.6)	3.8 (13.3)	2.9 (4.3)	5.4 (28.3)
Bispyribac-sodium	25	4.5 (20.0)	3.5 (12.0)	6.2 (37.3)	5.3 (27.3)	1.7 (2.0)	2.8 (7.0)	2.5 (5.8)	4.6 (21.0)
Bispyribac-sodium	30	4.9 (24.0)	2.7 (6.7)	5.0 (24.3)	4.7 (21.3)	1.9 (2.5)	2.2 (4.3)	2.0 (3.2)	4.1 (15.5)
Cyhalofop-butyl *fb* 2, 4-D	90 *fb* 1000	6.4 (40.0)	4.9 (24.0)	5.9 (34.7)	8.0 (64.0)	2.2 (3.8)	3.4 (10.6)	2.3 (4.3)	5.6 (30.7)
Cyhalofop-butyl *fb* metsulfuron-methyl	90 *fb* 4	6.4 (40.0)	4.8 (22.7)	5.1 (25.3)	8.5 (72.0)	3.0 (8.3)	4.1 (16.0)	1.8 (2.2)	5.6 (31.1)
Butachlor*fb* 2, 4-D	1500 + 1000	7.1 (50.7)	5.3 (28.0)	5.5 (30.7)	6.5 (43.3)	2.8' (7.0)	4.3 (18.7)	2.2 (4.4)	5.4 (28.7)
Butachlor*fb* metsulfuron-methyl	1500 *fb* 4	6.5 (42.7)	4.7 (22.7)	4.9 (26.7)	8.6 (74.7)	2.4 (5.1)	4.6 (20.0)	1.9 (2.9)	5.5 (29.9)
Farmer's practice		2.8 (7.0)	5.9 (33.3)	6.2 (37.3)	7.4 (54.7)	1.0 (0.0)	4.5 (19.0)	1.9 (2.7)	5.5 (29.8)
Unweeded check		9.2 (86.7)	8.5 (70.7)	10.1 (101.3)	10.8 (116.0)	4.5 '(19.7)	7.0 (48.0)	4.6 (19.9)	8.9 (78.3)
LSD (P=0.05)		2.2	2.0	1.7	1.5	1.0	1.6	0.8	1.3

Values in the parentheses are the original means, DAT - Days after transplanting

Table 3. Effect of treatments on yield attributes and grain yield of transplanted rice

Treatment	Dose (g/ha)	Plant height (cm)		Panicle length (cm)		Effective tillers (no./m²)		Spikelets/ panicle		Grain yield (t/ha)	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Bispyribac-sodium	20	57.1	94.9	21.5	23.1	50.8	45.3	8.8	12.8	2.78	2.54
Bispyribac-sodium	25	57.1	99.3	20.9	22.9	51.2	49.9	8.9	13.4	2.90	2.67
Bispyribac-sodium	30	58.4	102.0	21.6	23.5	51.3	45.8	9.2	13.6	3.09	2.87
Cyhalofop-butyl *fb* 2, 4-D	90 *fb* 1000	56.4	93.3	21.5	23.3	49.2	43.6	8.7	12.7	2.08	2.50
Cyhalofop-butyl *fb* metsulfuron-methyl	90 *fb* 4	56.3	98.7	21.3	22.9	39.7	48.4	8.8	13.1	3.00	2.49
Butachlor *fb* 2, 4-D	1500 + 1000	55.5	100.4	21.4	23.9	47.2	45.1	8.3	12.7	2.28	2.57
Butachlor *fb* metsulfuron-methyl	1500 *fb* 4	56.2	100.2	21.5	22.5	47.0	44.9	8.9	13.3	2.57	2.61
Farmer's practice		57.3	90.5	21.5	22.9	50.0	49.2	8.8	12.3	2.52	2.54
Unweeded check		55.1	91.7	19.8	22.5	39.3	43.6	8.7	11.8	1.55	1.61
LSD (P=0.05)		1.8	NS	0.8	NS	1.2	NS	NS	0.9	0.34	0.38

Values in the parentheses are the original in means

Table 4. Economics and other impact indices of treatments in transplanted rice

Treatment	Dose (g/ha)	GR (x10³ `/ha)	GRwc (x10³ `/ha)	CWC (x10³ `/ha)	NRwc (x10³ `/ha)	MBCR	WMI	AMI	HEI	WI
Bispyribac-sodium	20	21.92	8.86	3.08	5.78	1.88	2.52	1.52	2.05	-5.1
Bispyribac-sodium	25	22.98	9.92	3.68	6.24	1.69	2.42	1.42	2.79	-10.2
Bispyribac-sodium	30	24.54	11.48	4.29	7.19	1.67	2.33	1.33	4.63	-17.7
Cyhalofop-butyl *fb* 2, 4-D	90 *fb* 1000	18.93	5.88	2.75	3.12	1.13	2.25	1.25	1.25	9.6
Cyhalofop-butyl *fb* metsulfuron-methyl	90 *fb* 4	22.55	9.49	2.33	7.17	3.08	2.62	1.62	2.16	-8.3
Butachlor*fb* 2, 4-D	1500 + 1000	20.01	6.96	2.66	4.29	1.61	2.31	1.31	1.58	4.3
Butachlor*fb* metsulfuron-methyl	1500 *fb* 4	21.36	8.31	2.24	6.07	2.71	2.46	1.46	1.91	-2.3
Farmer's practice		20.88	7.82	4.40	3.42	0.78	2.39	1.39	1.81	0.0
Unweeded check		13.05	-	-	-	-	-	-	-	37.5

GR - Gross returns, GRwc - Gross returns due to weed control, CWC - Cost of weed control, NRWC - Net returns due to weed control, MBCR - Marginal benefit : cost ratio, WMI - Weed management index, AMI - Agronomic management index, HEI - Herbicide efficiency index, WI - Weed index.

decrease by 15.3 kg/ha (Y=3250-15.3 x, R^2=0.855 where Y is grain yield in kg/ha and x is weed density/m²). Every g/m² increase of weed biomass by harvest would results in 32.5 kg/ha grain yield reduction of rice (Y= 31.29-32.5 x, R^2=0.870).

Impact assessment

The weed control treatments registered 1.03 to 3.08 times higher gross returns than weedy check (Table 4). Total gross and additional gross returns over weedy check were highest under bispyribac-sodium 30 g/ha followed by bispyribac-sodium 25 and 20 g/ha, cyhalofop-butyl *fb*. 2,4-D, farmers' practice and cyhalofop-butyl *fb* metsulfuronmethyl. Bispyribac-sodium at 30 kg/ha was the best in terms of net returns due to weed management. This was followed by cyhalofop-butyl *fb* 2,4-D, bispyribac-sodium 20 g/ha and bispyribac-sodium 25 g/ha. However, cyhalofop-butyl *fb* metsulfuron-methyl gave the highest net profit/rupee invested. It was followed by butachlor + metsulfuron-methyl and bispyribac-sodium 20 g/ha. It was mainly due to low herbicide cost ultimately leading to lower application cost. The cost of weed control with new herbicide was more than the recommended herbicidal treatments which could be offset with increased grain yield. However, the cost of the new treatment was not more than the farmer's practice. Herbicide efficiency index (HEI), which indicates weed killing potential and phytotoxicity on the crop (Walia 2008), was highest under bispyribac-sodium 30 g/ha. In terms of weed index (WI), bispyribac-sodium 30 g/ha was superior than other treatments. Bispyribac-sodium 30 g/ha was followed by bispyribac-sodium 25 g/ha, cyhalofop-butyl *fb* metsulfuron-methyl and bispyribac-sodium 20 g/ha both for HEI and WI. Weed management index (WMI) and agronomic management index (AMI) were highest under cyhalopfop-butyl *fb* metsulfuron-methyl which was followed by bispribac 20 g/ha, butachlor *fb* metsulfuron-methyl, bispyribac-sodium 25 g/ha and farmers' practice.

Based on the results of present investigation, it was concluded that post-emergence application of bispyribac-sodium at 30 g/ha could be a suitable herbicide for effective control of mixed weed flora in transplanted rice.

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Field demonstrations on chemical weed control in transplanted rice

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ABSTRACT

Fourty field demonstrations on chemical weed control practices were laid at four villages of Delang block of Puri district in transplanted rice during *Kharif* season of 2010 to 2012 to analyze the performance and profitability of new generation herbicides, *viz*. oxadiargyl, pyrazosulfuron-ethyl, pretilachlor and chloromuron-ethyl + metsulfuron-methyl at 70, 25, 750 and 4 g/ha, respectively on weed growth and productivity of transplanted rice at farmer's fields. The farmers' fields were found infested with mixed flora of grasses, sedges and broad-leaved weeds. The herbicides used for demonstrations were found to be highly effective in controlling weeds and thereby increasing grain yield of rice by 23–42% over farmers' practice based on the intensity and growth of different weed flora. The economic benefits of herbicide demonstration over the farmers' practice varied from ₹ 4,362 - 9,343/ha.

Key words: Chemical control, Farmers' practice, Field demonstration, Herbicide, Transplanted rice, Weed

Rice (*Oryza sativa*) is the staple food for majority of the population of Odisha. It also holds a significant contribution in the economy of the state. In *Kharif*, rice constitutes more than 70% of total net sown area. The average productivity of the state in the season is below the national level though majority of the rice area in *Kharif* season is covered under transplanted method of rice cultivation. One of the major production constraints in rice production is the poor management of weed due to scarcity of labour in the peak period of transplanting. Hence, successful weed control is essential for obtaining optimum yield of rice (Hussain *et al.* 2008).

The general method of hand weeding as practiced by the farmers is labour intensive, time taking and expensive. Moreover in *Kharif* season, due to continuous rains the manual weeding is problematic and uneconomic. In these situations herbicides play a significant role in controlling the weeds and thereby increasing the production. Hence, selective new generation herbicides were demonstrated at farmers' field to show the efficacy of herbicides and profitability with considerable yield advantage over farmers practice.

MATERIALS AND METHODS

The field demonstrations were carried out in transplanted rice with four established herbicides at randomly selected four villages (Sadhangoi, Singhberhampur, Sujanpur and Munida) of Delang block of Puri district of Odisha during *Kharif* 2010 to 2012. Out of four villages, total 40 adopted farmers were selected (10 farmers from each villages) where the demonstrations were carried out. The selected farmers of the demonstration area were of small and marginal in nature. The soil samples from each adopted farmers were analyzed and found to be low in organic carbon which ranges between (0.23-0.38%) and available N (201-232 kg/ha), medium in available P (28.3-32.7 kg/ha) and available K (262-294 kg/ha). Oxadiargyl 70 g/ha, pyrazosulfuron-ethyl 25 g/ha, pretilachlor 750 g/ha and chloromuron-ethyl+ metsulfuron-methyl 4 g/ha were tested in the farmers field to observe its effectiveness in controlling the weeds and thereby increasing the productivity of rice. All the herbicides were applied as per their recommended practice. Weeds were recorded at different stages and at harvest and the weed control efficiency was calculated as per the method suggested by Mani *et al.* (1973).

The grain yield of the crop with the economics of treatments in each demonstration were recorded and compared with the yield of the farmers' practices. The data were calculated and analyzed to draw the valid inferences.

RESULTS AND DISCUSSION

Major infested weeds at demonstration sites were: *Cynodon dactylon* (L.), *Echinochloa colona* (L.) Link. *Eleusine indica* (L.) Gaertner and *Digitaria ciliaris* L. (Scop.) among grasses, *Cyperus rotundus* L., *Cyperus iria* L. and *Fimbristylis miliaceae* (L.) Vahl among sedges. Among broad-leaved weeds *Ageratum conyzoides* (L.), *Alternanthera sessilis* (L.) DC., *Chrozoffera rottleri* (L.) and *Cleome viscosa* (L.) were dominant. The other weeds

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present in low intensity were: *Dactyloctenium aegypticum* (L.) Willd., *Ludwigia parviflora* (Jacq.), *Eclipta alba* (L.) and *Paspalum scrobiculatum* (L.).

All the herbicides under trial were found effective in controlling weed growth (Table 1). The weed count and dry matter were found higher in farmers practice in all the locations of field demonstrations. Higher weed control efficiency (WCE) was found in all the demonstrated plots of herbicide applications over farmers' practice in all the stages of observations. The WCE varied from 68-84% at 60 DAT depending on the floral composition, density and growth of weeds at different locations. The grain and straw yield was increased from 23-42% and 18-26%, respectively over farmers' practice in different herbicides applied fields at different locations, depending on the growth and intensity of weed populations (Table 2). The average highest grain yield of 4.24 t/ha was found to be at locations with the application of oxadiargyl at 70 g/ha, followed by pyrazosulfuron-ethyl (3.96 t/ha). The higher economic benefit of ₹ 9,343 was realized in oxadiargyl treated plots over the farmers' practice, followed by the pyrazosulfuron-ethyl treatment (₹ 8,425). The increased grain yield was attributed mainly to the timely and effective control of weeds during initial stages of crop growth (Mukherjee

Table 1. Effect of different herbicides on weed growth in transplanted rice at farmers' field (meen of 3 years)

No. of field demonstrations/ farmers' practice	Herbicides treatment intervention/ farmers practice (two HW at 20 and 45 DAT)	Weed count (no./m^2)			Weed dry matter (g/m^2)			WCE (%)		
		30 DAT	60 DAT	Harvest	30 DAT	60 DAT	Harvest	30 DAT	60 DAT	Harvest
10 field demonstrations at four locations	Oxadiargyl 70 g/ha	13.7	23.9	34.6	5.9	11.2	18.5	87	84	81
Farmers practice	FP	44.9	65.8	86.7	27.3	29.8	41.9	-	79	54
10 field demonstrations at four locations	Pyrazosulfuron-ethyl 25 g/ha	8.9	14.3	27.4	8.1	8.3	11.9	80	83	76
Farmers practice	FP	35.4	59.5	105.4	19.4	31.4	62.8	-	74	61
10 field demonstrations at four locations	Pretilachlor 750 g/ha	11.2	20.7	41.6	9. 8	9.2	21.3	68	73	71
Farmers practice	FP	54.8	49.6	116.8	32.7	23.5	56.8	-	68	42
10 field demonstrations at four locations	Chloromuron-ethyl + metsulfuron-methy4 g/ha	21.7	27.9	50.7	9.5	16.1	26.1	72	76	71
Farmers practice	FP	36.1	69.1	156.3	23.7	31.4	84.3	-	64	48

DAT-Days after transplanting; HW- Hand weeding, FP- Farmers' practice

Table 2. Effect of different herbicides on yield and economics of transplanted rice at farmers' field (mean of 3 years)

No. of field demonstrations/ farmers' practice	Treatment intervention/ farmers' practice	Grain yield (t/ha)		Straw yield (t/ha)		Yield increase over FP (%)		B:C ratio	Cost of treatments (`/ha)	Benefit over FP (`/ha)
		FP	Treated	FP	Treated	Grain	Straw			
10 field demonstrations at four locations	Oxadiargyl 70 g/ha	-	4.24	-	5.10	42	26	2.59	1,064	9,343
Farmers' practice	FP	2.95	-	4.06	-	-	-	1.11	3,600	-
10 field demonstrations at four locations	Pyrazosulfuron-ethyl 25 g	-	3.96	-	4.87	32	21	2.41	1,654	8,425
Farmers' practice	FP	2.99	-	4.16	-	-	-	1.09	3,600	-
10 field demonstrations at four locations	Pretilachlor 750 g/ha	-	3.86		4.85	23	18	2.48	1,421	6,273
Farmers' practice	FP	3.15	-	4.01	-	-	-	1.14	3,600	-
10 field demonstrations at four locations	Chloromuron-ethyl + metsulfuron-methyl 4 g/ha	-	3.42	-	4.31	26	20	2.39	2,013	4,362
Farmers' practice	FP	2.71	-	4.25	-	-	-	1.21	3,600	-

and Singh 2005). The average yield of all the locations of farmers' practice was found to be below 3.00 t/ha.

The demonstration indicated that both the grain and straw yield along with benefits due to treatments of herbicides was higher than the farmers' practice. The findings were also corroborated with Singh (2009). The applications of herbicides have registered higher B: C ratio in comparison with farmer's practice in all the locations. Among all the herbicides applied, oxadiargyl at 70 g/ha gave the highest B: C ratio of 2.59 followed by pretilachlor at 750 g/ha (2.48). The cost of herbicides including its application varied from ₹ 1,064 - 2013 was less than the farmers' practice, resulting yield advantage of 23 - 42% at different locations.

The field demonstration through farmers' participation plays a key role in transfer of useful technology. As the rate of adoption of herbicide use in the state is very poor in comparison to other chemicals used in agriculture, it is pertinent to do fruitful demonstrations of herbicides with proper dose and time of applications to get more benefit from the technology along with its rapid dissemination.

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Chemical management of non-grassy weeds in direct-seeded rice

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ABSTRACT

Field experiments were conducted during *Rabi* 2011-12, *Kharif* 2012 and *Rabi* 2012-13 to evaluate the bioefficacy of carfentrazone-ethyl at 20 and 25 g/ha on 15-20 DAS with 2,4-D Na salt 800 g/ha on 20-25 DAS, weed free situation and un-weeded check as treatments in randomized block design replicated four times. *Fimbristylis miliacea, Cyperus difformis, Cyperus iria, Schenoplectus pungens* were the major sedges and *Monochoria vaginalis, Ludwigia perennis* and *Sphenoclea zeylanica* were the dominant broad-leaved weed species. Application of carfentrazone-ethyl 20 g/ha on 15-20 DAS proved effective in controlling sedges and broad-leaved weeds in direct-seeded rice. Carfentrazone-ethyl 40 DF 20 g/ha recorded higher grain yield (3.68 t/ha) with weed control efficiency of 90.7% and weed index of 9.5. It was comparable with 2,4-D Na salt 800 g/ha (3.65 t/ha) with weed control efficiency of 96.7% and weed index of 10.5. There was 72% reduction in grain yield due to the infestation of non-grassy weeds in direct-seeded rice. Weed free situation recorded the highest grain yield (4.07 t/ha) but its B: C ratio was lower than carfentrazone-ethyl 20 g/ha and 2,4-D Na salt 800 g/ha. Carfentrazone-ethyl, both at 20 and 25 g/ha did not exhibit any phytotoxic effect in rice plant.

Key words: Broad-leaved weeds, Carfentrazone-ethyl, Chemical control, Sedges, Weed control efficiency, Weed index

Weed infestation is one of the major reasons for poor productivity in direct-seeded rice. Weeds interfere with normal crop growth by competing for available nutrients, light and water. Uncontrolled weeds reduce the grain yield by 96% in dry direct-seeded rice and 61% in wet direct-seeded rice (Maity and Mukerjee 2008). In direct-seeded rice, initial 30 to 40 days of crop growth is critical. The yield decrease in direct-seeded rice increases with the increase in competition duration during the initial period. Manual and mechanical methods are not effective in controlling sedges and broad-leaved weeds in direct-seeded rice because of the high labour cost, scarcity of labour during the critical period of weed competition and unfavorable weather at weeding time. Hence usage of herbicides is becoming increasingly popular as a viable alternative to hand weeding. There is a shift in weed flora from grassy weeds to sedges and broad-leaved weeds and from annuals to perennials due to the continuous use of herbicides for the control of annual grassy weeds (Rajkhowa *et al.* 2006). To avoid undesirable weed shift and herbicide resistance in weeds, the continuous use of herbicides with similar mode of action has to be restricted. Hence, it is imperative to identify alternative herbicides for effective control of sedges and broad-leaved weeds. Therefore the present study was undertaken to evaluate the bio efficacy of carfentrazone-ethyl, a new low dose post-emergent contact herbicide which kills weed by desiccation of leaves for the control of sedges and broad-leaved weeds in direct-seeded rice.

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MATERIALS AND METHODS

Field experiments were conducted during *Rabi* 2011-12 (December 2011-April 2012), *Kharif* 2012 (June 2012-October 2012) and *Rabi* 2012-13 (December 2012-April 2013) at the experimental farm of Rice Research Station, Moncompu, Alappuzha, Kerala (geographically situated at 9º 5´ N latitude and 76º 5´E longitude and at an altitude 1 m below MSL). The soil of the experimental site was silty clay in texture with pH 6.17 (wet), organic Carbon 1.59%, available P 49.28 kg/ha and available K 51.33 kg/ha. The experiment was laid out in randomized block design with five treatments, *viz.* carfentrazone-ethyl 40 DF 20 g/ha on 15- 20 days after sowing (DAS), carfentrazone-ethyl 40 DF 25 g/ha on 15-20 DAS, 2,4-D Na 80 WP 800 g/ha on 20-25 DAS, weed free situation and un-weeded check in four replications. In all the treatments, grassy weeds were controlled by the application of cyhalofop-butyl at 0.08 kg/ha on 18 DAS. The total rainfall received during the cropping season was 387 mm, 1150.6 mm and 217.1 mm respectively, during *Rabi* 2011-12, *Kharif* 2012 and *Rabi* 2012-13.

The pre-germinated seeds of medium duration rice variety '*Uma*' were sown on 21 December 2011, 6 June, 2012 and 13 December 2012. The seed rate adopted for sowing was 100 kg/ha. The crop was fertilized with 90, 45, 45 of N, P_2O_5, K_2O kg/ha. One third dose of N and K and half P were applied at 15 DAS, one third dose of N and K and half P at 35 DAS and remaining one third N and K at 55 DAS. All other agronomic measures were adopted as per the package of practice recommendations of Kerala Agricultural University (KAU 2011). Herbicides were applied with the help of a hand operated knapsack sprayer fitted with flat fan nozzle at a spray volume of 300 l/ha. Observations on density of broad-leaved weeds and sedges were recorded with the help of a quadrate (0.25 x 0.25 m) placed randomly at two representative sites in each plot at 30 DAS and 60 DAS. Broad-leaved weeds and sedges were collected separately from the same area at 60 DAS for recording the weed dry weight of sedges and broad-leaved weeds and their total weed dry weight. Weed samples were sun dried before oven drying at 65^0C until constant weight was attained. The data on weed density and weed dry weight were subjected to square root transformation ($\sqrt{x+0.5}$) to normalize their distribution. Weed control efficiency (WCE) was computed using the total dry weight of weeds and weed index (WI) was computed using the grain yield of weed free check and yield of treated plots. Yield attributing characters like panicles/m^2, panicle weight, fertile grains per panicle and 1000 grain weight were recorded at harvest from 10 randomly selected hills. Number of panicles was recorded by placing a quadrate (0.25 x 0.25 m) at two spots in each plot. The grain yield was recorded at 13% moisture. The cost of cultivation was worked out based on the labour and input cost incurred towards rice cultivation in different treatments. Economics of cultivation was worked out based on the minimum support price for rice (₹17/kg) given by the Government of Kerala during 2012 and straw one rupee per kilogram. The data except WCE and WI were analyzed using ANOVA and the least significant difference (LSD) values at 5% level of significance were calculated and used to test significant difference between treatment means.

RESULTS AND DISCUSSION

Weed flora and density

The observations made on the weed flora at different stages indicated that sedges were the predominant non-grassy weeds present in the experimental field. *Fimbristylis miliacea*, *Cyperus difformis*, *Cyperus iria*, *Schenoplectus pungens* were the major sedges and *Monochoria vaginalis*, *Ludwigia perennis* and *Sphenoclea zeylanica* were the dominant broad-leaved weed species present in the field. On an average, total non-grassy weed population at 30 DAS comprised of broad-leaved weeds (9.69%) and sedges 90.31%. At 60 DAS, total non-grassy weed population comprised of broad-leaved weeds (13.22%) and sedges (86.78%) (Table 1.). There was a decline in the population of sedges in the unweeded check as the crop advanced in its age which may be due to slight increase in the population of broad-leaved weeds and consequent intraspecific competition.

The density of broad-leaved weeds and sedges under herbicidal treatments was significantly lower than the unweeded control (Table.1). Data on weed density at 30 and 60 DAS indicated that the lowest population of sedges and broad-leaved weeds were recorded in 2, 4-D Na salt applied at 800 g/ha on 20-25 DAS. Among the different dosages of carfentrazone-ethyl tested, 20 g/ha applied on 15-20 DAS recorded lower density of broad-leaved weeds at 30 DAS, while the density of sedges was lower in higher concentration of 25 g/ha. This was statistically at par with 2,4-D Na salt and significantly superior to weed free situation. The findings were in conformity with that of Yaduraju and Mishra (2008) who reported that hand weeding failed to control sedges due to regeneration or escape of weeds. The data at 60 DAS revealed that carfentrazone-ethyl applied at 20 g/ha was better than its higher concentration in reducing the density of broad-leaved weeds as well as sedges.

Weed dry matter and weed control efficiency

The dry matter accumulation by weed varied in accordance with the weed population recorded under the different treatments. Significant reduction in weed dry weight of broad-leaved weeds and sedges was observed due to weed control measures (Table 1). Among the herbicides tested, 2,4-D Na salt recorded the lowest dry weight of broad-leaved weeds and sedges and total weed dry weight. Among the different doses of carfentrazone-ethyl tested, both doses were statistically at par in reducing the dry weight of sedges and broad-leaved weeds. However, lower dose of 20 g/ha was better in reducing the dry weight of broad-leaved weeds and higher dose of 25 g/ha was found to be better in reducing the dry matter of sedges. Among the different weed control measures, 2,4-D Na salt recorded the highest weed control efficiency (96.7%). Carfentrazone-ethyl applied at 20 g/ha registered 90.7% weed control efficiency which was higher than its higher dose which registered a weed control efficiency of 88.8%. This was due to better reduction in the population and dry matter of broad-leaved weeds.

Table 1. Effect of treatments on density and dry matter of broad-leaved weeds and sedges (pooled data of three seasons)

Treatment	Dose (g/ha)	Weed density (no./m^2) 30 DAS BLW	30 DAS Sedges	60 DAS BLW	60 DAS Sedges	Weed dry weight at 60 DAS (g/m^2) BLW	Sedges	Total weed dry weight at 60 DAS (g/m^2)	WCE (%)
Carfentrazon-ethyl	20	6.21 (2.59)	8.38 (2.98)	13.04 (3.68)	16.81 (4.16)	5.75 (2.50)	4.93 (2.33)	22.93 (4.84)	90.6
Carfentrazone-ethyl	25	10.19 (3.27)	3.70 (2.05)	22.16 (4.76)	19.04 (4.42)	9.93 (3.23)	3.74 (2.06)	27.48 (5.29)	88.8
2,4-D Na salt	800	2.60 (1.76)	2.89 (1.84)	3.15 (1.91)	4.84 (2.31)	1.09 (1.26)	2.26 (1.66)	8.08 (2.93)	96.7
Weed-free		22.93 (4.84)	81.95 (9.09)	28.77 (5.41)	16.64 (4.14)	1.75 (1.50)	3.15 (1.91)	11.13 (3.41)	95.4
Unweeded		42.93 (6.59)	399.9 (20.01)	51.34 (7.20)	336.9 (18.37)	16.81 (4.16)	131.9 (11.51)	245.3 (15.68)	
LSD (P=0.05)		1.2	1.55	1.45	2.87	0.75	0.99	1.18	

Figures in parentheses are transformed values; BLW- Broad-leaved weeds, WCE- weed control efficiency; DAS - Days after sowing

Table 2. Effect of treatments on yield attributes and yield of direct-seeded rice (pooled data of three seasons)

Treatment	Dose (g/ha)	Panicles /m^2	Panicle weight (g)	Fertile grains/ panicle	1000-grain weight (g)	Grain yield (t/ha)	Weed index
Carfentrazone-ethyl	20	290	2.39	86.9	24.02	3.68	9.5
Carfentrazone-ethyl	25	272	2.28	91.0	23.38	3.32	18.5
2,4-D Na salt	800	282	2.28	91.6	24.28	3.65	10.3
Weed-free		330	2.43	104.0	25.19	4.07	-
Unweeded		147	1.55	56.2	22.74	1.14	72.0
LSD (P=0.05)		19	0.18	7.4	0.44	0.30	

Yield attributes and yield

The yield attributing characters were significantly influenced by the weed control treatments (Table 2). Weed free situation recorded significantly higher number of panicles/m^2, fertile grains per panicles and test weight compared to other treatments. Data on panicles/m^2 revealed that tested herbicides did not exhibit any phytotoxic effect in crop plants. Among the herbicide treatments, carfentrazone applied at 20 g/ha recorded higher number of panicle/m^2, panicle weight and test weight compared to others. Reduction in the weed population provided a competition free environment for rice, enhancing the uptake of nutrients and translocation of photosynthates to sink which in turn influenced the yield attributes positively. Un-weeded check recorded the lowest number of panicles/ m^2, panicle weight, fertile grains per panicle and test weight. This was due to severe weed competition exerted by sedges and broad-leaved weeds for space, light and nutrients throughout the growth period. The results are in conformity with the findings of Gopinath and Kundu (2008) and Saha (2009).

Adoption of different weed management measures increased the grain yield from 3.32 - 4.07 t/ha (Table 2). The increase ranged from 65.6% - 71.91% over un-weeded control. Among the weed control treatments, weed free situation recorded the highest grain yield of 4.07 t/ha. This might be due to the competition free environment maintained by the manual removal of associated weeds. Among the different herbicides tested, carfentrazone-ethyl 20 g/ha recorded higher grain yield which was at par with 2,4-D Na salt applied at 800 g/ha due to better control of sedges and broad-leaved weeds and also due to the improved yield attributes. Paswan *et al.* (2012) reported that application of carfentrazone-ethyl 20 g/ha recorded maximum grain yield in wheat compared to 2,4-D Na salt at 750 g/ha. Un-weeded check recorded the lowest grain yield (1.14 t/ha) due to the negative impact on yield attributes imposed by competition by weeds. Mohan *et al.* (2010) has also reported similar results.

Weed index is the measure of reduction in grain yield due to crop- weed competition compared to weed free situation. In the present study 72% reduction in grain yield

Table 3. Effect of treatments on economics of rice (pooled data of three seasons)

Treatment	Dose (g/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Gross returns ($x10^3$ `/ha)	Cost of cultivation ($x10^3$ `/ha)	Net returns ($x10^3$ `/ha)	B:C ratio
Carfentrazone-ethyl	20	3.68	4.72	81.63	34.62	47.01	2.36
Carfentrazone ethyl	25	3.32	4.45	74.28	34.74	39.54	2.14
2,4-D Na salt	800	3.65	4.82	81.43	34.48	46.95	2.36
Weed-free		4.07	5.38	90.75	39.20	51.55	2.32
Unweeded		1.14	1.72	26.27	31.38	-5.11	0.84
LSD (P=0.05)		0.30	0.29				

was noticed due to the infestation of broad-leaved weeds and sedges in direct-seeded rice. Among herbicides, application of carfentrazone-ethyl 20 g/ha on 15-20 DAS recorded the lowest weed index (9.5) followed by 2, 4-D Na salt applied at 800 g/ha on 20-25 DAS (10.5). The lower weed indices recorded in these treatments indicated lesser grain yield reduction due to minimum crop-weed competition at critical stages.

Even though manual weeding required high labour cost compared to herbicide treatments, weed free situation registered high gross returns and net returns due to high grain and straw yield. Among the herbicide treatments, carfentrazone-ethyl applied at 20 g/ha recorded higher gross returns and net returns due to higher grain yield followed by 2,4-D Na salt applied at 800 g/ha. However the B:C ratio recorded was same in the two treatments (2.36) due to the low cost of 2,4-D compared to carfentrazone-ethyl and high straw yield (Table 3). Weed free situation recorded lesser B: C ratio than carfentrazone ethyl 40 DF applied at 20 g/ha and 2, 4-D Na salt applied 800 g/ha due to high cost of labour with resultant increase in cost of cultivation. Yaduraju and Mishra (2008) reported that manual and mechanical method used to control sedges could not find much place among farmers because of high labour cost, scarcity of labour during the critical period of weed competition and un-favourable weather at weeding time. The lowest B: C ratio was recorded in carfentrazone-ethyl applied at 25 g/ha.

It can be concluded that application of carfentrazone-ethyl 20 g/ha on 15-20 DAS can be recommended for the control of broad-leaved and sedges (non-grassy weeds) in direct-seeded rice with higher grain yield, gross returns, net returns and B: C ratio. It can be used as an alternative to 2,4-D Na salt, a popular herbicide for controlling non - grassy weeds in rice.

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Yield performance of rainfed rice under planting methods and weed control measures

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ABSTRACT

A field experiment was conducted at Kotwa, Azamgarh during rainy season of 2008 and 2009 to evaluate the comparative efficacy of various planting methods and weed control measures on weeds density growth, yield attributes, grain yield and economics of rice variety *'Godawari'*. Four main rice establishment techniques comprised with six sub-plot weed control practices was laid out in split plot design and replicated thrice. *Echinichloa colona*, *E. crusgalli*, *Cyperus rotundus*, *C. difformis* and *Commelina benghalensis* were predominant weed species. Among the rice establishment techniques, puddled transplanted practices proved best for reducing weed dry matter accumulation and produced significantly highest mean grain yield (3.89 t/ha) along with yield contributing parameters in comparison to rest planting methods. Direct drum-seeded rice under puddled condition were observed to be significantly superior and recorded 2.82 t/ha more mean grain yield over direct-dry seeding. Application of pretilachlor 750 g/ha pre-emergence followed by cyhalofop-butyl 60 g/ha post-emergence at 25 DAS/DAT was found quite effective against mixed weed flora which recorded statistically similar grain yield to that of repeated hand weedings. The integration of herbicide with tools, *viz*. pretilachlor 750 g/ha supplemented with mechanical weeding at 25 DAS/DAT again found equally effective in increasing the grain yield as pre- and post-emergence applied herbicides.

Key words: Planting techniques, Rice, Weed control, Yield, Yield parameters

Uttar Pradesh in India is important rice growing state with broad-spectrum agro-ecosystems where transplanting method persists as the major practice of rice planting under puddle condition. Often, farmers fail to transplant the seedlings in time either due to prolonged dry spell or intense rainfall resulting lower yields. Paucity of labours and increasing cost of transplanting encouraged many rice growers to switch over from transplanting to other planting methods of rice. Under these circumstances, the direct seedling of sprouted seeds, unpuddled transplanting and unpuddled stale transplanting appears to be the alternate practices. In wet-seeded rice, weed control is the most crucial factor because the soil conditions are favorable for simultaneous of weeds seeds along with rice seeds and also caused complete reduction in yield (Singh and Singh, 1996). Thus, to avoid yield loss and to keep weed under threshold's level, planting methods become of paramount importance. Location specific information is still lacking about the efficacy of weed management practices on the performance of rice grown under various cultures. Hence, the present investigation was carried out under rainfed lowland shallow favorable situations.

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MATERIALS AND METHODS

A field experiment was conducted at Krishi Vigyan Kendra, N.D. University of Agriculture & Technology, Faizabad, Kotwa, Azamgarh during rainy season of 2007 and 2008 in sandy clay loam having 7.3 pH, organic carbon 0.45%, available N, P and K were 210, 14.6 and 230.7 kg/ha, respectively. A set of 24 treatment combinations consisting of four rice establishment techniques, *viz.* direct sowing with zero till drill under unpuddled wet seed bed, direct drum seeding of pre-germinated seeds under puddle conditions, unpuddled transplanting and transplanting under puddle situation kept as main-plot treatments and coupled with six sub-plot weed control measures like manual weeding at 20, 40 and 60 DAS/DAT, weedy check, mechanical weeding at 25 DAS/DAT, pretilachlor 750 g/ha applied at 48 hours of DAS/DAT, pretilachlor at pre-emergence integrated with mechanical weeding at 25 DAS/DAT and pretilachlor at pre-emergence combined with cyhalofop-butyl at 60 g/ha as post-emergence herbicide was laid out in split plot design with three replications. Rice cultivar '*Godawari*' was used 60 and 30 kg/ha for direct-seeding and nursery raising at same day in last week of June. As per spacing, thinning was done at 15 DAS to keep intra space 10 cm during both the years of study. The N, P_2O_5 and K_2O was applied at 120, 60 and 40 kg/ha through DAP, urea and muriate of potash. The 25% nitrogen and full dose of P_2O_5 and K_2O were applied as basal while remaining, nitrogen was applied in two equal *i.e.* 50% nitrogen was given at active tillering and 25% at panicle initiation stage. For transplanting of seedlings in unpuddled culture, a basic ploughing followed by planking was done by rotavator after which water level was maintained for the purpose. Cyhalofop-butyl was applied at 25 DAS/DAT. Weeds were collected four times for count and dry weight through 0.25 m^2 quadrate. Observations related to crops, yield attributes, yields and other parameters were recorded carefully to interpret interferences during both the years.

RESULTS AND DISCUSSION

The dominant weeds observed in the experimental field were: *Echinochloa colona* (L.) Link; *E. crusgalli* (L.) Beauv; *Cynodon dactylon* (L.) Pers; and *Paspalum distichum* L. in grasses; *Cyperus rotundus* L. and *C. iria* L. in sedges and *Trianthema monogyna* L. and *Commelina benghalensis* L. in broad-leaved group. These weed groups constitute 25, 60 and 15% of total weed population in experimental plots.

Effect on weeds

All rice establishments brought significant effect on decreasing weed dry matter production. The highest value of weed dry weight (138.5 g/m^2) was registered in direct sowing under unpuddled wet seed bed in comparison to rest of the rice cultures. Transplanting under puddle condition had given detrimental impact on weed growth and resulted lowest producer of weed dry weight in both the years (Table 1).

By and large, all the weed control measures were observed to be significantly better than weedy check. In spite of repeated manual weeding, the application of pretilachlor 0.75 kg/ha supplemented with cyhalofop-butyl 0.06 kg/ha post-emergence recorded 85.8% lower weed dry weight over weedy check and found comparable with pre-emergence pretilachlor 0.75 kg/ha integrated with mechanical weeding. Weeds in uncontrolled plots accumulated about two times higher dry matter to that of weeds present in those plots which treated once. This confirms the results of Prasad (1995) that pre- and post-emergence use of anilofos and 2,4-D both 0.4 kg/ha as effective as hand weeding twice at 20 and 40 DAT.

Table 1. Effect of varying planting methods and weed control measures on weeds in rice (mean of two years)

Treatment	Weed density (no./m^2) at 60 DAS	Weed weight (g /m^2)	WCE (%)
Planting method			
Direct-seeded	210.1	138.5	-
Direct-drum seeded	119.9	85.0	-
Unpuddled transplanted	63.5	35.0	-
Transplanted	34.7	17.1	-
LSD (P= 0.05)	1.57	4.77	-
Weed control method			
Mechanical weeding twice	138.0	96.4	45.5
Pretilachlor	100.1	63.4	64.5
Pretilachlor *fb* mechanical weeding	71.2	46.2	76.9
Pretilachlor*fb* cyhalofop-butyl	55.3	25.2	85.9
Weed free	24.5	10.5	94.2
Weedy check	253.4	176.8	0.00
LSD (P= 0.05)	2.49	2.80	-

Effect on crop

Paddy transplanted under puddle conditions produced significantly higher effective tillers per meter row length, more filled grains/panicle and longest panicles. However, among the unpuddled culture, transplanting of raised nursery in well ploughed field being irrigated for transplanting had proved its superiority in enhancing yield enhancing parameters than direct seeding. The highest mean grain yield (3.89 t/ha) was recorded under puddle transplanted method, followed by unpuddled transplanting (3.51 t/ha) during 2008 and 2009, respectively. On an average, puddle transplanting increased the grain yield by 84.6, 37.8 and 10.7%, respectively over direct seeding, drum seeding and transplanting under unpuddled situation (Table 2). The highest yield under puddle transplanting culture may be owing to better crop growth, initial crop-weed competition free environment and better yield contributing parameters by efficient utilization of available resources, which had direct impact on increasing the grain yield. The results were well corroborating with the findings of Jaiswal and Singh (2001).

All weed control measures increased yield and yield attributes considerably over control. The crop growth under weed-free environment recorded maximum number of effective tiller, filled grains/panicle and longest panicle as well as highest producer of yield than the remaining practices. Application of pretilachlor 750 g/ha applied at 48 hours of DAS/DAT combined with cyhalofop-butyl at 60 g/ha post-emergence herbicide appeared as the efficient

Table 2. Effect of varying planting methods and weed control measures on rice (mean of 2 years)

Treatment	Effective tillers (running/m)	Filled grains/ panicle	Grain yield (t/ha)	Benefit : cost ratio
Planting method				
Direct-seeded	36.8	99.3	2.11	1.19
Direct-drum seeded	35.3	126.5	2.82	1.17
Unpuddled transplanted	49.7	134.7	3.51	1.25
Transplanted	52.9	159.7	3.89	1.42
LSD (P= 0.05)	2.79	12.6	0.21	-
Weed control method				
Mechanical weeding	36.0	118.1	2.65	1.09
Pretilachlor	43.0	130.2	3.01	1.32
Pretilachlor*fb* mechanical weeding	48.9	137.4	3.34	1.33
Pretilachlor*fb* cyhalofop-butyl	51.0	147.4	3.43	1.40
Weed free	51.8	156.0	3.60	1.35
Weedy check	27.5	94.1	2.23	1.00
LSD (P= 0.05)	2.72	6.53	0.20	-

weed control treatment that provided almost equal grain yield to weed-free but did not differ significantly with pre-emergence pretilachlor 750 g/ha integrated with mechanical weeding at 25 DAS/DAT. The relatively higher grain yield under these treatments might be due to detrimental effect on weeds which suppressed weed growth efficiently as a resultant of lower crop-weed competition and weed dry weight in per unit area. The deleterious effect of pre- and post-emergence spraying of anilofos and 2,4-D EE on weeds in different paddy cultures provided best weed control along with higher grain yield (Thomas and Sreedevi 1993).

On the basis of above findings, it may be concluded that higher grain yield of rice can be achieved under puddle transplanting method of paddy establishment coupled with the application of pretilachlor 750 g/ha applied at 48 hours of DAS/DAT combined with cyhalofop-butyl at 60 g/ha post-emergence herbicide. The same culture of rice production was found more profitable to the rice growers under rainfed lowland rice situations in eastern Uttar Pradesh. The production of weed dry matter was inversely related with subsequent growth and yield of crop.

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Effect of crop establishment and weed management practices on weed growth and productivity of Basmati rice

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ABSTRACT

A field experiment was conducted at village Binuria of the district Birbhum, West Bengal, India during rainy seasons (*Kharif*) of 2008 and 2009 to study the effect of crop establishment methods and weed management practices on weed growth and productivity of aromatic rice *cv.* '*Basmati 370*'. Three crop establishment methods *viz.* drum seeding (DS), system of rice intensification (SRI) and conventional transplanting (CTR) were assigned in main plots and six weed management practices, *viz.* weed-free check (WFC), unweeded check (WC), pyrazosulfuron-ethyl (PSE) at 20 g/ha, cono weeder (CW) twice at 15 and 30 DAS/DAT, combination of pyrazosulfuron-ethyl (PSE) at 20 g/ha and cono weeder twice (PSE + CW) and metsulfuron -methyl 10% + chlorimuron- ethyl 10% (Almix) at 4 g/ha in sub-plots, replicated thrice. *Cynodon dactylon*, *Echinochloa colona* and *Oryza rufipogon* under grasses, *Hydrolea zeylanica, Ludwigia parviflora, Sphenoclea zeylanica, Monochoria vaginalis, Sagittaria sagitifolia* and *Marsilea quadrifolia* among broad-leaved and *Cyperus iria, C. difformis* and *Fimbristylis miliacea* among the sedges were predominant weeds. *Hydrolea zeylanica* was the most pre-dominant species in SRI as well as conventional transplanting method while *Fimbristylis miliacea* in drum seeding. SRI recorded significantly lower number of total weeds at 60 DAT, the highest number of panicles (231/m^2), filled grains (98/panicle) and grain filling efficiency (84.79%) producing the highest grain yield (3.23 t/ha), 19.68 and 25.8% higher than that of CTR and DS methods respectively. Pyrazosulfuron-ethyl in combination with cono-weeder recorded the lowest weed population and dry weight at 40 DAS/DAT, higher grain yield (2982 kg/ha), 20.58% more over weedy check and was equivalent to sole application of pyrazosulfuron-ethyl and metsulfuron-methyl + chlorimuron-ethyl.

Key words: Cono weeder, Drum seeding, Metsulfuron-methyl + chlorimuron-ethyl, Pyrazosulfuron-ethyl, SRI, Weed management

India is bestowed with a rich diversity of aromatic rice. *Basmati Rice*, a variety of long grain with a fine texture, is the world's best rice for cooking and the leading aromatic fine quality rice in the world trade. In India, Basmati rice is characterized by extra long, superfine slender grains having a length to breadth ratio of more than 3.5, sweet taste, soft texture, delicate curvature and an extra elongation with least breadth-wise swelling on cooking (Yoshihashi 2005). This highly aromatic rice is India's gift to the whole world. Among several grown and marketed Basmati varieties, only six in India are recognized as traditional varieties of which '*Basmati 370*' or '*Punjab Basmati*' is most popular one which conform various standards of genetic purity as prescribed under the provisions of the Seed Act 1966. The crop of '*Basmati 370'* is about 165 cm tall, highly photosensitive and grows under high fertility conditions. It grows best on average fertility soils. '*Basmati 370'* rice variety is a *Kharif* crop and gives an approximate yield of 1.2 t of paddy per acre. Improper planting technique is one of the important factors limiting rice yield. The conventional method of planting rice in India is through transplanting after raising nursery, which is not only more laborious and time consuming but also expensive and inconvenient. Conventional method of transplanting can be replaced by direct seeding thereby reducing labour needs by more than 20% in terms of working hours required. In such situation, direct seeding is helpful because of less labour and time requirement, low cost of cultivation due to skipping of nursery raising and transplanting, maintaining recommended plant population and early crop maturity by 7-12 days (Gill 2008). Productivity of direct seeded rice is comparable with conventional transplanting method (Yadav and Singh 2006, Gangwar *et al*. 2008). The system of rice intensification (SRI) – a technique for rice culture is being practiced/evaluated in almost 22 countries. The proponents

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of SRI have claimed substantial increases in rice yields, sometimes as high as 3-4 times, with the consequent increase in the productivity of land, labour, water and capital (Uphoff 2002). System of rice intensification increases rice yield over the conventional method of cultivation by 32% and net returns by 67%, while decreases labour input by 8% in West Bengal, India (Sinha and Talati 2007). Weed menace is more in wet direct-seeded rice than in transplanted rice and the loss may be to the extent of 50-60% and even a complete crop failure. Manual weeding in rice becomes difficult because of possible damage to rice plants, problems in differentiating grassy weeds, scarcity of labours and more time and cost involvement. Chemical weed management using herbicide alone or in combination may result in effective and economic control of weeds.

Cultivation of *'Basmati 370'* is mainly confined to the foot hills of the Himalayas along with some distant pockets in few states of our country (Siddiq 2002). *'Basmati 370'* is new introduction in this region particularly lateritic belt of West Bengal. At present only a small fraction of land is occupied by this cultivar in this region, so there is lack of information about establishment method, weed management and productivity of this variety. With this background, the present study was undertaken to study the effect of crop establishment methods and weed management practices on weed growth and productivity of '*Basmati 370*' in the lateritic belt of West Bengal.

MATERIALS AND METHODS

Field experiments were conducted during *Kharif* seasons of 2008 and 2009 at the farmer's field at village Binuria (GPS point: $23^0$39.951' N, $87^0$37.971' E and 51 m above MSL), adjacent to Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India located in the lateritic belt of West Bengal. The experimental site represents low rainfall area of the state, with average annual rainfall of 1480 mm. The mean monthly temperature varied between 36.98 °C in April (the hottest month) and 11.7 °C in January (the coldest month) and mean relative humidity between 57.8% in March and 86.6% in August. The experimental soil (lateritic soil) was clay loam (38.6% sand, 22.8% silt and 38.6% clay) in texture, slightly acidic in reaction (6.1 pH in 1:2.5 soil: water) having 328 kg/ ha available N (by $KMNO_4$ method), 22.5 kg/ha Olsen's P and 228.7 kg/ha of 1 N neutral ammonium-acetate-extractable K (by emission spectro-photometry).

The experiment comprising three rice establishment methods *viz*. drum seeding (DS), system of rice intensification (SRI) and conventional transplanting (CTR) in main plots and six weed management practices comprising two controls (weed free and unweeded check), two herbicides *viz.* pyrazosulfuron-ethyl (PSE) at 20 g/ha on 6 days after sowing or transplanting (DAS/DAT) and metsulfuron-methyl 10% + Chlorimuron-ethyl 10% (Almix) at 4 g/ha on 20 DAS/DAT, mechanical weeding with cono weeder (CW) at 15 and 30 DAS/DAT and one chemical and mechanical combination (PSE + CW) in sub plots of 12 m^2 plots was conducted under split- plot design with three replications.

In case of drum seeding, a modified drum seeder (IRRI model) was used. It was an eight row seeder spaced at 20 cm row spacing and required 9 kg of pressure to operate the machine. The drum was mounted on two wheels which were placed at both ends. Pre-germinated seeds (soaking for 24 hours in water and treated with mancozeb at 2 g/litre of water for five minutes followed by incubation for 36-48 hours in jute bag under moist condition) of paddy cultiver *'Basmati- 370'* were filled in the drums after drying in shade for 2 hours and the drum seeder was manually dragged on the field after draining the water to saturation on July, 04 in 2008 and 2009. On the same day seeds were sown in nursery bed for SRI (in raised bed, germinated seeds were spread and covered with well rotten dry FYM and ash to facilitate transplanting of younger seedlings) and CTR (in well puddled nursery bed in densely spread out of germinated seeds). Eleven day old seedlings were transplanted singly for SRI in well puddled, clean, moist plots measuring 4 × 3 m at 25 × 25 cm hill spacing on July, 15^{th} in both the years and for conventional transplanting, 21 day old seedlings were transplanted on 25^{th} July 2008 and 2009 respectively maintaining 25 × 20 cm hill spacing in well puddled 4 × 3 m plots with 2-3 seedlings/hill.

The recommended dose of fertilizer (RDF) for Basmati rice in the experiment was at 80: 40: 40 kg N, P_2O_5 and K_2O/ha, respectively in the form of urea, single super phosphate (SSP) and muriate of potash (MOP). Half of the fertilizer N and K, full dose of P, along with 5 t/ha farm yard manure (FYM) were applied as basal (at the time of puddling). Remaining half of N and K was applied in two equal splits once at tillering and rest at panicle initiation stage.

The crop was harvested at the end of October to first week of November and DS plots were harvested 3-4 days before SRI and later one harvested 2-3 days prior to CTR. Plant protection measures were adopted as per need. Observations on weed counts (number/m^2) and weed dry weight (g/m^2) were taken by sampling randomly at 5 places with the help of 0.25 m^2 quadrates at 40 and 60 days and the data were transformed using $\sqrt{x + 0.5}$ before statistical analysis. Weed control efficiency [WCE= {(WC-Wt)/WC} x 100] was also calculated [average weed dry weight per unit area in weedy check (WC) and average weed dry weight per unit area in treatment plot (Wt)]. Plant height, panicle numbers, were recorded at the day of crop harvest based on randomly selected 10 plants/hills of each plot and length of panicle, filled grains/ panicle were recorded at 2-3 days after crop harvest based on randomly selected ten panicles. Test weight of grains was computed by taking 1000 bold seeds from each plot after proper sun-drying. Weed Index [WI= $\{(Y_{WF}-Y_T)/ Y_{WF}\} \times 100$] was calculated from the grain yield data of weed management treatments [average grain yield of rice in weed free plot (Y_{WF}) and average grain yield of rice in weed management treatments (Y_T)].

RESULTS AND DISCUSSION

Weeds and weed growth

The experimental field was infested with three categories of weeds under nine families. The total number of species was 12, out of which, *Echinochloa colonum* (L.) Link, *E. crus-galli* (L.) Beauv. and weedy rice - *Oryza rufipogon* Griff. among grasses, *Hydrolea zeylanica* (L.) Vahl., *Ludwigia parviflora* Roxb., *Marsilea quadrifolia* L., *Sphenoclea zeylanica* Gaertn., *Monochoria vaginalis* (Burm.f.) C. Presl. and *Sagittaria sagitifolia* L. among broad-leaved and *Cyperus iria* L., *C. difformis* L. and *Fimbristylis miliacea* (L.) Vahl. among sedges were present as major weeds in rice field. *Hydrolea zeylanica* was the most predominant species in SRI and Conventional Transplanting plots whereas, *Fimbristylis miliacea* in drum seeding plots during both the years. Rice establishment methods had significant effect on the reduction of weed

Table 1. Effect of crop establishment and weed management practices on weed population, dry weight and weed control efficiency (mean of two years)

Treatment	Weed population (no./m^2)								Total weed dry weight (g/m^2)		Weed control efficiency (%)	
	40 DAS/DAT				60 DAS/DAT							
	Grass	Broad-leaved	Sedge	Total	Grass	Broad-leaved	Sedge	Total	40 DAS/ DAT	60 DAS/ DAT	40 DAS/ DAT	60 DAS/ DAT
Crop establishment												
DS	2.04 b (6.5)	2.61 c* (15.2)	1.69 b (4.7)	3.45 c (26.3)	1.67 b (3.7)	2.53 b (11.6)	2.57 c (8.1)	3.84 c (23.4)	3.64 c (29.7)	4.73 c (36.4)	-	-
SRI	1.83 a (5.0)	2.04 a (8.4)	1.31 a (2.1)	2.73 a (15.5)	1.37 a (2.0)	1.95 a (5.9)	1.62 a (3.2)	2.65 a (11.1)	2.22 a (6.0)	3.23 a (17.3)	-	-
CTR	2.07 b (6.2)	2.30 b (11.4)	1.43 a (3.1)	3.16 b (20.7)	1.60 b (3.4)	2.45 b (10.0)	2.09 b (5.1)	3.42 b (18.4)	2.58 b (8.4)	4.21 b (28.8)	-	-
LSD (P=0.05)	0.13	0.12	0.12	0.23	0.20	0.36	0.17	0.29	0.10	0.37	-	-
Weed management												
PSE at 20 g	0.98 b (0.5)	0.71 a (0.0)	0.71 a (0.00)	0.98 b (0.5)	0.98 b (0.5)	0.90 a (0.4)	1.79 c (3.0)	2.01 c (3.8)	1.01 b (0.6)	2.45 c (6.0)	99.5	93.9
CW	3.56 c (12.4)	3.47 b (11.9)	2.05 b (3.9)	5.29 c (28.2)	2.26 c (5.0)	4.30 c (18.3)	3.12 d (10.0)	5.71 d (33.2)	5.62 c (31.8)	7.12 d (51.8)	70.46	47.8
PSE + CW	0.95 b (0.4)	0.71 a (0.0)	0.71 a (0.0)	0.95 b (0.4)	0.98 b (0.5)	1.03 b (0.6)	1.36 b (1.5)	1.72 b (2.6)	0.98 b (0.5)	2.08 b (4.0)	99.53	95.9
MSM + CMU at 4 g	0.99 b (0.6)	0.71 a (0.0)	0.71 a (0.0)	0.99 b (0.6)	0.83 a (0.2)	1.03 b (0.7)	1.47 b (1.8)	1.73 b (2.6)	1.02 b (0.7)	2.09 b (4.1)	99.36	95.8
Weed-free check	0.71 a (0.0)	0.71 a (0.0)	0.71 a (0.0)	0.71 a (0.0)	0.71 a (0.0)	0.71 a (0.0)	0.71 a (0.0)	0.71 a (0.0)	0.71 a (0.0)	0.71 a (0.0)	100	100
Unweeded check	4.69 d (21.5)	7.60 c (58.1)	3.98 c (15.7)	9.74 d (95.3)	3.51 d (12.0)	5.88 d (35.0)	4.11 e (16.6)	7.94 e (63.5)	10.36 d (107.7)	9.90 e (99.1)	0	0
LSD (P=0.05)	0.20	0.09	0.08	0.21	0.18	0.23	0.13	0.22	0.23	0.28	-	-

Values given in parentheses are original means; *Means followed by common letters do not differ significantly at P = 0.05 level; DS- Drum Seeding; SRI- System of rice intensification; CTR- Conventional transplanting; PSE - Pyrazosulfuron-ethyl at 20 g/ha at 6 DAS/DAT; PSE + CW - Combination of PSE + cono-weeder (twice application at 15 and 30 DAS/ DAT); MSM + CMU - Metsulfuron-methyl 10% + chlorimuron-ethyl 10% at 4 g/ha at 20 DAS/DAT.

population. SRI plots had the lowest number of weeds in respect of morphological groups as well as total weeds at 40 and 60 DAS/DAT whereas drum seeding plots had the highest number of weeds. Effective reduction of broad-leaved, grasses and sedges was recorded with PSE + cono-weeder, PSE and Almix alone and these were statically at par with weed free check. However, regeneration of sedges occurred in all weed management treatments (Table 1). None of the treatments could effectively control weedy rice (*Oryza rufipogon*). All the treatments were significantly superior to weedy check. Pal *et al*. (2012) also found similar results.

Among the crop establishment methods, SRI had the lowest dry weight of total weed and drum seeding plots had the highest dry weight of weeds both at 40 and 60 DAS/DAT. The treatment PSE + cono weeder significantly reduced the total weed dry weight followed by PSE and Almix alone (Table 1). Absolute WCE was only in weed free check, above 95% in PSE + cono weeder, PSE and Almix and below 75% in Cono weeder. Besides that Almix had the certain level of phytotoxicity in DS and SRI treated plots at the early stage of crop growth.

Effect on rice

Weed management treatments had the significant effect on crop height at harvest. PSE + cono weeder and weedy check plots recorded the tallest and shortest plants respectively; whereas, rice establishment techniques had no significant effect on crop height at harvest. Rice establishment techniques had significant effect on production of tillers/m^2. SRI and DS recorded the highest and the lowest number of tillers respectively. Among the weed management treatments PSE + cono weeder recorded the higher number of tillers/m^2 over others except weed-free check followed by cono weeder alone simply due to effective weed suppression and better root aeration in this integrated approach. However, Almix recorded the highest efficiency regarding panicle production; followed by PSE, PSE + cono weeder and weedy check.

Number of filled grains per panicle was significantly influenced both on the rice establishment methods and weed management practices. The number of filled grains and grain filling efficiency were highest under SRI and were significantly superior over DS and CTR which were however at par with each other. Among the weed management practices PSE + cono weeder recorded higher number of filled grains (98/panicle) which was statistically at par with weed free check followed by sole application of PSE and Almix (Table 2). Weed free check registered significantly higher grain filling efficiency (89.1%) over other treatments followed by PSE + cono weeder (84.7%), sole application of PSE (82.7%) and Almix (82.1%). Test weight (1000 seeds weight) was significantly influenced both by rice establishment system and weed management

Table 2. Effect of crop establishment and weed management practices on plant height, yield components, harvest index and weed index (mean of two years)

Treatment	Plant height at harvest (cm)	Effective tillers /m^2	Filled grains/ panicle	Grain filling efficiency (%)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Weed index (%)
Crop establishment									
DS	147.0	203.4 b	85.3 b	79.7 b	21.87 b	2.57 b	9.13 b	21.9 b	-
SRI	149.7	230.8 a	97.8 a	84.9 a	22.82 a	3.23 a	9.52 b	25.3 a	-
CTR	148.6	228.1 a	88.1 b	80.0 b	22.07 b	2.70 b	10.44 a	20.6 b	-
LSD (P=0.05)	NS	17.7	3.63	3.6	0.27	4.43	0.50	2.7	-
Weed management practice									
PSE at 20g	146.1 c	221.1 bc	91.3 bc	82.7 b	22.26 b	2.90 bc	9.69 c	23.0	5.01
Conoweeder (CW)	151.8 ab	230.3 abc	89.0 c	78.9 c	21.92 c	2.76 d	9.80 bc	21.9	9.35
PSE+CW	152.4 a	241.9 ab	97.1 ab	84.7 b	22.48 b	2.98 ab	10.12 ab	22.7	2.35
MSM+CMU at 4g	146.8 bc	210.9 c	87.8 c	82.1 bc	22.37 b	2.84 cd	0.96 c	22.8	6.86
Weed free check	144.7 c*	248.7 a	101.9 a	89.1 a	22.79 a	3.05 a	1.03 a	22.9	0.00
Unweeded check	148.8 abc	171.7 d	75.3 d	71.6 d	21.70 c	2.47 e	8.64 d	22.2	19.00
LSD (P=0.05)	5.14	22.7	6.65	3.7	0.26	0.13	0.38	NS	-

*Means followed by common letters do not differ significantly at P = 0.05 level; DS- Drum Seeding; SRI- System of rice intensification; CTR- Conventional transplanting; PSE - Pyrazosulfuron-ethyl at 20 g/ha at 6 DAS/DAT; PSE + CW - Combination of PSE + cono-weeder (twice application at 15 and 30 DAS/ DAT); MSM + CMU - Metsulfuron-methyl 10 % + chlorimuron-ethyl 10 % at 4 g/ha at 20 DAS/DAT.

treatments. SRI produced more bold seeds than that of CTR and DS. On the other hand weed-free check recorded significantly the highest test weight, followed by PSE + Cono weeder, Almix and PSE; which were at par; whereas, weedy-check recorded the lightest grains.

SRI recorded significantly the highest grain yield (3235 kg/ha) which was 19.7 and 25.8% higher over CTR and DS, respectively. Though the lowest (2572 kg/ ha) grain yield was recorded under DS but it was at par with CTR (2703 kg/ha). About 19% yield loss was occurred due to weed competition in Basmati rice. Weed-free check recorded the highest grain yield and was at par with PSE + cono weeder (2.98 t/ha), followed by sole application of PSE, Almix, cono weeder and the significantly lowest gain yield was in weedy-check. Crop establishment methods and weed management treatments had no significant interaction effect. The results corroborate the findings of Kumar *et al*. (2012). Conventional transplanting recorded the highest straw yield and DS the lowest and the later was statistically at par with SRI. The opposite result was observed with respect to HI. PSE + cono weeder recorded significantly higher straw yield followed by Cono weeder, PSE and Almix. Weed management treatments had no significant effect on HI. PSE + cono weeder recorded lower weed index (WI) value (2.35%) followed by sole application of PSE, almix and cono weeder.

It can be concluded that application of PSE at 20 g/ha at 6 DAS/DAT and twice application of cono weeder at 15 and 30 DAS/DAT was the most effective weed management practice and among the rice establishment systems SRI was the most appropriate system in Basmati rice in the *Kharif* season. Thus, SRI system along with pyrazosulfuron-ethyl at 20 g/ha at 6 DAT + cono weeder may be recommended for Basmati rice cultivation in the lateritic belt of West Bengal.

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Competitiveness of rice cultivars under stale seedbed in dry direct–seeded rice

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ABSTRACT

A field experiment was conducted to study the performance of cultivar and weed management practices under stale seed bed in dry direct seeded rice. The treatment consisted of combination of two methodsof rice sowing *i.e.* dry seeding after stale seed bed by glyphosate 1 kg/ha and shallow tillage and two weed management treatment (weedy and two hand weeding) in main plot and four cultivars *viz. 'BPT-5204, Sarjoo -52, PRH-10'* and *'HUBR2-1'* in sub-plot replicated thrice in split plot design. The results revealed that '*Sarjoo-52'* was found to be more competitive than other cultivars in terms of grain yield and economics. Studies on competitive traits revealed that number of grains/panicle had highest direct positive effect whereas number of panicles/m^2 via number of grains/panicle had more indirect effect on grain yield.

Key words: Competitive traits, Cultivars, Dry direct-seeded rice, Stale seed bed, Weed management

Due to climate change and changing weather patterns, there is change in the rainfall pattern. It has been observed at Varanasi (Uttar Pradesh, India) that the average rain fall has decreased in past decades, resulting in water scarcity (Singh *et al.* 2011). Increasing shortage of water had compelled farmers to adopt dry direct seeded rice (Dry-DSR). Weeds are a major constraints to the success of DSR in general and to Dry-DSR in particular (Johnson and Mortimer 2005, Singh *et al.* 2006, Rao *et al.* 2007). In absence of effective weed control measures, yield losses are high in direct seeded rice than in transplanted rice (Rao *et al.* 2007).

The success of stale seed bed depends on several factors like method of seed bed preparation, method of killing emerged weeds, weed species, duration of the stale seed bed (Ferrero 2003) and environmental condition (temperature during the stale seed bed period). Weed species especially *Cyperus iria, Cyperus difformis, Fimbristylis miliaceae* and *Eclipta prostrate*) can be relatively more susceptible to the stale seed bed technique combined with zero-till because of their low seed dormancy and their inability to emerge from a depth greater than one cm (Chauhan and Johnson 2009, 2010). Renu *et al.* (2000) found that a stale seed bed with herbicide (paraquat) was more effective in weed suppression than the mechanical method in dry-DSR because herbicides kill weeds without bringing new seeds to the germination zone.

Differences in the competitiveness of upland and rain fed low land rice cultivars against weed infestation have been well documented (IRRI 1994). Upland rice cultivars can differ by up to 75% in their suppression of weeds (Garrity*et al.* 1992). Studies have shown the competitive ability of rice cultivars against weeds like *Echinochloa phyllopogen, E. oryzoides, Brachiaria brizantha* or *B. decumbens* (Fischer and Gibson 2001). Rice establishment method is one of the important factors influencing nature of weed flora infesting DSR. In stale seed bed technique, after seed bed preparation, the field is irrigated and left unsown to allow weeds to germinate and which are killed either by a non-selective herbicide or by carrying out tillage prior to the sowing of rice. This technique not only reduces weeds emergence but also reduces the number of weed seeds in the soil seed bank (Rao *et al.* 2007). Keeping above facts in view, an experiment was conducted to study the performance of rice cultivars under stale bed method in dry direct-seeded rice.

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MATERIALS AND METHODS

A field experiment was conducted during rainy season of 2009, 2010 and 2011 at Agricultural Research Farm, Institute of Agricultural Sciences, Varanasi, Uttar Pradesh. The soil of the experimental field was sandy clay loam in texture having pH 7.5, organic carbon 0.40%, available N 284 kg/ha, P 16.9 kg/ha and K 140 kg/ha. Treatment comprised of two rice establishment methods *viz.*, dry seeding after using (i) stale seed bed method by shallow ploughing (ii) glyphosate 1 kg/ha, two hand weeding and weedy check in main plot and four cultivar in sub plot, *viz. 'BPT-5204, Sarjoo -52, PRH-10'* and *'HUBR2-1'* in a split plot design replicated thrice. In stale bed treatment to facilitate weed emergence, irrigation was applied in first week of June 2009, 2010 and 2011, thereafter, first flush of weeds was controlled either by application of glyphosate 1 kg/ha or shallow tillage. The crop was sown by the help of zero till ferti - cum seed drill using seed rate of 30 kg/ha on 20, 19 and 21st June, 2009, 2010 and 2011, respectively on dry beds and irrigated thereafter to facilitate germination of rice seeds. A uniform dose of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O were applied in the form of urea, DAP and potassium in each experimental plot. One third of nitrogen and full dose of phosphorus and potassium were applied as basal dose and remaining amount of nitrogen was applied in two equal splits at tillering and panicle initiation stages. Glyphosate 1 kg/ha was applied as pre planting treatment in stale seed bed treatment with the help of hand operated knapsack sprayer, fitted with flat fan nozzle using water at 300 liter/ha. Weed density and weed dry weight data were recorded at 30 and 60 DAS. Observations on weed density and weed dry weight were recorded randomly from two places in each plot using 0.25 m^2 quadrate. The data recorded on weeds were subjected to square root transformation ($\sqrt{x+0.5}$) to satisfy the condition of homogeneity of variance. Biometrical observations on growth attributes, yield attributes and yields were also recorded during course of investigation.

Path coefficient analysis was carried out to study the relationship between two characters through direct and by way of indirect influence of the other characters under weedy conditions. Path coefficient analysis of yield attribute and yield data under weedy condition was done with a software SPAR developed by Indian Agricultural Statistical Research Institute (Huan *et al.* 1999)

RESULTS AND DISCUSSION

Weed composition

The major weeds infesting experimental field at 40 days after sowing were: *Cynodon dactylon* (6.2%), *Dactyloctenum aegypticum* (2.2%) *Echinochloa colona* (20.3%), *Echinochloa crusgalli* (5.9%), *Leptochloa chinenis* (1.7%) among grasses; *Ammannia baccifera* (1.9%), *Caesulia axillaries* (4.5%), *Commelina benghalensis* (6.1%), *Physalis minima* (6.3%), *Eclipta alba* (3.3%), *Euphorbia hirta* (5.1%), *Phyllanthus niruri* (12.6%), *Ludwigia* spp. (1.3%), *Trianthema monogyna* (3.8%) among broad-leaved weeds and *Cyperus difformis* (5.4%) among Sedges.

Effect on weed and growth attributes

Non significant variations in dry weight was observed due to stale bed method of rice establishment and cultivars at 30 and 60 days of crop growth except weed density at 30 days stage (Table 1) where stale bed using glyphosate 1kg/ha significantly reduced weed density in comparison to stale bed using shallow tillage. Stale bed using glyphosate 1 kg/ha recorded significantly better performance of growth attributes, *viz*. plant height, number of tillers/m^2, dry matter accumulation, crop growth rate and leaf area index as compared to stale bed method using shallow tillage. However, during 30 to 60 days growth period stale bed using shallow tillage recorded significantly higher relative growth rate in comparison to stale bed using glyphosate 1 kg/ha.

Amongst cultivars, '*Sarjoo-52*' had better performance of growth attributes as compared to '*BPT-5204*' and '*PRH-10*'. Rice cultivar '*HUBR2-1*' and '*Sarjoo-52*' had statistically comparable values of dry matter accumulation, RGR, CGR and leaf area index whereas with respect to plant height and number of tillers/m^2, both cultivars were at par with each other. Similarly, rice cultivar '*BPT-5204*' and '*PRH-10*' were at par with each other with respect to dry matter accumulation, RGR, CGR and leaf area index. Weed free plots recorded significantly better performance of all the growth attributes in comparison to weedy plots.

Effect on yield attributes and yield

Dry seeded after stale bed using glyphosate 1 kg/ha recorded significantly more number of panicles/m^2, longer panicles, more number of grains/panicle and panicle weight, grain yield and harvest index (Table 2). Cultivar '*Sarjoo-52*' exhibited significantly better performance of yield attributes, *viz*. number of panicles/m^2, number of grains/panicle and panicle weight in comparison to '*PRH-10, BPT-5204*' and '*HUBR 2-1*'. the cultivars '*Sarjoo-52*' and '*HUBR 2-1*' had comparable panicle length and test weight. However, the harvest index of '*PRH-10*' was maximum and it was at par with '*Sarjoo-52*' which recorded maximum grain yield and it was significantly superior to all the cultivars. The cultivars '*HUBR 2-1*' and '*PRH-10*' had statistically comparable grain yield and the former cultivar had significantly higher grain yield than '*BPT-5204*'. Weed free treatment recorded significantly higher yield attributes and yield in comparison to weedy.

Path coefficient analysis was done to study the relationship between two characters through their direct and by way of indirect influence of the other characters. (Table 3). On which basis path diagram was developed to show relationship between and yield attributes yield. Genotypic correlations were partitioned into direct and indirect effects on grain yield. The analysis revealed that among

Table 1. Effect of stale bed method, weed management and cultivar on weed and crop growth in direct-seeded rice (mean data of three years)

Treatment	Weed density (no./m²)		Weed dry weight (g/m²)		60 DAS			Relative growth rate (g/g/day)	60 DAS	
	30 DAS	60 DAS	30 DAS	60 DAS	Plant height (cm)	No. of tillers /m²	Dry matter accumulation (g/m/row)	30-60 DAS	Crop growth rate (g/m²/day)	Leaf area index
Rice establishment										
Dry seeded after stale bed using shallow tillage	8.15 (60.4)	11.30 (125.1)	4.75 (19.8)	10.51 (118.9)	50.8	175.6	31.15	0.044	0.75	2.89
Dry seeded after stale bed using glyphosate1kg/ ha	7.25 (63.8)	10.49 (118.6)	4.74 (19.8)	10.27 (115.7)	54.2	195.9	36.66	0.038	0.84	3.28
LSD(P=0.05)	0.82	NS	NS	NS	1.1		5.75	0.005	0.18	0.28
Weed management										
Weedy	14.69 (212.2)	21.08 (400.7)	8.79 (69.6)	20.07 (441.6)	46.6	114.1	24.97	0.044	0.61	1.55
Two hand weedings	0.71	NS	0.71	0.71	58.3	257.4	42.84	0.038	0.98	4.62
LSD(P=0.05)	0.82	0.49	0.77	0.84	1.1	69.9	5.75	0.005	0.18	0.28
Cultivar										
'BPT- 5204'	7.98 (59.2)	10.58 (109.4)	4.84 (28.3)	9.93 (93.1)	46.1	188.8	28.09	0.038	0.65	2.62
'HUBR 2-1'	7.50 (55.7)	11.20 (128.0)	4.60 (25.2)	10.28 (114.6)	54.5	176.6	37.80	0.045	0.92	3.35
'PRH-10'	7.78 (57.7)	11.22 (131.4)	4.73 (27.6)	11.23 (125.6)	50.8	165.7	27.63	0.036	0.59	2.72
'Sarjoo – 52'	7.53 (55.9)	10.58 (108.6)	4.83 (27.2)	10.12 (109.0)	58.4	212.0	42.09	0.045	1.02	3.66
LSD (P=0.05)	NS	NS	NS	NS	2.5	18.1	5.26	0.005	0.18	0.72

DAS – Days after sowing. Original data are subjected to square root transformation

Table 2. Effect of stale bed method, weed management and cultivar on yield attributes, grain and straw yields, harvest index, B:C ratio and production efficiency in direct-seeded rice (average data of three years)

Rice establishment	No. of panicles/ m²	Panicle length (cm)	No. of grains /panicle	Panicle weight (g)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	B: C ratio	Production efficiency (` /ha/day)
Dry seeded after stale bed using shallow tillage	265.3	21.6	81.1	8.9	21.9	2.32	4.17	34.9	1.9	389.0
Dry seeded after stale bed using glyphosate 1 kg/ha	325.1	22.2	100.6	9.3	23.5	2.59	4.34	37.5	2.0	430.8
LSD (P=0.05)	26.5	0.8	15.4	0.7	0.5	0.18	NS	1.7		
Weed management										
Weedy	168.5	20.3	71.4	7.0	21.3	1.24	2.23	35.1	1.1	211.8
Two hand weeding	421.9	23.5	110.3	11.3	24.0	3.67	6.25	37.4	2.7	603.6
LSD (P=0.05)	26.5	0.8	15.4	0.7	0.5	0.18	0.31	1.7		
Cultivar										
'BPT- 5204'	282.2	20.5	91.8	8.0	21.5	2.13	3.76	35.3	1.8	321.4
'HUBR 2-1'	285.9	22.5	88.9	9.4	23.3	2.35	4.32	34.5	2.4	465.6
'PRH-10'	287.8	21.8	84.4	8.1	22.1	2.23	3.66	37.9	1.6	412.4
'Sarjoo – 52'	324.9	22.9	98.3	11.1	23.8	3.10	5.28	37.2	2.4	477.1
LSD (P=0.05)	23.6	0.6	6.2	0.9	0.4	0.171	0.27	2.4		

Table 3. Correlation matrix of yield attributes and yield under weedy conditions

	No of panicles /m^2	No of grains/ panicle	Test weight	Grain yield
No of panicles/m^2	1	0.946 (r_{12})	0.8346 (r_{13})	0.6757 (r_{14})
No of grains/panicle		1	0.6665 (r_{32})	0.6471 (r_{24})
Test weight			1	0.5939 (r_{34})
Grain yield				1

Direct and indirect effects based on path coefficient analysis

No of panicles/m^2 and grain yield (r_{14})
- Direct effect P_{14} = 0.119
- Indirect effect via number of grains/ panicle $P_{24}r_{12}$ = 0.3483
- Indirect effect via test weight $P_{34}r_{13}$ = 0.2075
- Total (direct + indirect effect) r_{14} = 0.6757

Number of grains/panicle and grain yield (r_{24})
- Direct effect P_{24} = 0.3682
- Indirect via number of panicle/ m^2 ($P_{14}r_{12}$) =0.1134
- Indirect via test weight ($P_{34}r_{23}$) = 0.1655
- Total (direct + indirect) r_{24} = 0.6471

Test weight and grain yield (r_{34})
- Direct effect P_{34} = 0.2483
- Indirect via number of panicle /m^2 ($P_{24}.r_{13}$) = 0.1002
- Indirect via number of grains /panicle (r_{23} P_{24})=0.2454
- Total (direct + indirect) (r_{34}) = 0.5939

three characters studied, number of grains/panicle exerted maximum positive direct effect on grain yield followed by test weight and number of panicles /m^2. When indirect positive contributions were considered number of panicles/ m^2 via number of grains/panicle and test weight via number of grains/panicle were proved to be better characters influencing grain yield.Cultiv ar '*Sarjoo-52'* recorded the highest B: C ratio and production efficiency amongst all the cultivars. Amongst rest of the cultivars,' *HUBR 2-1'* recorded higher B: C ratio and production efficiency as compared to '*BPT-5204'* and '*PRH-10'*. This might be due to '*HUBR 2-1'* being aromatic rice consequently recorded better price of grain and B:C ratio. Cultivar '*Sarjoo-52'* proved to be more competitive than rest of the cultivar with respect to yield and economics point of view. Number of grains/panicle had highest positive direct effect and indirect positive effect via number of panicles/m^2 on yield under weedy condition.

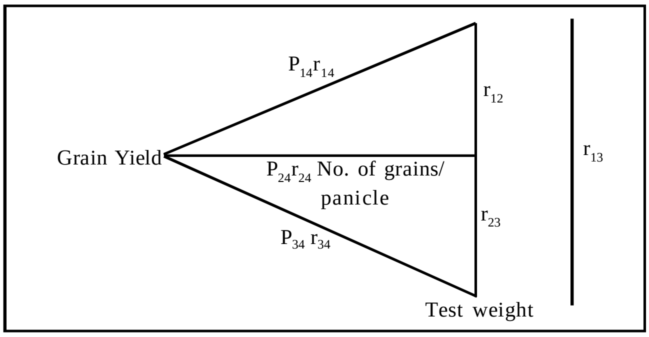

Fig.1. Path diagram showing causal relationship between yields attribute and yield

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Herbicide adoption pattern in rice and wheat among Haryana farmers

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ABSTRACT

A systematic study on herbicide adoption by farmers in rice and wheat growing areas of Haryana conducted during 2008-2009, revealed that in Sirsa and Fatehabad districts of state, 95% farmers applied herbicide to control weeds in transplanted rice whereas in north-eastern Haryana, all farmers applied herbicides in rice crop. In Sirsa and Fatehabad districts, EC formulation of butachlor was the choice of 45% farmers followed by anilofos (26%), pretilachlor (12%) and oxadiargyl (8%). In Karnal, Kurukshetra, Ambala and Kaithal districts, pretilachlor was the first choice of 42% farmers followed by butachlor (24%) None of the farmer used anilofos. Even 11% farmers used pyrazosulfuron not approved by CCS HAU, Hisar for effective weed control. Twenty two (22) per cent farmers also applied post-emergence herbicide bispyribac-sodium in addition to pre-emergence herbicide because of poor control given by pre-emergence herbicides. In all 50-60% farmers applied herbicides timely (3 DAT). In Sirsa and Fatehabad, splash method of herbicide application is most popular used by 54% farmers where as, in north-eastern Haryana mixing of herbicide with DAP at 3-7 DAT, is most popular method used by 61% farmers. None of farmer in north-eastern districts used sand mix application of herbicide in rice which was the only method approved by CCSHAU, whereas in Sirsa and Fatehabad, only 8% farmers used this technology. In wheat, 94 -96% farmers of state used herbicide to control *P. minor* and other weeds. In Hisar, sulfosulfuron was the choice of majority of farmers (56%) followed by clodinafop (28%) where as in Kurukshetra district 44 % farmers used sulfosulfuron + metsulfuron (RM), 14% meso+iodosulfuron (Atlantis) and 16% used various brands of sulfosulfuron and only 20% used clodinafop. None of farmer used fenoxaprop and only 4% farmers of Hisar used isoproturon. In Kurukshetra, 66% farmers used flat fan nozzle but in Hisar majority of farmers (52%) used hollow cone nozzle which is the main reason for poor efficacy of herbicides at farmer's fields. Eighty six farmers in Kurukshetra used recommended brands of sulfosulfuron+ metsulfuron (RM) as against 25% of sulfosulfuron.

Key words: Chemical control, Herbicide adoption pattern, Rice, Weed management, Wheat

Weeds are responsible for heavy reduction in rice and wheat crops grown in rice-wheat/rice-sugarcane-sugarcane-wheat, rice-potato-wheat and cotton-wheat cropping patterns among different districts of Haryana state. Little seed canary grass (*Phalaris minor*), which is a very serious weed of wheat in rice-wheat cropping system in N-W India has developed resistance against isoproturon (Malik and Singh 1995). To tackle the resistance problem fenoxaprop-p-ethyl, sulfosulfuron and clodinafop-propargyl have been recommended (Malik and Yadav 1997) and are being used by the farmers on large scale. Various herbicides have been recommended for the control of weeds especially in wheat and rice and are being used by the farmers on large scale. Sometimes, there are complaints by poor efficacy of herbicides at some locations especially against *P. minor* in wheat and *Echinochloa glabrescence* in rice. So, it becomes evitable to assess the gap in technology, so that further refinement can be made. Some times there is some lacuna on the part of farmers in adoption of herbicide technology leading to erratic results. Keeping it in view, a systematic survey of rice and wheat growers on herbicide adoption level was conducted in Sirsa, Fatehabad, Ambala, Hisar, Kaithal, Karnal and Kurukshetra districts of state known as rice and wheat bowl of Haryana.

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MATERIALS AND METHODS

Survey on information regarding adoption pattern of herbicides in rice was conducted in Rania (Sirsa) and Jakhal (Fatehabad) blocks during *Kharif* 2008 and different rice growing villages of north-eastern Haryana comprising Ambala, Karnal, Kurukshetra and Kaithal districts during

Kharif 2009. In all 78 and 117 rice growing farmers were interviewed during 2008 and 2009, respectively. Similarly information on herbicide adoption in wheat was collected from farmers of Hansi and Narnaund tehsils of Hisar during 2007 and Shahbad and Ladwa tehsils of Kurukshetra district during *Rabi* 2008. In all 50 farmers were interviewed during each year.

RESULTS AND DISCUSSION

Herbicide adoption pattern in rice

In Sirsa and Fatehabad districts, 95% farmers applied herbicide to control weeds in transplanted rice where as in north-eastern Haryana, 100% farmers used herbicides to control weeds in transplanted rice (Table 1). Five percent farmers in Sirsa and Fatehabad did not apply any herbicide because of no weed infestation owing to good control achieved by them in previous years. In Sirsa and Fatehabad, 45% farmers applied herbicide at recommended time (3 DAT) where as 50% farmers applied late up to 7 DAT because of late emergence of weeds due to heavy puddling done at transplanting time and to avoid stress to crop due to early application of herbicide but In Karnal, Kurukshetra, Ambala and Kaithal, majority of farmers (60%) applied herbicide at recommended time (3 DAT) where as 40% farmers applied late up to 7 DAT. In Sirsa and Fatehabad, various brands of butachlor and anilofos were more popular among 45% and 26% farmers, respectively. Only 8% farmers used oxadiargyl for effective weed control and 12% farmers used pretilachlor where in north-eastern districts of state, 42% used pretilachlor and only 24% preferred to use butachlor. Only 15% farmers used oxadiargyl and 11% farmers applied pyrazosulfuron not approved by CCS HAU Hisar for effective weed control. Twenty two per cent farmers also applied post emergence herbicide bispyribac- sodium in addition to pre-emergence herbicide because of poor control given by pre-emergence herbicides owing to poor water level maintained at the time of herbicide application.

In Sirsa and Fatehabad districts, 54% farmers applied herbicides by splash method by making holes in the lid of bottle where as 30% farmers applied herbicide by mixing in DAP applied at 3-7 DAT. In north-eastern Haryana, 61% farmers applied herbicides by mixing in DAP where as 39% farmers applied by splash method by making holes in the lid of bottle or bottle supplied by pesticide dealers exclusively made for this purpose. Sand mix application of herbicide recommended method by university was not adopted by any of the farmers in north- eastern Haryana where as in Sirsa and Fatehabad, only 8% farmers used this technology. Malik *et al.(*2012) reported that during Kharif 2009 in Jind district of Haryana, 96% farmers use herbicides to control weeds in transplanted rice. In addition, 10% farmers also used post-mergence herbicide bispyribac sodium due to poor control achieved with use of pre-emergence herbicides. 58% farmers in Jind Applied herbicide late(7DAT)and among different herbicides pretilachlor was the choice of 44% farmers.

In Hansi and Narnaund, 96% farmers used herbicide to control *P. minor* in wheat out of which 56% used Adoption pattern of weed management technology in wheat

Table 1. Adoption of weed management technology in rice among Haryana farmers

Particular	No. of farmers (%)	
	2008	2009
Application of recommended herbicide		
Application of herbicide at recommended dose	40	77
Application of herbicide less than recommended dose	55	23
Application of herbicide higher than recommended dose	0	0
Herbicide not used	5	0
Use of other methods of weed control		
Hand weeding	0	0
Crop rotation	0	0
Herbicide not applied due to good control in previous years	5	0
Application time		
Application of herbicide at recommended time	45	60
Application of herbicide after recommended time	50	40
Herbicide not applied	5	0
Method of herbicide application		
Sand mixed application	8	0
Soil mixed broadcast	0	0
DAP mixed broadcast	30	61
Urea mixed broadcast	11	4
Spray of herbicide	0	22
Making small holes in lid of bottle (Splash method)	54	39
Herbicide not applied	5	0
Use of different herbicide		
Butachlor	45	24
Anilofos	26	9
Pretilachlor	15	42
Oxadiargyl	8	15
Pyrazosulfuron (not approved by university)	0	11
Pre-em herbicide + bispyribac-sodium (in addition to pre-emergence herbicide)	0	22
No herbicide	5	0

various brands of sulfosulfuron and 28% used clodinafop. None of farmer used fenoxaprop in both Hisar as well as Kurukshetra district. only 4% farmers in Hisar used isoproturon whereas in Shahbad Markanda and Ladwa tehsils of Kurukshetra where rice-potato-sunflower/rice–wheat or rice-wheat/rice-sugarcane-sugarcane-wheat were the main cropping sequences, 94% farmers used herbicide to control *P. minor* in wheat crop out of which 44% used sulfosulfuron + metsulfuron (RM) available with trade name Total, 14% used meso + iodosulfuron R.M. (Atlantis), 16% used various brands of sulfosulfuron where as only 20% used clodinafop (Table 2). None of farmer used fenoxaprop and isoproturon where as only 6% farmers did not apply any herbicide due to no *P. minor* infestation in wheat grown after 2-3 years of sugarcane and sunflower cultivation. Poor efficacy of fenoxaprop against resistant population of *P. minor* is well documented by Dhawan *et al.* (2009) and Punia *et al.* (2010) which is the main reason for not being used by the farmers.

Herbicide sulfosulfuron + metsulfuron (RM) available with trade name 'Total' in market was the choice of only 4% farmers in Hisar where as 44% used this herbicide in Kurukshetra having good efficacy against clodinafop resistant population reported from some areas in this district (Punia *et al.* 2008). In Hansi and Narnaund of Hisar, 78% farmers applied herbicides at recommended time as against 84% in Kurukshetra and only 54% farmers used recommended dose where as in Kurukshetra, 72% farmers used recommended dose of various herbicides. In Hisar, only 36% farmers used flat fan nozzle where as majority of farmers (52%) used hollow cone nozzle which is the main reason for poor efficacy at farmers fields but in Kurukshetra 68% farmers used flat fan nozzle. In Kurukshetra, 62% farmers used 300-375 litres of water and 74% farmers used recommended brands of various herbicides as approved by CCS HAU, Hisar, whereas 60% farmers in Hisar used less than recommended quantity of water which is another reason for poor control and phytotoxic effect of herbicides on crop. Lathwal *et al.* (2010) in a survey of wheat farmers of Kurukshetra district during 2008-09, found that 74% farmers used 300-375

Table 2. Adoption of weed management technology in wheat among Haryana farmers

Particular	No. of farmers (%)	
	Hisar (2007)	Kurukshetra (2008)
Application of recommended herbicide		
Application of herbicide at recommended dose	54	72
Application of herbicide less than recommended dose	42	22
Application of herbicide higher than recommended dose	0	0
Herbicide not used *	8	6
Use of other methods of weed control		
Hand weeding	0	0
Crop rotation	0	6
Herbicide not applied due to good control in previous year	8	0
Application time		
Application of herbicide at recommended time	78	84
Application of herbicide after recommended time	18	10
Herbicide not applied	8	6
Type of nozzle used		
Flat fan	36	66
Hollow cone	52	12
Flood-jet	6	16
Power spray	0	0
Sand or urea mix	2	0
Herbicide not applied	8	6
Use of different herbicide		
Sulfosulfuron	56	16
Clodinafop	28	20
Fenoxaprop	0	0
Sulfosulfuron+metsulfuron	4	44
Metribuzin	2	0
Meso + iodosulfuron	2	14
Isoproturon	4	0
No herbicide	8	0
Use of water for herbicide spray		
200 L/ha	24	0
225 L/ha	38	10
260 L/ha	8	22
300 L/ha	12	28
375 L/ha	8	34
Sand or urea mix	2	0
No herbicide use	8	6

Table 3. Recommended brands of different herbicides used by farmers in Kurukshetra district (2008)

Herbicide	Recommended brand	Unrecommended brand	% farmers using recommended brands
Sulfosulfuron	1	3	25.0
Clodinafop	8	2	80.0
Sulfosulfuron + metsulfuron (RM)	19	3	86.3
Meso + iodosulfuron (RM)	7	0	100.0
Total (mean)	35	12	74.4

litres of water/ha with only 40% farmers using flat fan nozzle to spray various herbicides in wheat. Eight six (86%) farmers in Kurukshetra used recommended brands of sulfosulfuron+ metsulfuron(RM) as against 25% of sulfosulfuron (Table 3).

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Ready-mix formulation of clodinafop-propargyl + metsulfuron-methyl against complex weed flora in wheat

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ABSTRACT

Bio-efficacy of ready-mix formulation of clodinafop-propargyl 15% + metsulfuron-methyl 1% WP was studied against complex weed flora in wheat during 2006-07 and 2007-08 at Hisar, India. Among different herbicidal treatments, clodinafop 0.06 kg/ha was found very effective (95-98%) only against grassy weeds. Metsulfuron 0.004 kg/ha was effective (88-90%) only against broad-leaf weeds. Sequential application of clodinafop 0.06 kg *fb* metsulfuron 0.004 kg/ha being statistically at par with clodinafop-propargyl + metsulfuron- methyl at 0.06 + 0.004 kg/ha and above proved very effective against complex weed flora and the control of grassy and broad-leaved weeds to the extent of 95%. clodinafop- propargyl + metsulfuron- methyl being at par with clodinafop *fb* metsulfuron 0.06 and 0.004 kg/ha recorded the number of spikes, 1000-grain weight and grain yield of wheat statistically similar to that of weed free check. There was no additional gain in grain yield of wheat by using higher doses of clodinafop- propargyl + metsulfuron- methyl beyond 0.06 + 0.004 kg/ha. Weeds allowed growing throughout the crop seasons resulted into 42.9 and 45.1% reduction in the grain yield of wheat during 2006-07 and 2007-08, respectively. There was no residual impact of clodinafop-propargyl + metsulfuron-methyl at x dose (0.06+ 0.004 kg/ha) and 2x dose (0.12 + 0.008 kg/ha) on succeeding crops of sorghum and moongbean. HPLC analysis indicated that there were no residues of clodinafop-propargyl + metsulfuron-methyl (x and 2x doses) at wheat harvest in soil, grains and straw. There was also no adverse effect of herbicides on physico-chemical properties of soil.

Key words: Complex weed flora, Persistence, Premix formulation, Ready mix formulation, Wheat, Weed control efficiency

Phalaris minor and *Avena ludoviciana* are two pre-dominating grassy weeds which frequently infest wheat crop in different regions of India.Up to 1990s, *Phalaris minor* was effectively controlled by isoproturon but due to continuous use of this herbicide for 10-15 years coupled with rice-wheat monocropping, resistance in *P. minor* evolved against this herbicide in 1992-93 (Malik and Singh 1995). Consequently three alternate herbicides, clodinafop, fenoxaprop and sulfosulfuron were recommended for control of isoproturon-resistant *P. minor* in rice-wheat growing areas. These herbicides performed very well against isoproturon- resistant *P. minor* and restored wheat yields in north-west India particularly in Haryana and Punjab (Malik and Yadav 1997, Chhokar and Malik 2002, Chhokar *et al*. 2006). However, due to effective control of this single predominating weed, a shift in weed flora in favour of broad-leaved weeds was observed from last 4-5 years in this cropping system. *Rumex retroflexus*, *Malwa parviflora* and *Convolvulus arvensis* along with many other broad-leaved weeds frequently started infesting wheat fields in rice-wheat cropping system. To overcome the problem of broad-leaved weeds, three herbicide, *viz.* 2,4-D, metsulfuron and carfentrazone were recommended in Haryana and they are still performing quite well.

The problem of complex weed flora in wheat was successfully solved through sequential application of clodinafop, fenoxaprop or sulfosulfuron at 30-35 DAS *fb* 2,4-D, metsulfuron or carfentrazone. But it required two separate operations for aforesaid herbicide applications particularly in case of 2,4-D and metsulfuron which cause antagonistic effect on the efficacy of clodinafop and fenoxaprop (Yadav *et al*. 2002) and thus, adds to cost. Another herbicide as premix formulation of sulfosulfuron + metsulfuron was recommended against complex weed flora and it did very well but residual toxicity of this herbicide on sensitive succeeding crops (sorghum and maize) in rotation put a question mark on its wide acceptability. Likewise, mesosulfuron + iodosulfuron recommended against complex weed flora was reported to cause phyto-toxicity not only to wheat crop but also to succeeding sorghum crop. Keeping these points in view, performance

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of clodinafop-propargyl 15% + metsulfuron-methyl 1%, WP, was studied in order to have another suitable alternative against complex weed flora in wheat under different cropping sequences.

MATERIALS AND METHODS

To evaluate the bio-efficacy of premix formulation of clodinafop-propargyl 15% + metsulfuron-methyl 1% WP (clodinafop- propargyl + metsulfuron- methyl), a field experiment was conducted during *Rabi* seasons of 2007-07 and 2007-08 at Research Farm of Department of Agronomy, CCS Haryana Agricultural University, Hisar, India. The experimental field was sandy loam in texture, low in available N (127.5 kg/ha), medium in available (18.0 kg/ha) and high in (498.7 kg/ha) with slightly alkaline in reaction (pH 8.2). The wheat variety *'PBW 343'* was sown on 29 November during 2006-07 and 30 November during 2007-08 using a seed rate of 85 kg/ha under furrow irrigated raised-bed system (FIRBS) by keeping two rows/ bed on the top of beds. The crop was raised with all recommended package of practices excepting herbicidal treatments. The experiment consisting of 10 treatments, *viz.* clodinafop 0.06 kg, metsulfuron 0.004 kg, clodinafop-propargyl + metsulfuron- methyl 0.045 + 0.003 kg, 0.054 + 0.0036 kg, 0.06 + 0.004 kg, 0.12 + 0.008 kg and 0.18 + 0.012 kg, clodinafop *fb* metsulfuron 0.06 and 0.004 kg/ha (sequential application) along with weedy and weed free check was laid out in randomized block design with four replications. The plot size was 6.0 x 2.1 m. The spray of herbicides was done at 42-45 (days after sowing) DAS with knapsack sprayer fitted with flat fan nozzle using 500 L of spray volume per ha.

The data on the density of individual weeds was recorded at 60 days after sowing and data on the dry weight of grassy and broad-leaved weeds was recorded at 60 and 120 DAS by placing three quadrates (0.5 x 0.5 m) per plot. Visual phytotoxicity on wheat crop was recorded at 15 and 30 days after treatment (DAT) using 0-100 scale (where 0 = no mortality and 100 = complete mortality). Since there was no crop phytotoxicity either at 15 or 30 DAT, the data recorded on this aspect has not been included herein. Residual effect of clodinafop- propargyl + metsulfuron-methyl at x dose (0.06+0.004 kg/ha) and 2 x dose (0.12 + 0.008 kg/ha) in comparison to untreated check was also evaluated on succeeding crops of sorghum and moongbean grown in sequence of wheat. Residual analysis of clodinafop-propargyl 15% + metsulfuron-methyl 1% WP applied in wheat at 0.06 +0.004 kg/ha and 0.12 + 0.008 kg/ha compared to untreated check was also undertaken in soil, wheat grains and straw at harvest by using HPLC. The data on yield and yield attributes were recorded to draw inference of results.

RESULTS AND DISCUSSION

Effect on weeds

The experimental field during 2006-07 was infested with *Phalaris minor*, *Avena ludoviciana*, *Melilotus alba*, *Chenopodium album*, *Rumex retroflexus*, *Coronopus didymus*, *Anagallis arvensis* and *Convolvulus arvensis* to the extent of 11.4, 57.1, 8.6, 5.7, 2.9, 5.7, 5.7 and 2.9%, respectively (Table 1). Whereas, the corresponding figures during 2007-08 were 9.4, 52.3, 7.0, 9.4, 7.4, 7.0, 5.5 and 4.7%, respectively (Table 2). Among different herbicidal treatments, clodinafop 0.06 kg/ha was found very effective (95-98%) only against grassy weeds (Table 3 and 4). Metsulfuron 0.004 kg/ha was effective (88-90%) only against broad-leaved weeds. Sequential application of clodinafop 0.06 kg *fb* metsulfuron 0.004 kg/ha being

Table 1. Weed density (no./m^2) at 60 DAS as affected by different treatments during 2006-07

Treatment	Dose (kg/ha)	*Phalaris minor*	*Avena ludoviciana*	*Melilotus alba*	*Chenopodium album*	*Rumex retroflexus*	*Coronopus didymus*	*Anagallis arvensis*	*Convolvulus arvensis*
Clodinafop	0.06	1.37(1)	1.65(2)	4.10(16)	3.00(8)	2.60(6)	3.30(10)	3.15(9)	2.60(6)
Metsulfuron	0.004	4.57(20)	9.20(84)	1.37(1)	1.35(1)	1.00(0)	1.00(0)	1.00(0)	1.95(3)
CP + MM	0.045+0.003	1.65(2)	2.40(5)	1.65(2)	1.65(2)	1.35(1)	1.35(1)	1.37(1)	1.95(3)
CP + MM	0.054+0.0036	1.65(2)	2.40(5)	1.65(2)	1.37(1)	1.37(1)	1.37(1)	1.35(1)	1.97(3)
CP + MM	0.06+0.004	1.37(1)	1.65(2)	1.37(1)	1.37(1)	1.00(0)	1.00(0)	1.00(0)	1.65(2)
CP + MM	0.12+0.008	1.00(0)	1.35(1)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.65(2)
CP + MM	0.18+0.012	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.65(2)
Clodinafop *fb* metsulfuron	0.06/0.004	1.35(1)	1.65(2)	1.35(1)	1.35(1)	1.37(1)	1.00(0)	1.00(0)	1.95(3)
Weed free	-	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
Weedy check	-	4.10(16)	8.97(80)	3.60(12)	3.03(8)	2.17(4)	3.00(8)	3.00(8)	2.20(4)
LSD (P=0.05)		0.72	0.46	0.44	0.43	0.36	0.26	0.28	0.50

Figures in parentheses are original values and were transformed to $\sqrt{(x+1)}$ before statistical analyses, CP + MM - Clodinafop-propargyl + metsulfuron-methyl.

statistically at par with clodinafop-propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha and above proved very effective against complex weed flora and the control of grassy and broad-leaved weeds was to the extent of 95%. The density and dry weight of grassy as well as broad-leaved weeds were reduced with corresponding increase in the dose of clodinafop-propargyl + metsulfuron-methyl-406. However, clodinafop-propargyl + metsulfuron-methyl 0.06 + 0.004 kg/ha and its higher doses were equally effective against mixed weed flora compared to sequential application of clodinafop 0.06 kg *fb* metsulfuron 0.004 kg/ha.

Effect on crop

The impact of different weed control treatments was clearly reflected in terms of yield and yield parameters of wheat (Table 3 and 4). Among different herbicidal treatment, clodinafop-propargyl + metsulfuron-methyl-406 0.06 + 0.004 kg/ha and clodinafop *fb* metsulfuron 0.06 and 0.004 kg/ha recorded the number of spikes, 1000-grain weight and grain yield of wheat statistically similar to that of weed free check. There was no additional gain in grain yield of wheat by using higher doses of clodinafop-propargyl + metsulfuron-methyl beyond 0.06 + 0.004 kg/ha. The reason for lower yields in case of clodinafop and metsulfuron alone could obviously be due to almost no control of broad-leaved and grassy weeds, respectively.

Residual effects

There was no residual impact of clodinafop-propargyl + metsulfuron-methyl at x dose (0.06+ 0.004 kg/ha) and 2 x dose (0.12 + 0.008 kg/ha) on sorghum and moong bean (Table 5 and 6). HPLC studies also indicated that there

Table 2. Weed density (no./m^2) at 60 DAS as affected by different treatments during 2007-08

Treatment	Dose (kg/ ha)	*Phalaris minor*	*Avena ludoviciana*	*Melilotus alba*	*Chenopodium album*	*Rumex retroflexus*	*Coronopus didymus*	*Anagallis arvensis*	*Convolvulus arvensis*
Clodinafop	0.06	1.70(2)	1.67(2)	3.45(11)	3.87(14)	2.80(7)	3.00(8)	2.80(7)	2.40(5)
Metsulfuron	0.004	3.85(14)	8.60(73)	1.37(1)	1.67(2)	1.37(1)	1.00(0)	1.00(0)	2.40(5)
CP + MM	0.045+0.003	1.70(2)	2.40(5)	1.67(2)	1.97(3)	1.70(2)	1.35(1)	1.37(1)	2.40(5)
CP + MM	0.054+0.0036	1.37(1)	1.97(3)	1.70(2)	1.67(2)	1.37(1)	1.37(1)	1.00(0)	2.60(6)
CP + MM	0.06+0.004	1.37(1)	1.97(3)	1.35(1)	1.70(2)	1.35(1)	1.00(0)	1.00(0)	1.97(3)
CP + MM	0.12+0.008	1.00(0)	1.37(1)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.97(3)
CP + MM	0.18+0.012	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.97(3)
Clodinafop *fb* metsulfuron	0.06/0.004	1.35(1)	1.70(2)	1.70(2)	1.70(2)	1.37(1)	1.00(0)	1.00(0)	1.67(2)
Weed free	-	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
Weedy check	-	3.60(12)	8.25(67)	3.15(9)	3.62(12)	2.60(6)	3.17(9)	2.80(7)	4.02(6)
LSD (P=0.05)		0.33	0.39	0.42	0.37	0.35	0.27	0.19	1.41

Figures in parentheses are original values and were transformed to $\sqrt{(x+1)}$ before statistical analyses, CP + MM - Clodinafop-propargyl + metsulfuron-methyl.

Table 3. Effect of different treatments on dry weight of weeds, yield and yield attributing characters of wheat during 2006-07

Treatment	Dose (kg/ha)	Dry weight of weeds (g/m^2) 60 DAS Grassy weeds	60 DAS Broad-leaved	120 DAS Grassy weeds	120 DAS Broad-leaved	WCE (%) 120 DAS Grassy weeds	WCE (%) 120 DAS Broad-leaved	Spikes (no./m^2)	1000-grain weight (g)	Grain yield (t/ha)
Clodinafop	0.06	6.4	39.1	5.2	59.6	98	3	397	36.6	4.31
Metsulfuron	0.004	129.6	3.4	252.4	6.2	2	90	325	34.9	3.19
CP + MM	0.045+0.003	12.8	6.1	18.1	9.9	93	84	414	38.1	4.58
CP + MM	0.054+0.0036	10.9	5.0	18.0	7.4	93	88	426	39.7	4.78
CP + MM	0.06+0.004	5.8	3.9	2.6	3.7	99	94	452	41.3	4.98
CP + MM	0.12+0.008	2.5	1.7	0.0	0.0	100	100	457	41.8	5.05
CP + MM	0.18+0.012	0.0	1.5	0.0	0.0	100	100	456	41.9	5.05
Clodinafop *fb* metsulfuron	0.06/0.004	5.3	3.8	2.6	3.1	99	95	452	41.5	4.99
Weed free	-	0.0	0.0	0.0	0.0	100	100	458	41.9	5.05
Weedy check	-	128.5	30.7	259.0	61.8	0	0	315	33.1	2.88
LSD (P=0.05)		3.3	1.6	7.0	2.4	-	-	10	0.9	0.12

Figures in parentheses are original values and were transformed to $\sqrt{(x+1)}$ before statistical analyses, CP + MM - Clodinafop-propargyl + metsulfuron-methyl.

Table 4. Effect of different treatments on dry weight of weeds, yield and yield attributing characters of wheat during 2007-08

Treatment	Dose (kg/ha)	Dry weight of weeds (g/m^2)				WCE (%) at 120 DAS		Spikes ($no./m^2$)	1000-grain weight (g)	Grain yield (t/ ha)
		60 DAS		120 DAS						
		Grassy weeds	Broad-leaved	Grassy weeds	Broad-leaved	Grassy weeds	Broad-leaved			
Clodinafop	0.06	7.7	41.0	9.6	76.9	95.5	4.3	386	35.8	4.19
Metsulfuron	0.004	100.4	5.2	202.9	10.0	5.0	87.6	319	34.2	3.31
CP + MM	0.045+0.003	22.4	8.4	41.9	16.1	80.4	80.0	410	37.7	4.48
CP + MM	0.054+0.0036	15.4	7.1	28.2	12.4	86.8	84.6	423	39.4	4.61
CP + MM	0.06+0.004	7.2	5.4	4.9	5.6	97.7	93.0	455	41.6	4.83
CP + MM	0.12+0.008	3.2	2.4	2.3	1.4	98.9	98.2	457	41.8	4.88
CP + MM	0.18+0.012	0.1	2.2	0.0	0.2	100.0	99.7	454	41.7	4.88
Clodinafop *fb* metsulfuron	0.06/0.004	6.8	5.3	4.5	4.5	97.9	94.4	454	41.6	4.84
Weed free	-	0.0	0.0	0.0	0.0	100.0	100.0	457	41.8	4.89
Weedy check	-	103.7	38.3	213.6	80.4	0.0	0.0	312	32.9	2.68
LSD (P=0.05)		3.8	2.0	6.8	1.9	-	-	3	1.2	0.06

Figures in parentheses are original values and transformed to $\sqrt{(x+1)}$ before statistical analysis; CP + MM - Clodinafop-propargyl + metsulfuron-methyl.

Table 5. Residual effect of different herbicides applied in wheat on yield of succeeding crop of sorghum

Treatment	Dose (kg/ha)	Plant height at 45 DAS (cm)		No. of plants/m.r.l at 45 DAS		Green fodder yield at 60 DAS (t/ha)	
		2007	2008	2007	2008	2007	2008
CP + MM	0.06 + 0.004	132.6	134.3	14.7	14.5	0.359	0.375
CP + MM	0.12 + 0.008	134.0	132.8	13.8	13.8	0.357	0.374
Untreated check	-	132.4	134.2	13.6	14.2	0.360	0.376
LSD (P=0.05)	-	NS	NS	NS	NS	NS	NS

Table 6. Residual effect of different herbicides applied in wheat on yield of succeeding crop of moong bean

Treatment	Dose (kg/ha)	Plant height at 45 DAS (cm)		No. of plants /m.r.l at 45 DAS		Green fodder yield at 60 DAS (t/ha)	
		2007	2008	2007	2008	2007	2008
CP + MM	0.06 + 0.004	71.9	71.9	14.7	13.9	0.886	0.888
CP + MM	0.12 + 0.008	71.5	71.7	14.6	13.8	0.868	0.885
Untreated check	-	72.0	72.3	14.7	14.2	0.867	0.909
LSD (P=0.05)	-	NS	NS	NS	NS	NS	NS

were no residues of clodinafop-propargyl + metsulfuron-methyl (x and 2 x doses) at wheat harvest in soil, grains and straw. Persistence studies clearly indicated that this herbicide can safely be used in wheat under different crop rotations without any cause of concern.

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Nutrient uptake by chickpea + mustard intercropping system as influenced by weed management

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ABSTRACT

A field experiment was consisted of four intercropping systems, *viz*. sole chickpea, sole mustard, chickpea + mustard (additive series) and chickpea + mustard (replacement series) and six weed management practices *viz*. weedy check, weed free, pendimethalin 1 kg/ha as pre-emergence (PE), fluchloralin 1 kg/ha as pre-plant incorporation (PPI), isoproturon 0.75 kg/ha as post-emergence (POE) and quizalofop-ethyl 50 ml/ha as post-emergence. These treatments were evaluated under split plot design with three replications. Results revealed that sole stands of chickpea and mustard removed highest amount of N, P and K which were followed by additive series and replacement series whereas among the weed management practices, highest amount of N, P and K was removed by weed free treatment followed by pendimethalim 1kg/ha and fluchloralin 1 kg/ha while the lowest N, P and K was removed by isoproturon 0.75 kg/ha followed by quizalofop-ethyl 50 ml/ha. Among the different intercropping treatments, weeds removed significantly highest N, P and K from sole mustard followed by sole chickpea, replacement series and additive series. Among weed management practices, the uptake of N, P and K in weeds was found to be significantly less in all the weed management practices as compared to weedy check treatment.

Key words: Chickpea, Mustard Intercropping, Weed management

Weed infestation is one of the major limiting factors in the productivity of the crops both under rainfed and irrigated situations. Weeds always pose a serious threat to the stability of crop yields. However, yield loss by weeds in different crops varies from situation to situation. On an average, the reduction in crop yield to the tune of 20-40% has been reported in weed infested crops which calls for effective weed control measures. Initial slow growth of crops and adequate soil moisture provide conducive conditions for profuse growth of weeds relatively in wide spaced crops. Control of weeds is vitally important not only to check the losses, caused by them but also to increase the fertilizer use efficiency. The present study was, therefore, undertaken to assess the losses of nutrients caused by weeds in chickpea + mustard intercropping and to minimise these losses by controlling them.

MATERIALS AND METHODS

A field experiment was conducted at the Research Farm, Main Campus, Chatha of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (J&K) during *Rabi* season of 2009-10 and 2010-11 under split plot design with three replications. The treatment consisted of four intercropping systems, *viz*. sole chickpea (30 cm), sole mustard (30 cm), chickpea + mustard in additive series (an additional row was opened in between two rows of chickpea for sowing of mustard in additive series) and chickpea + mustard in replacement series (one row of chickpea was replaced with one row of mustard) and six weed management practices, *viz*. weedy check, weed free, pendimethalin 1 kg/ha as pre-emergence (PE), fluchloralin 1 kg/ha as pre plant incorporation (PPI), isoproturon 0.75 kg/ha as post-emergence (POE) and quizalofop-ethyl 50 ml/ha as post-emergence. The experiment soil was sandy loam in texture (sand 66.2%, silt 18.5% and clay 15.5%), slightly alkaline in reaction (pH 7.27), medium in organic carbon (0.53%) and available N (252.5 kg/ha), P (13.7 kg/ha) and K (162.9 kg/ha). Full dose of DAP as recommended for chickpea was applied as basal at the time of sowing.

Furrows were opened manually with the help of liners at a specified row to row distance of 30 cm. Chickpea *GNG-469* and mustard *RSPR-01* was sown on 5 November, 2010 and 31 October, 2011. A seed rate of 70 kg and 5 kg/ha for chickpea and mustard was used in their sole plots and additive series, respectively. Whereas the seed rate for replacement series was used as 50% less as compared to seed rate used in the sole and additive series. The seeds of chickpea and mustard were sown in

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furrows by *Kera* method in sole stand treatments whereas an additional row was opened in between two rows of chickpea for sowing of mustard in additive series treatments and in replacement series treatments where sowing of chickpea and mustard were done in alternate rows. All the herbicides were applied through knapsack sprayer using flat-fan nozzle as per treatment. Weedy plots remained infested with natural population of weeds till the harvesting of crops with root elongation. The mustard was harvested on 28 March, and chickpea on 30 April, 2010 whereas, mustard on 25 March and chickpea on 28 April, 2011. Weed population and weeds dry weight was recorded at 30 days interval and at harvest. The weed dry weight was taken with the help of iron frame of one meter square from each plot. The total N, P and K content in crops and weeds (at harvest of crops) was determined by Kjeldhal method. The uptake of N, P and K by crops was calculated by multiplying with yield of crops while uptake of nutrients by weeds was calculated by multiplying with the dry matter accumulation of weeds at harvest by the respective percentage composition of N, P and K.

RESULTS AND DISCUSSION

Weed

The experimental field was mainly infested with broad-leaved weeds in the decreasing order of their occurrence including *Medicago sativa, Anagallis arvensis, Trachyspermum* spp., Similarly, grassy weeds included *Cynodon dactylon* and *Poa annua* and the prominent weed amongst sedges was found to be *Cyperus rotundus* during both the years. Among the intercropping systems, at harvest, the minimum weed density and weed dry weight of 8.78 and 7.59/m^2 and 8.48 and 6.56 g/m^2 were recorded in additive treatment followed by replacement treatment during 2009-10 and 2010-11, respectively (Table 1) which might be due to the lesser space available to the weeds due to intercrops and ultimately lesser availability of resources to the weeds. Highest population of weeds was observed in weedy check over weed free treatment. Application of pendimethalin 1 kg/ha was highly effective in controlling the weeds especially *Medicago sativa* and *Anagallis arvensis*. Weed management practices had statistically significant effect on weed population during both the years. The lowest weed population of all the species was registered under application of pendimethalin 1kg/ha in comparison to other treatments during both the years. Arya (2004) reported similar results in favour of pendimethalin. Singh and Singh (1998) reported that preplant incorporation of fluchloralin 1.5 kg/ha significantly reduced the density and biomass of weeds (*Cyperus rotundus* and *Anagallis arvensis*) by 38.6 and 46.1%, respectively compared to unweeded control.

Productivity

Chickpea: In respect of intercropping systems, chickpea in sole stand recorded significantly higher grain and

Table 1. Influence of weed management practices on weed growth and grain/seed yield, stover yield of chickpea and mustard

Treatment	Weed density/m^2 (at harvest)		Weeds dry weight (g/m^2)		Grain/seed yield (t/ha)				Stover yield (t/ha)			
					Chickpea		Mustard		Chickpea		Mustard	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole chickpea	10.11(140.6)	9.58(128.9)	8.87(96.1)	7.54(72.8)	0.86	0.94	-	-	2.12	2.17	-	-
Sole mustard	-	-	-	-			1.10	1.20	-	-	3.28	3.38
Chickpea + mustard aditive series	8.78(106.3)	7.59(100.3)	8.48(93.2)	6.56(53.8)	0.63	0.73	0.93	1.03	1.93	1.97	3.13	3.24
Chickpea + mustard replacement series)	9.86(135.3)	8.08(93.8)	8.72(77.3)	7.36(69.8)	0.50	0.60	0.71	0.82	1.71	1.85	2.97	3.02
LSD (P= 0.05)	0.09	0.08	0.06	0.1	0.92	1.02	0.94	1.20	1.62	0.96	1.49	1.04
Weed management												
Fluchloralin 1 kg/ha (PPI)	8.41(70.0)	6.37(41.7)	8.24(62.8)	6.27(34.5)	0.70	0.81	0.96	1.12	1.98	2.06	3.20	3.31
Pendimethalin 1 kg/ha (PE)	7.77(59.7)	5.33(29.3)	7.88(56.7)	5.74(28.2)	0.77	0.87	1.03	1.17	2.07	2.12	3.27	3.38
Isoproturon 0.75 kg/ha (POE)	9.65(92.3)	8.74(76.0)	9.1(77.8)	7.37(49.2)	0.62	0.75	0.87	1.02	1.88	1.99	3.10	3.21
Quizalofop-ethyl 50 ml/ha (POE)	9.35(87.0)	8.38(70.7)	8.77(72.9)	7.04(44.9)	0.68	0.78	0.94	1.08	1.98	2.02	3.16	3.26
Weedy check	21.33(455.4)	20.7(428.4)	16.31(264.5)	15.5(236.1)	0.38	0.37	0.57	0.42	1.47	1.62	2.71	2.62
Weed free	1(0)	1(0)	1(0)	1(0)	0.83	0.94	1.11	1.28	2.13	2.17	3.34	3.48
LSD (P= 0.05)	0.07	0.08	0.07	0.11	0.89	0.91	0.89	1.14	1.08	0.97	1.02	1.04

stover yield and was followed by additive and replacement series which was probably because of less competition for sunlight, space, water and nutrients for sole crop as compared to intercropping treatments wherein the competition of crop plants might have curtailed efficient utilization of natural resources and restricted growth of chickpea from initial stages to harvest resulting in yield competition for main and intercrops. However, between additive and replacement treatments, significantly higher grain and stover yield of chickpea under additive series mainly might have happened due to significantly higher plant population as compared to replacement series (Table 1). These results of yield attributes are in conformity with the results of Tripathi *et al.* (2005) and Kumar and Singh (2006).

Higher grain and stover yield of chickpea were recorded where weed free environment was provided to the crop throughout its crop growing period. The grain and stover yield of chickpea as recorded with the application of pendimethalin 1 kg/ha was found to be statistically at par with weed free treatment and fluchloralin 1 kg/ha might be due to effective control of weeds with the application of pendimethalin as a result of which there was poor growth and population of the weeds. Further, under this treatment weeds were unable to compete with the crop plants and resulted in better expression of yield attributing characters and thus gave higher yield. Among the other herbicidal treatments, the lowest grain yield of chickpea was recorded with isoproturon 0.75 kg/ha which in turn was observed to be statistically at par with quizalofop-ethyl 50 ml/ha and fluchloralin applied at 1 kg/ha. This confirms the findings of Yadav *et al.* (1983) and Singh *et al.* (1986). The lowest grain and stover yield of chickpea was noticed in weedy check as a consequence of stiff competition imposed by weeds resulting in poor source and sink development with poor yield contributing characters and higher weed index. The above results could be corroborated with the findings of Rout and Satapathy (1996), Sinha *et al.* (2000) and Kolage *et al.* (2004).

Mustard: Chickpea and mustard in sole stand also recorded significantly higher values of grain and stover yields and was followed by additive and replacement series. The optimum space as available for mustard plants under sole stand reduced the competition for moisture, nutrients and light among the mustard plants than other intercropping combinations which might be responsible for the production of higher yield attributes of sole crop of mustard (Table 1). These results were in agreement with the findings of Prasad (1996) and Singh *et al.* (2008). The possible reason for higher yield of mustard in additive treatment rather than the replacement treatment might have been achieved due to the fact besides the single plant yield remaining inferior in additive treatment the overall yield per unit area improved due to cumulative effect of higher plant populations in additive treatment during first and second years of cropping.

Among the weed management practices, higher grain and stover yields of mustard were recorded where weed free environment was provided to the crop throughout its crop growing period. The grain and stover yields of mustard as recorded with the application of pendimethalin 1 kg/ha followed by fluchloralin 1 kg/ha, however, found to be statistically at par to that of weed free treatment and fluchloralin 1 kg/ha, also might be due to reduced crop-weed competition and enhancement in most of the crop-growth parameters under the favourable environmental situation. These results are in conformity with the findings of Sinha *et al.* (1999). Under this treatment, weeds were unable to compete with the crop plants which resulted in better expression of yield attributing characters and thus gave higher yield. Among the other herbicidal treatments, the lowest grain and stover yields of mustard was recorded with isoproturon 0.75 kg/ha which in turn was observed to be statistically at par with quizalofop-ethyl 50 ml/ha and fluchloralin applied 1 kg/ha.

Nutrient removal by crops

Chickpea : Irrespective of the treatments, highest N, P and K removal from grain of chickpea was recorded with sole stand followed by additive series and replacement series during both the cropping seasons of *Rabi* 2009-10 and 2010-11, respectively (Table 2). The higher removal of these nutrients by sole chickpea as compared to intercropping treatments probably happened due to vigorous growth and better root system under optimum spacing which had helped in adequate supply of these nutrients resulting in higher biological yield coupled with their effective transfer to the ultimate sink *i.e.* the grains thus leading to numerically higher chickpea grain nutrient contents of N, P and K. Obviously, this was due to lesser competition from weeds and ultimately better growth of crop. Among weed management practices, highest N, P and K removal from grain and stover of chickpea was removed from weed free treatment during 2009-10 and 2010-11, respectively. The greater nutrient removal by crop could be attributed to poor competition of weeds with chickpea. The nutrient removal by crop was significantly increased due to application of herbicides and hand weeding as compared to weedy control. Hand weeding and use of herbi-

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

Treatment	N				P				K			
	Grain		Stover		Grain		Stover		Grain		Stover	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole chickpea	65.0	70.1	40.4	41.1	9.62	11.19	15.7	17.39	27.8	30.2	48.6	50.5
Sole mustard	-	-	-	-	-	-	-	-	-	-	-	-
Chickpea + mustard (additive series)	63.0	67.6	38.3	39.7	7.65	9.64	14.62	16.53	25.6	27.9	47.0	49.4
Chickpea + mustard (replacement series)	60.8	66.9	36.2	37.5	5.91	7.74	13.31	15.27	23.5	25.0	45.7	48.2
LSD=P(0.05)	2.9	2.4	NS	NS	2.16	2.25	NS	NS	2.6	3.5	NS	NS
Weed management												
Weedy check	45.9	44.3	31.7	33.7	3.61	4.47	8.29	10.17	16.3	13.6	41.3	44.9
Weed free	68.3	74.9	41.5	42.9	10.75	12.03	17.47	20.14	29.3	32.4	49.5	51.6
Fluchloralin 1kg/ha (PPI)	66.3	73.3	39.6	40.3	8.35	10.53	15.5	17.21	27.4	30.1	48.4	50.6
Pendimethalin 1kg/ha (PE)	67.3	74.3	40.8	41.8	9.46	11.17	16.61	18.95	28.7	31.4	49.3	51.2
Isoproturon 0.75kg/ha (POE)	64.4	70.9	37.4	38.6	6.71	9.39	14.61	15.32	25.6	29.1	46.9	48.4
Quizalofop-ethyl 0.50 kg/ha (POE)	65.5	71.5	38.6	39.4	7.49	9.56	14.8	16.58	26.5	29.7	47.2	49.4
LSD=P(0.05)	5.6	5.4	4.4	4.7	1.7	1.18	1.5	2.34	3.1	2.91	4.6	3.3

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

cides effectively controlled the weeds and consequently made more nutrients available to the crop thereby higher removal of nutrients by crop. Similar results were also reported by Singh and Malik (1992). Among the herbicides, highest N, P and K from grain and stover of chickpea was removed from pendimethalin 1 kg/ha and was found to be statistically at par with isoproturon 0.75 kg/ha and quizalofop-ethyl 50ml/ha and fluchloralin 1kg/ha during both the seasons respectively. This could possibly be attributed to higher weed-control efficiency resulting in more favourable environment for growth and development of crop plants apparently due to the lesser weed competition. The results conformed with the findings of Angiras and Singh (1989), Sreenivas and Satyanarayana (1996) and Mundra *et al.* (2002).

Mustard (grain and stover): N removal by mustard grain was observed under sole stand of mustard, additive series and replacement series which were seen not to be significantly influenced by intercropping systems whereas numerically highest N and significantly higher P and K uptake in mustard stover was recorded with sole stand followed by additive series and replacement series which in turn where P and K found significantly different to one another during 2009-10 and 2010-11, respectively (Table 3). These results were in accordance with those of Singh *et al.* (1997), Kawtra and Mishra (1999), Singh (2005), Singh and Rana (2006) and Singh *et al.* (2008). Similar to intercropping systems, weed management practices also failed to show any influence on the N and K removal by mustard grains whereas highest P in mustard grains and N, P and K removal by mustard stover was recorded where weed free environment was provided to the crop during crop growing season followed by pendimethalin 1 kg/ha and fluchloralin and both were found to be statistically similar to weed free treatment during both the seasons, respectively. Similar results were also reported by Singh and Malik (1992).

NPK uptake by weeds: At harvest significantly higher N, P and K was removed by sole cropping of mustard followed by sole cropping of chickpea, replacement and additive series though being at par with one other during 2009-10 and 2010-11, respectively. This might have happened due to growing of intercrop in spaced chickpea rows which while utilizing the space efficiently reduced the intensity and dry matter of weeds leading to lower NPK uptake by weeds. The removal of N, P and K by weeds were reduced significantly by various herbicidal and manual weeding treatments and it almost nil under weed free treatment whereas the significantly highest N, P and K uptake by weeds were recorded in the weedy check treatment (Table 4). These results confirm the findings of Sreenivas and Satyanarayana (1996) and Mundra *et al.* (2002). Among the herbicides, significantly higher value of NPK uptake was recorded in the treatment isoproturon 0.75

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

Treatment	N				P				K			
	Grain		Stover		Grain		Stover		Grain		Stover	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping												
Sole chickpea	-	-	-	-	-	-	-	-	-	-	-	-
Sole mustard	67.1	74.2	38.1	38.7	8.26	9.84	2.96	3.35	99.5	112.5	29.2	29.9
Chickpea + mustard (additive series)	65.0	73.2	36.2	37.0	7.07	8.79	2.56	2.69	97.6	111.5	27.6	28.7
Chickpea + mustard (replacement series)	63.2	72.1	34.3	34.8	5.58	8.24	2.14	2.14	95.8	110.4	25.9	26.9
LSD (P=0.05)	NS	NS	2.4	2.2	1.94	1.19	0.35	0.46	NS	NS	1.0	1.0
Weed management												
Fluchloralin 1kg/ha (PPI)	66.4	74.3	36.4	38.1	7.65	9.45	2.86	2.75	98.2	111.3	28.1	29.2
Pendimethalin1kg/ha (PE)	67.4	75.7	38.2	39.1	8.35	10.33	3.24	3.2	99.3	112.2	29.5	30.7
Isoproturon 0.75kg/ha (POE)	64.8	72.2	35.1	35.5	6.46	8.56	2.41	2.41	96.3	109.4	26.7	27.7
Quizalofop-ethyl 50 ml/ha (POE)	65.5	73.2	35.4	37.3	6.94	8.98	2.46	2.48	97.4	110.3	27.4	28.8
Weedy check	58.2	67.2	33.3	29.6	3.37	5.17	0.85	1.87	93.9	112.0	22.9	22.0
Weed free	68.4	76.4	38.7	41.6	9.05	11.26	3.49	3.62	100.4	113.6	30.8	32.6
LSD (P=0.05)	NS	NS	2.8	3.5	1.38	0.96	0.49	0.47	NS	NS	2.0	1.9

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

Treatment	N		P		K		Net returns ($x10^3$ `/ha)		B:C ratio	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Intercropping										
Sole chickpea	26.4	20.4	8.08	3.75	29.9	28.0	10.32	12.10	0.72	0.86
Sole mustard	27.4	24.0	8.21	4.32	31.5	33.4	12.06	12.98	1.14	1.21
Chickpea + mustard (additive series)	21.2	14.9	6.37	2.67	24.1	20.4	2.27	2.61	1.5	1.75
Chickpea + mustard (replacement series)	25.3	19.3	7.63	3.45	28.9	26.6	16.65	20.51	1.34	1.65
LSD (P=0.05)	0.8	0.9	0.13	0.12	1.1	0.9	_	_	_	_
Weed management										
Fluchloralin 1kg/ha (PPI)	25.3	17.0	6.72	3.06	32.9	23.8	15.83	2.22	1.55	1.88
Pendimethalin 1kg/ha (PE)	22.8	15.1	5.93	2.51	30.2	21.4	17.30	23.44	1.57	1.85
Isoproturon 0.75kg/ha (POE)	28.8	22.2	8.84	4.57	38.2	31.5	12.90	19.78	1.36	1.73
Quizalofop-ethyl 50 ml/ha (POE)	26.1	19.9	8.25	4.15	35.0	29.2	14.07	19.95	1.3	1.56
Weedy check	43.6	43.7	15.7	7.01	35.3	56.7	4.18	13.22	0.56	0.29
Weed free	0	0	0	0	0	0	12.12	18.85	0.73	0.92
LSD (P=0.05)	3.9	2.9	0.45	0.36	1.9	1.5	_	_	_	_

kg/ha followed by quizalofop ethyl 50 ml/ha and were found statistically at par with each other during both the seasons of *Rabi* 2009-10 and 2010-11, respectively. The removal of N, P, K by weeds was reduced significantly by various herbicidal and manual weeding treatments and it was minimum under weed free treatment. However, they were at par in respect of NPK removal/ha by the weeds. These observations are in agreement with those of Thakur (1988) and Dashora *et al.* (1990).

Economics

The results showed that the maximum values of net returns *i.e*, ` 22,729 and ` 26,101/ha and B:C ratio of 1.50 and 1.75 were recorded in chickpea + mustard (additive series) intercropping treatment during both the years of study. This might be due the additional benefit of component crop of mustard along with the main crop of chickpea. The results are in line with Singh *et al.* (2003). Maximum net returns (` 17,307/ha) and benefit:cost ratio (1.57) were recorded with the application of pendimethalin 1 kg/ha in chickpea and mustard intercropping system during the years of 2009-10 whereas in second year highest B:C ratio was obtained with the application of fluchloralin 1 kg/ha. However, minimum net returns and B:C ratio were recorded in weedy check in chickpea + mustard intercropping system.

Results of present investigation suggest that, among the intercropping systems, chickpea + mustard (additive series) found to be best in terms of chickpea yield and sole mustard in terms of chickpea yield. The application of pendimethalin 1 kg/ha resulted in significantly higher grain yield of chickpea and mustard. The highest uptake by crops and lowest removal of nutrients by weeds was also with the application of pendimethalin 1 kg/ha.

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Chemical weed management in lentil

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ABSTRACT

The effect of chemical weed management practices in lentil was studied during 2010-11 and 2011-12 at Agra (Utter Pradesh). The treatments included: control, pendimethalin 0.50 kg/ha, pendimethalin 0.75 kg/ha, pendimethalin 1.0 kg/ha, pendimethalin 1.25 kg/ha, pendimethalin 1.50 kg/ha and hand weeding. All herbicidal treatments including hand weeding significantly controlled the weeds. Among all the treatments hand weeding gave the highest weed control (84.8%) and produced lower weed biomass (54.0 g/m^2). It gave maximum net income (` 30,850) with CBR of 1:4.4. Pendimethalin 1.5 kg/ha controlled the weeds effectively but germination of seeds were affected. Highest grain yield (1.50 t/ha) was recorded from hand weeding plot with 48.6 and 52.0% increase in yield during 2011 and 2012, respectively.

Key words: Chemical control, Hand weeding, Lentil, Pendimethalin, Weed

Weeds control is one of the major limitations to growing lentil crop world-wide. Lentil yield reduction in excess of 80% due to weed competition has been recorded (Mohamed *et al.* 1997). Weeds compete with lentil for nutrients moisture and space as well as harbouring insects, pests and pathogens that may adversely affect the crop. Relatively short height and slow early growth of the crop demands special attention to be paid for controlling weeds (Yadav *et al.* 2007). This paper presents the observations on effect of various doses of pendimethalin to prevent weed infestation and subsequent grain yield increases in cultivar *'Pusa lentil-62'* in semi-arid region of Agra.

MATERIALS AND METHODS

A field experiment was conducted during *Rabi* season 2010-11 and 2011-12 at the experimental farms of Dayalbagh Educational Institute, Agra under irrigated conditions. Agra is situated in western Uttar Pradesh between 27-11^0 latitude North and 78^0 longitude east with an altitude of 169 m above sea level. Dayalbagh Eco-village is situated at a distance of about two km from the city of Agra on its northern periphery. The soil of Dayalbagh eco-village was sandy loam in texture, low in organic carbon (0.4%), K (115.8 kg/ha), medium in P (40 kg/ha) with the pH of 7.2. The experiment was laid out under RCBD with seven treatments and four replications. The treatments included: 1) control, 1) pendamethalin 0.50 kg/ha, 2) pendamethalin 0.75 kg/ha, 3) pendamethalin 1.0 kg/ha, 4) pendamethalin 1.25 kg/ha, 5) pendamethalin 1.50 kg/ha, 6) hand weeding, 7). Different concentrations of pendamethalin was applied at pre-sowing stage of crop with flat fan nozzle by foot sprayer. A basal dose of urea (46% N) and Phosphorus (16% P_20_5) by single super phosphate was applied in each plot. Four to five irrigations were given during the cropping period. All other agronomic practices were kept uniform in each treatment. Four hand weedings were done at different DAS. Cultiver *'Pusa lintil'* with a seed rate of 20 kg/ha was sown at 25 cm row spacing on 4 November 2010 and 11 November 2011, respectively. Data on plant population density, weed density, plant height, pods/plant, 100-seed weight, grain yield, biological yield and harvest index were recorded and analysed statistically (Gomez and Gomez 1976). Dry weight of weeds was calculated by drying the samples in an oven at 70^{0}C for 48 hours.

RESULTS AND DISCUSSION

Weed density

Density of weeds were significantly influenced by the application of herbicide and hand weeding (Table 1). *Chenopodium alba*, *Asphodelus tenuifolius*, *Fumaria officianalis* were the dominant weed species. *Spergula arvensis, Amaranthus, Chenopodium murale* and common grass were other less dominant weed species. Hand weeding provided highest weed control (84.8%). Among all the herbicidal applications, pendimethalin 1.50 kg/ha gave maximum mortality of weeds (79.2%) followed by pendimethalin 1.25 kg/ha (75.4%). Application of pendimethalin as pre-emergence proved better for control of weeds and high yield (Yasin *et al.* 1995).

Weed biomass

Hand weeding and herbicide treatments significantly reduced the dry weight of weeds. Among all the treat-

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ments, hand weeding produced the lowest weed biomass (54.0 g/m^2). According to Ahmad *et al*. (1996), pre-sowing application of herbicide and hand weeding were equally and much more effective in reducing the dry weight of weeds (Table 1).

Vegetative traits of lentil

Application of hand weeding showed significant increase in plant population density (17.9 and 19.8%) in the two years. This increase in plant population density was due to reduction in competition between weeds and plants. Pendimethalin 1.50 kg/ha showed significant reduction in plant population density because germination of seeds was. Application of herbicide and hand weeding improved the plant height and primary branches of plant, as result of increase in the lateral growth of plants (Table 2).

Reproductive traits and yield components of lentil

Application of all the treatment influenced grain yield and biological yield significantly over control (Table 3). Maximum grain yield and biological yield was obtained in hand weeding (1.50 and 4.14 t/ha) with an average increase of 49.3 and 30%, respectively. This increase in yield was due to the increase in pods/plant (18.5%). Among the herbicides pendimethalin 1.25 kg/ha gave the average

Table 1. Impact of different weed control treatments on weed growth in lentil

Treatment	Average weed density/m^2							Mortality (%)	Average weed biomass (g/m^2)
	C. album	*F. officianalis*	*A. tenuifolius*	*C. murale*	*S. arvensis*	Others	Total weeds		
Pendimethalin 0.50 kg/ha	6.2	4.5	8.0	3.2	3.0	5.5	30.4	47.7	183.0
Pendimethalin 0.75 kg/ha	4.7	4.2	5.2	3.0	3.2	4.0	24.3	58.2	147.0
Pendimethalin 1.00 kg/ha	4.0	3.0	4.0	2.5	2.2	3.2	18.9	67.5	114.0
Pendimethalin 1.25 kg/ha	2.7	2.0	2.7	2.7	2.0	2.2	14.3	75.4	85.5
Pendimethalin 1.50 kg/ha	2.5	1.5	2.2	2.2	1.7	2.0	12.1	79.2	73.5
Hand weeding	1.7	1.5	2.0	2.0	1.5	2.0	10.7	84.8	54.0
Control (weedy plot)	13.5	12.2	13.5	6.0	6.0	7.0	58.2	-	349.5
LSD (P=0.05)	2.31	1.55	1.65	1.47	1.37	1.42	4.22	-	25.3

Table 2. Impact of weed control treatments on vegetative traits of lentil

Treatment	Plant population (m^2)		Plant height (cm)		Branches/plant	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Pendimethalin 0.50 kg/ha	62	60.0	27.7	27.1	6.2	6.7
Pendimethalin 0.75 kg/ha	65	64.0	29	28.7	6.7	7.0
Pendimethalin 1.00 kg/ha	66	69.2	29.7	30	7.5	7.5
Pendimethalin 1.25 kg/ha	68.2	71.2	30.5	30.5	7.5	7.5
Pendimethalin 1.50 kg/ha	65.5	66.2	29.7	29.5	6.7	7.5
Hand weeding	68.5	72.0	30.5	31.0	7.5	8.0
Control (weedy plot)	56.2	57.7	25.3	25.5	6.0	6.5
LSD (P=0.05)	3.19	3.09	1.14	1.07	1.07	0.96

Table 3. Impact of weed control treatments on reproductive traits of lentil

Treatment	Pods/plant		Grain yield (t/ha)		Biological yield (t/ha)		Harvest index (%)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Pendimethalin 0.50 kg/ha	58.0	58.0	0.87	0.90	3.42	3.42	25.4	26.0
Pendimethalin 0.75 kg/ha	62.0	62.0	0.97	1.00	3.71	3.74	26.1	26.4
Pendimethalin 1.00 kg/ha	68.2	68.2	1.12	1.46	3.81	3.84	29.3	38.0
Pendimethalin 1.25 kg/ha	69.0	69.0	1.18	1.54	4.09	4.11	28.8	37.4
Pendimethalin 1.50 kg/ha	66.2	66.2	1.06	1.05	3.78	3.81	28.0	27.5
Hand weeding	69.5	69.5	1.50	1.58	4.14	4.16	36.2	37.9
Control (weedy plot)	56.5	56.7	0.77	0.80	2.81	3.03	25.1	26.0
LSD (P= 0.05)	2.93	3.52	0.41	0.64	0.39	0.35	NS	NS

Table 4. Impact of hand weeding and pendimethalin on the economic returns of lentil (pooled data of two years)

Treatment	**Grain yield (t/ha)**	Additional income (x10^3 `/ha)	Additional expenditure (x10^3 `/ha)	Net benefit (x10^3 `/ha)	Cost: benefit ratio (CBR)
Pendimethalin 0.50 kg/ha	0.88	4.81	1.21	3.61	1:2.8
Pendimethalin 0.75 kg/ha	0.98	9.91	1.81	8.10	1:4.4
Pendimethalin 1.0 kg/ha	1.29	17.90	2.41	15.49	1:6.4
Pendimethalin 1.25kg/ha	1.36	21.35	3.02	18.33	1:6.0
Pendimethalin 1.50kg/ha	1.06	13.85	3.62	10.22	1:2.8
Hand weeding	1.54	37.85	7.00	30.85	1:4.4
Control (weedy plot)	0.78	-	-	-	-

yield (1.36 t/ha) with an average increase of 42.3% followed by pendimethalin 1.0 kg/ha (1.29 t/ha) with an average increase of 39.5%. Pendimethalin 1.50 kg/ha produced lower grain yield (1.06 t/ha) than other treated plots. It was due to the phytotoxicity of lentil crop which affected germination. However control gave the lowest yield of 0.78 t/ha. Weed growth was significantly reduced by the use of herbicides and resulted in increase in yield up to 50% than control (Choudhary *et al.* 2011).

Economics

The highest additional return of ` 30,850 with cost: benefit ratio of 1: 4.4 obtained by hand weeding (Table 4). Among the herbicide pendimethalin 1.25 kg/ha gave the maximum net return of 18,329 with CBR of 1:6.0 followed by pendimethalin 1.0 kg/ha (` 15,488) with CBR of 1:6.4 and this treatment provide maximum CBR. Lowest CBR (1:2.8) was obtained by the application of pendimethalin 1.50 kg/ha due to phototoxic effect of crop by affecting germination, followed by hand weeding (1:4.4) due to high labour cost.

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Integrated weed management of lambsquarter and nut sedge in lentil

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ABSTRACT

A field study was conducted during 2010-11 and 2011-12 to evaluate the effect of integrated weed management on two lentil associated weeds *viz*., *Chenopodium* spp., *Cyperus* spp. and economics of the weed management packages. Two hand weedings (HW) at 30 and 45 DAS was the most effective method for containing *Chenopodium* spp. and *Cyperus* spp. counts and dry matter from 60 DAS to harvest. Imazethapyr 2EC and pendimethalin controlled the intensity and corresponding dry matter of *Chenopodium* significantly but poorly affected *Cyperus* which was better suppressed with treatment where mechanical weeding was either a component or as a sole treatment. Among sole herbicides, imazethapyr was the most effective for *Cyperus* and *Chenopodium* weed control whereas, pendimethalin incorporated integrated package was effective on *Chenopodium* while imazethapyr associated integrated system was effective on *Cyperus* weeds. Average weed control efficiency at 75 DAS and crop harvest reflected that two HW was most efficient for control of *Chenopodium* (77.6%) and *Cyperus* (75.3%) followed by pendimethalin 1 kg/ha supplemented with imazathapyr 37.5 g/ha on both the weed species (75.3 and 81.2%), respectively. The effect of sole chlorimuron and quizalofop-ethyl on both the weeds were least, but better than control. Pendimethalin 1 kg/ha *fb* mechanical weeding recorded better yield attributes, highest yield of lentil and cost: benefit ratio (1.37 t/ha and 2.80) but minimum weed index (4.53), next to hand weeding. Hand weeding performed well in all aspects except the lower benefit cost ratio. Hence, integration of pendimethalin 1 kg/ha with mechanical weeding (hoeing) was considered to be the profitable treatment besides being more ecofriendly than chemical-chemical sequential application.

Key words: *Chenopodium, Cyperus,* Economics, Grain yield, Herbicides, Lentil

Lentil (*Lens culinaris* Medikus) has become an important food legume crop in the farming and food systems of many countries globally. Its seed is a rich source of protein, minerals, and vitamins for human nutrition, and the straw is a valued animal feed. Its ability in nitrogen and carbon sequestration improves soil nutrient status, which in turn provides sustainability in production systems (Sarker and Erskine 2006). India is the largest producer of lentil and contributes about 32% of lentil production. However India's rank in productivity is low that is, 23rd in the world (Reddy and Reddy 2010). It is a poor competitor due to its short height and slow early growth. Lentil's low competitive ability is compounded when growing season temperatures are low or when moisture is scarce. Increased cost of manual weeding, its poor efficiency and non-availability during critical periods made herbicides very attractive in lentil. Integrated weed management has the potential to restrict weed populations to manageable levels, In adopting any integrated weed control methods, economic factor is the most important and deciding factor.

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MATERIALS AND METHODS

The experimental soil showed organic carbon 0.60%, pH 7.7, electrical conductivity 0.26 ds/m, 216, 26 and 236.46 kg/ha available NPK, respectively. The research field lying at 25^0 18'N latitude and $88^0$36'E latitude at an altitude of 128.93 meters from the mean sea level in the north Gangetic alluvial plains received total rainfall of 14.9 and 34.6 mm during lentil crop seasons of 2010-11 and 2011-12, respectively. Two years weekly mean maximum temperature ranged from 15.3 - 35.8^0 C and minimum temperature varied from 6.5 to 19.0^0 C. Fertilizer NPKS 20-40-30-15 kg/ha was applied common to all the treatments. Sowing of the crop lentil variety '*HUL 57*' was done on November 15 in both the years. Treatments consisted weedy check (control); weed free; hand weeding 30 DAS and 45 DAS (khurpi aided); mechanical weeding (MW) 30 DAS and 45 DAS (twin wheel hoe); quizalofop-ethyl 50 g/ha 40 DAS; imazethapyr 37.5 g/ha 40 DAS; chlorimuron-ethyl {Pre plant incorporation (PPI)} 4 g/ha; pendimethalin {pre-emergence(PE)} 1 kg/ha; pendimethalin 30 EC + imazethapyr 2 EC (PE) 0.75 kg/ha; pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha;

chlorimuron-ethyl (PPI) 4 g/ha *fb* quizalofop-ethyl 50 g/ha 40 DAS; chlorimuron-ethyl (PPI) 4 g/ha *fb* imazethapyr 37.5 g/ha 40 DAS; pendimethalin (PE) 1 kg/ha; quizalofop- ethyl 50 g/ha 40 DAS; pendimethalin (PE) 1 kg/ha *fb* imazethapyr 37.5 g/ha 40 DAS; chlorimuron-ethyl (PPI) 4 g/ha *fb* MW 45 DAS; pendimethalin (PE) 1 kg/ha *fb* MW 45 DAS. Weed samples were collected by placing a quadrate (0.50 x 0.50 m) randomly in each plot at 60, 90 DAS and crop harvest. Data for weed components were subjected to square root transformation $\sqrt{(x+0.5)}$ for uniformity. Data analyses were done with RCBD. The economic analyses were carried out by computing the market price of inputs and outputs of both the experimental seasons prevailing at Varanasi city. The names in parentheses at the end of each herbicides are trade names of the concerned herbicides used in the experiment.

RESULTS AND DISCUSSION

Effect on *Chenopodium*

Chenopodium spp.was effectively controlled by pre-emergence application of pendimethalin 1 kg/ha and pendimethalin 30 EC + imazethapyr 2 EC (PE) that is Pursuit plus at both doses (0.75 and 1 kg/ha) from initial stage (30 DAS). At later stage (60 DAS) and crop harvest, the weed count indicated that, the weed was fairly controlled with imazethapyr 37.50 g/ha and quizalofop-ethyl 50 g/ha. Further weed reduction was observed with sequential application of pre-emergence pendimethalin with either mechanical weeding, imzethapyr or quizalofop-ethyl (Table 1). The finding is in line with Mojeni *et al*. (2005). The better performance of pendimethalin *fb* imazethapyr was also reported by Sasikala *et al.* (2006). Minimum dry matter in *Chenopodium* was correspondingly recorded considering the values taken at 30, 60, 90 DAS and crop harvest (Table 2). The performance of sole herbicide, chlorimuron-ethyl, though not remarkable, was however, better than control. Among the sole herbicides at 60 DAS, pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha was next most effective treatment after mechanical weeding twice and two hand weeding. Among the integrated management system, pendimethalin *fb* imazethapyr was the most effective treatment at the same stage. At crop harvest, no sole herbicide was better than two mechanical weeding and twice hand weeding. The vanishing herbicidal effect to the newly emerging weeds and the mechanical action of *Cyperus* removal along with the roots could be attributed to the superiority of two mechanical weeding and hand weeding over herbicides at later stages. Least dry matter was observed in the treatment, pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha among sole herbicides at 60 DAS whereas, it was significantly low in pendimethalin *fb* imazethapyr among the integrated weed management systems, respectively. At crop harvest, minimum dry matter of *Cyperus* was recorded with two hand weeding and pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha while pendimethalin *fb* mechanical weeding and pendimethalin *fb* imazethapyr which were statistically at par, indicated least dry matter. Carr *et al.* (1997) also supported the finding who reported that minimized weed and dry matter with herbicide supplemented by mechanical weeding/tillage in lentil.

Effect on *Cyperus*

Cyperus spp. was the most difficult to kill and the most populous weed in lentil during *Rabi* season. The initial period of growth and development was not remarkably observed with pre- emergence application of either pendimethalin, pendimethalin 30 EC + imazethapyr 2 EC (PE) or pre-plant incorporation of chlorimuron-ethyl (Table 1). Except at 30 DAS (first weed count taken before first hand weeding), the treatment, two hand weeding 30 and 45 DAS was the most effective treatment right from 60 DAS to crop harvest. Among the sole herbicide, sole application of imazethapyr, quizalofop-ethyl, chlorimuron-ethyl, pendimethalin and pendimethalin 30 EC + imazethapyr 2 EC (PE) were in the order of better performance for controlling *Cyperus* weed. However, they were all better than control. At initial stage, chlorimuron-ethyl applied as PPI was the only herbicide significantly affecting growth of *Cyperus* better than control. The finding was in conformity with Sharma and Raghuvanshi (1999) who reported that, chlorimuron-ethyl controlled sedges effectively. Little or no effect was observed with pendimethalin and pendimethalin + imazethapyr on the *Cyperus*. Amongst the integrated system, chlorimuron-ethyl applied as PPI and mechanical weeding showed minimum weed count at 60 DAS and 90 DAS while at crop harvest, it was minimum with pendimethalin *fb* mechanical weeding. However, least dry matter of *Cyperus* at the same crop stage was recorded in the treatments, chlorimuron-ethyl *fb* imazethapyr and pendimethalin *fb* imazethapyr at 90 DAS and crop harvest (Table 2). Weedy check exhibited maximum weed count and dry matter. In either case, imazethapyr was involved in the reduction of *Cyperus* count and dry matter accumulation. The result was also corroborated by Kumar (2008).

Weed control efficiency

Weed control efficiency (WCE) in *Chenopodium* recorded at 90 DAS and crop harvest indicated that hand

Table 1. Effect of IWM on weed count of *Chenopodium* and *Cyperus* at different crop growth stages (pooled mean of two years)

Treatment	30 DAS		60 DAS		90 DAS		Harvest	
	Chem.	*Cyperus*	*Chem.*	*Cyperus*	*Chem.*	*Cyperus*	*Chem.*	*Cyperus*
HW 30 DAS and 45 DAS	37.33 (6.15)	41.67 (6.49)	1.17 (1.29)	6.67 (2.68)	4.33 (2.20)	15.83 (4.04)	4.50 (2.24)	12.67 (3.63)
MW 30 DAS and 45 DAS	36.33 (6.07)	50.50 (7.14)	1.67 (1.47)	12.33 (3.58)	7.33 (2.80)	16.17 (4.08)	7.83 (2.89)	13.58 (3.75)
Quizalofop-ethyl 50 g/ha 40 DAS	38.67 (6.26)	43.50 (6.63)	12.17 (3.56)	34.33 (5.90)	10.17 (3.27)	29.17 (5.45)	19.00 (4.42)	20.17 (4.55)
Imazethapyr 37.5 g/ha 40 DAS	36.00 (6.04)	47.00 (6.89)	9.83 (3.21)	13.33 (3.72)	8.50 (3.00)	21.33 (4.67)	9.50 (3.16)	17.50 (4.24)
Chlorimuron-ethyl 4 g/ha (PPI)	21.67 (4.71)	46.67 (6.87)	31.50 (5.66)	43.17 (6.61)	32.83 (5.77)	31.67 (5.67)	26.33 (5.18)	25.17 (5.07)
Pendimethalin 1 g/ha (PE)	1.17 (1.29)	43.83 (6.66)	3.50 (2.00)	69.50 (8.37)	4.83 (2.31)	48.50 (7.00)	6.50 (2.65)	29.50 (5.48)
Imazethaspyr 0.75 kg/ha (PE)*	1.20 (1.30)	42.83 (6.58)	3.33 (1.96)	72.83 (8.56)	5.17 (2.38)	43.00 (6.60)	6.33 (2.61)	25.33 (5.08)
Pendimethalin + imazethapyr (PE) 0.75 kg/ha	1.00 (1.22)	49.83 (7.09)	3.00 (1.87)	68.83 (8.33)	4.83 (2.31)	42.33 (6.54)	5.50 (2.45)	25.50 (5.10)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* quizalofop-ethyl 50 g/ha 40 DAS	22.00 (4.74)	40.67 (6.42)	8.33 (2.97)	28.83 (5.42)	10.53 (3.32)	27.67 (5.31)	8.17 (2.94)	21.00 (4.64)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* imazethapyr 37.5 g/ha 40 DAS	23.33 (4.88)	41.17 (6.45)	9.00 (3.08)	23.00 (4.85)	6.83 (2.71)	24.50 (5.00)	7.00 (2.74)	16.50 (4.12)
Pendimethalin 1 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha 40 DAS	1.17 (1.29)	44.17 (6.68)	1.67 (1.47)	23.67 (4.92)	4.83 (2.31)	30.83 (5.60)	6.17 (2.58)	17.67 (4.26)
Pendimethalin 1 g/ha (PE) *fb* imazethapyr 37.5 g/ha 40 DAS	1.27 (1.33)	48.83 (7.02)	1.50 (1.41)	18.17 (4.32)	5.00 (2.35)	19.67 (4.49)	5.00 (2.35)	15.33 (3.98)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* MW 45 DAS	24.67 (5.02)	39.50 (6.32)	12.17 (3.56)	11.17 (3.42)	17.00 (4.18)	19.33 (4.45)	18.67 (4.38)	19.83 (4.51)
Pendimethalin 1 g/ha (PE) *fb* MW 45 DAS	1.55 (1.43)	48.83 (7.02)	2.17 (1.63)	14.83 (3.92)	5.17 (2.38)	20.83 (4.62)	4.83 (2.31)	14.00 (3.81)
Weedy check (control)	38.17 (6.22)	55.67 (7.49)	63.83 (8.02)	100.50 (10.05)	57.17 (7.59)	69.67 (8.38)	43.17 (6.61)	47.33 (6.92)
Weed free	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
LSD (P = 0.05)	0.44	0.58	0.35	0.49	0.55	0.56	0.40	0.46

*Pre-mixed product of pendimethalin 30 EC and imazethapyr 2 EC; PE - Pre-emergence; MW - Mechanical weeding. Data on weeds are subjected to transformation $\sqrt{(x+0.5)}$. Figures within parentheses are square root transformed values and outside the parentheses are original values.

weeding twice at 30 and 45 DAS and pendimethalin *fb* mechanical weeding which were statistically at par were most effective followed by pendimethalin 1 kg/ha that was statistically non-significant with pendimethalin + imazethapyr 0.75 and 1 kg/ha. At crop harvest, the maximum WCE on *Chenopodium* was observed with the treatment, hand weeding twice at 30 and 45 DAS closely followed by pendimethalin *fb* imazethapyr (Table 3). Among the treatments, maximum weed control efficiency in *Chenopodium* spp. evaluated at 90 DAS and crop harvest (average) was registered with pendimethalin 1 kg/ha *fb* imazethapyr 37.50 g/ha after hand weeding that was statistically at par with pendimethalin *fb* mechanical weeding. Among the sole herbicide applications at 90 DAS, highest WCE in *Chenopodium* spp. was associated with two hand weeding, pendimethalin and pendimethalin + imazethapyr, which were statistically at par and in *Cyperus* spp., it was with two hand weeding and pendimethalin *fb* imazethapyr. At crop harvest, highest WCE in both the weeds was observed in the treatment, two hand weeding and pendimethalin *fb* imazethapyr. The result indicated that, pendimethalin supplemented with either imzethapyr or mechanical weeding was on average, the most efficient treatment in controlling both the weeds. Similar reports were communicated by Punia *et al*. (2011) on high WCE with pre-emergence *fb* post-emergence (imazethapyr) and pendimethalin *fb* mechanical weeding by Patel *et al.* (2012) in pendimethalin *fb* intercultivation, respectively.

Table 2. Effect of IWM on dry matter (g/m^2) of *Chenopodium* and *Cyperus* at different crop growth stages (pooled mean of two years)

Treatment	30 DAS		60 DAS		90 DAS		Harvest	
	Cheno.	*Cyperus*	*Cheno.*	*Cyperus*	*Cheno.*	*Cyperus*	*Cheno.*	*Cyperus*
HW 30 DAS and 45 DAS	2.13 (1.78)	4.87 (2.32)	2.13 (1.66)	3.83 (2.08)	5.17 (2.74)	9.12 (3.10)	11.50 (3.34)	6.20 (2.59)
MW 30 DAS and 45 DAS	2.33 (1.86)	4.15 (2.16)	2.50 (1.78)	5.67 (2.48)	17.00 (2.84)	13.53 (3.75)	18.50 (4.34)	10.75 (3.35)
Quizalofop-ethyl 50 g/ha 40 DAS	2.27 (1.69)	6.10 (2.57)	9.07 (3.01)	7.72 (2.87)	32.47 (4.19)	15.93 (4.05)	23.70 (4.83)	12.72 (3.64)
Imazethapyr 37.5 g/ha 40 DAS	2.83 (1.80)	5.90 (2.53)	4.43 (2.27)	6.65 (2.67)	26.53 (4.09)	14.47 (3.87)	18.40 (4.51)	10.12 (3.26)
Chlorimuron-ethyl 4 g/ha (PPI)	1.67 (1.53)	6.25 (2.60)	10.90 (3.32)	10.65 (3.34)	25.90 (4.47)	25.30 (5.08)	24.40 (5.06)	20.28 (4.56)
Pendimethalin 1 g/ha (PE)	0.40 (1.06)	6.27 (2.60)	2.53 (1.98)	13.50 (3.74)	5.87 (2.70)	26.00 (5.15)	14.40 (3.75)	23.88 (4.94)
Imazethapyr 0.75 kg/ha (PE)*	0.93 (1.17)	5.63 (2.48)	2.23 (1.93)	13.35 (3.72)	9.93 (2.43)	24.72 (5.02)	13.33 (3.65)	26.33 (5.18)
Pendimethalin 30 EC + imazethapyr (PE) 0.75 kg/ha	0.73 (1.10)	6.10 (2.57)	3.00 (1.93)	12.92 (3.66)	6.67 (2.54)	22.58 (4.80)	13.20 (3.66)	20.40 (4.57)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* quizalofop-ethyl 50 g/ha 40 DAS	2.50 (1.64)	6.70 (2.68)	8.37 (3.01)	10.55 (3.32)	24.40 (4.55)	17.07 (4.19)	20.33 (4.34)	13.93 (3.80)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* imazethapyr 37.5 g/ha 40 DAS	2.47 (1.85)	7.30 (2.79)	2.50 (1.93)	6.23 (2.59)	33.67 (3.93)	14.02 (3.81)	15.67 (4.17)	9.73 (3.20)
Pendimethalin 1 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha 40 DAS	0.87 (1.07)	6.98 (2.74)	2.57 (2.04)	8.13 (2.94)	15.50 (3.35)	15.13 (3.95)	14.17 (3.73)	9.75 (3.20)
Pendimethalin 1 g/ha (PE) *fb* imazethapyr 37.5 g/ha 40 DAS	0.70 (1.13)	5.70 (2.49)	2.17 (1.83)	6.88 (2.72)	11.27 (2.44)	12.50 (3.61)	13.03 (3.60)	7.93 (2.90)
Chlorimuron-ethyl 4 g/ha (PPI) *fb* MW 45 DAS	2.50 (1.69)	5.98 (2.55)	5.73 (3.07)	7.87 (2.89)	36.83 (3.81)	18.00 (4.30)	21.53 (4.64)	12.45 (3.60)
Pendimethalin 1 g/ha (PE) *fb* MW 45 DAS	0.90 (1.11)	5.90 (2.53)	3.63 (2.08)	5.23 (2.39)	7.67 (2.54)	14.37 (3.86)	12.67 (3.60)	9.92 (3.23)
Weedy check (control)	2.83 (1.73)	8.92 (3.07)	27.27 (4.75)	22.13 (4.76)	59.40 (6.95)	55.53 (7.49)	41.87 (6.91)	45.18 (6.76)
Weed free	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
LSD (P =0.05)	0.17	0.29	0.33	0.57	0.56	0.57	0.69	0.59

Cheno. Spp. - Chenopdium species; *fb* - followed by; DAS - Days after sowing; Quiza.- Quizalofop-ethyl; Imaze. - Imazethapyr; Chlori. - Chlorimuron-ethyl; *pre-mixed product of pendimethalin 30 EC and imazethapyr 2 EC; PE - Pre-emergence; MW - Mechanical weeding; Data on weeds are subjected to transformation $\sqrt{(x + 0.5)}$. Figures within parentheses are square root transformed values and outside the parentheses are original values.

Effect on yield attributes

Among the treatments (Table 3), hand weeding twice at 30 and 45 DAS, mechanical weeding twice at 30 and 45 DAS and pendimethalin *fb* mechanical weeding at 45 DAS were in the increasing order of branches/plant with statistically non significance among them. The mechanical loosening of the soil, effective broad-leaved weed control at the initial stage and favourable soil environment due to the soil structural alteration could be attributed to the increased effective branches. The finding is in line with Muhammad (2010) who reported that, hand hoeing gave more branches in chickpea. Pod counts/plant was maximum in two hand weeding, pendimethalin *fb* mechanical weeding and pendimethalin *fb* imzethapyr treatments. The pod number in each plant had a positive correlation with the branches. More production of effective branches, better weed control of weeds and soil friability as a result of inter cultivation (mechanical weeding with twin wheel hoe) could be attributed to high pod count/plant. The result showed that, pod yield has been increased with the application of pendimethalin which was a component in both the best performing treatments. More pods with pendimethalin application was also reported by Rana (2002).

Table 3. Effect of IWM on WCE of *Chenopodium* and *Cyperus*, yield attributes, yield and economics of lentil (pooled mean of two years)

Treatment	WCE (%) at 90 DAS		WCE (%) at crop harvest		At crop harvest				Net returns (x10^3 `/ha)	BCR
	Cheno podium	*Cyperus*	*Cheno podium*	*Cyperus*	Branch/ plant	Pods/ plant	Yield (t/ha)	WI (%)		
HW 30 DAS and 45 DAS	77.0	83.7	73.2	86.2	8.12	65.07	1.39	2.81	56.07	2.53
MW 30 DAS and 45 DAS	69.6	75.6	61.0	76.2	7.22	58.88	1.30	8.89	51.90	2.44
Quizalofop-ethyl 50 g/ha 40 DAS	61.1	71.3	43.3	71.6	6.17	42.33	1.02	28.76	39.67	2.15
Imazethapyr 37.5 g/ha 40 DAS	65.1	73.8	52.1	77.6	6.52	50.93	1.11	21.95	44.78	2.57
Chlorimuron-ethyl 4 g/ha (PPI)	39.8	54.4	37.6	54.9	5.58	37.25	1.01	29.35	39.89	2.34
Pendimethalin 1 g/ha (PE)	74.8	53.1	68.0	47.0	6.83	58.35	1.04	26.86	41.07	2.25
Imazethapyr 0.75 kg/ha (PE)*	74.8	55.5	68.9	41.6	6.83	59.20	1.15	19.33	46.23	2.54
Pendimethalin + imazethapyr (PE) 0.75 kg/ha	74.4	59.2	70.1	54.7	6.67	60.05	1.19	16.41	47.95	2.56
Chlorimuron-ethyl 4 g/ha (PPI) *fb* quizalofop-ethyl 50 g/ha 40 DAS	57.6	69.3	61.9	69.2	6.25	52.75	1.03	27.64	40.16	2.12
Chlorimuron-ethyl 4 g/ha (PPI) *fb* imazethapyr 37.5 g/ha 40 DAS	62.3	74.7	61.1	78.4	5.93	55.92	1.09	23.43	43.50	2.41
Pendimethalin 1 g/ha (PE) *fb* quizalofop-ethyl 50 g/ha 40 DAS	73.4	72.8	67.5	78.4	6.33	57.87	1.22	14.84	48.32	2.39
Pendimethalin 1 g/ha (PE) *fb* simazethapyr 37.5 g/ha 40 DAS	77.0	77.5	71.3	82.4	6.78	61.15	1.29	9.33	52.50	2.72
Chlorimuron-ethyl 4 g/ha (PPI) *fb* MW 45 DAS	52.2	67.5	50.0	72.3	6.48	54.07	1.07	25.23	41.90	2.25
Pendimethalin 1 g/ha (PE) *fb* MW 45 DAS	75.7	74.2	70.4	78.2	7.63	62.33	1.36	4.51	55.59	2.80
Weedy check	0.0	0.0	0.0	0.0	4.17	24.48	0.62	56.21	13.98	0.85
Weed free	100.0	100.0	100.0	100.0	8.30	68.88	1.42	0.00	55.20	2.06
LSD (P=0.05)	-	-	-	-	1.13	8.53	0.15	0.00	-	-

Effect on grain yield

Hand weeding (HW) twice at 30 and 45 DAS (Khurpi aided hand pulling) showed superior effect next to weed free. Kaur *et al*. (2009) also confirmed the same result when HW in lentil was done at 25 and 45 DAS. Among the treatments (Table 3), two hand weeding gave maximum yield followed by pendimethalin with sequential mechanical weeding (hoeing with twin wheel hoe) which was statistically at par with pendimethalin *fb* imazethapyr. Twice hand weeding and weed free were statistically showing non-significant difference among them, while two HW and pendimethalin *fb* MW were at par. The latter, further showed its insignificance with pendimethalin *fb* imazethapyr in the grain yield. Among the treatments, Chlorimuron-ethyl sole registered the least yield but was higher that weedy check. Imazethapyr recorded maximum yield among the sole post emergence herbicides. Similar report was communicated by Anonymous (2009).

Weed index

Weed index is per cent reduction in grain yield due to weeds as compared to total yield of weed free treatment. Weedy check resulted in yield reduction to the tune of 56% (Table 3). The yield reduction was possibly due to the high intensity of weeds that robbed off the nutrient supply, sunlight and water besides limited space for comfortable crop growth and development. Among the treatments, chlorimuron-ethyl alone applied as PPI and sole quizalofop-ethyl applied as post emergence resulted in highest yield loss next to control. There was little loss in two hand weeding and no loss in weed free. Pendimethalin *fb* mechanical hoeing was the integrated system of weed management that showed lowest yield reduction after two hand weeding. Effective weed control with reduced weed flora and biomass could be attributed to the better performance in avoiding yield loss. Among the sole applied herbicides, imazethapyr at both doses (0.75 and 1 kg/ha) showed least yield reduction.

Economics

Cost incurred in single application of herbicides was comparatively less, but the low yield resulted in low net return and BCR. Weed free and two hand weeding were highest in yield and net return, but due to higher cost of cultivation associated, the net return and BCR correspondingly were low. Comparison between single herbicides indicated that, pendimethalin + imazethapyr (Pursuit plus) was the most profitable herbicide. Among the chemical-chemical sequential application, pendimethalin *fb* imazethapyr was the best option as it fetched a fair net return and high BCR. Pendimethalin *fb* mechanical weeding (hoeing) reflected highest net returns and BCR which may be the best choice for integrated weed management. Similar profitability with the treatment in lentil was also reported by Kalpana (2010). Under pendimethalin *fb* mechanical hoeing, comparatively low cost of the herbicide, lesser labour with more weeding coverage area in a short time particularly under sandy soils and rainfed condition may be reasons for profitability of the system.

Inference can be drawn from the outcome of the present study that, one herbicide as pre-emergence (pendimethalin 1 kg/ha) supplemented by one mechanical weeding (hoeing with twin wheel hoe) 45 DAS could be the best option under integrated weed management in lentil under rainfed conditions under sandy soils. The finding can be justified with the fact that, pendimethalin was an excellent herbicide for control of weeds propagated by seeds and mechanical hoeing that created favourable environment for microorganisms through weed incorporation and decomposition in the soil besides uprooting the weeds. quizalofop-ethyl 50 g/ha 40 DAS; imazethapyr 37.5 g/ha 40 DAS; chlorimuron-ethyl {Pre plant incorporation (PPI)} 4 g/ha; pendimethalin {pre-emergence (PE)} 1 kg/ha; pendimethalin 30 EC + imazethapyr 2 EC (PE) 0.75 kg/ha; pendimethalin 30 EC + imazethapyr 2 EC (PE) 1 kg/ha; chlorimuron-ethyl (PPI) 4 g/ha *fb* quizalofop-ethyl 50 g/ha 40 DAS; chlorimuron-ethyl (PPI) 4 g/ha *fb* imazethapyr 37.5 g/ha 40 DAS; pendimethalin (PE) 1 kg/ha; quizalofop- ethyl 50 g/ha 40 DAS; pendimethalin (PE) 1 kg/ha (Stomp) *fb* imazethapyr 37.5 g/ha 40 DAS; chlorimuron-ethyl (PPI) 4 g/ha *fb* MW 45 DAS; pendimethalin (PE) 1 kg/ha *fb* MW 45 DAS. Weed samples were collected by placing a quadrate (0.50 x 0.50 m) randomly in each plot at 60, 90 DAS and crop harvest. Data for weed components were subjected to square root transformation $\sqrt{(x+0.5)}$ for uniformity. Data analyses were done with RCBD. The economic analyses were carried out by computing the market price of inputs and outputs of both the experimental seasons prevailing at Varanasi city. The names in parentheses at the end of each herbicides are trade names of the concerned herbicides used in the experiment.

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Non-chemical methods of weed management in maize under organic production system

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ABSTRACT

A field experiment was conducted to study the non-chemical methods of weed management in organically grown maize during the year 2010 and 2011. Among the 9 weed management treatments, soybean intercropping + one mechanical weeding (20 DAS) and 2 mechanical weeding (20 and 40 DAS) + mash intercropping being at par with each other resulted in significantly lower weed dry weight, higher yield attributes and maize equivalent yield over other treatments. One mechanical weeding at 20 DAS gave highest benefit-cost ratio of 4.3 followed by 2 mechanical weeding at 20 and 40 DAS and soybean intercropping + 1 MW (20 DAS), which gave the benefit : cost ratio of 2.3.

Key words: Equivalent yield, Maize, Organic, Weed control, Weed control efficiency

Maize (*Zea mays* L.*)* is a versatile crop, growing across a range of agro–ecological zones. Being a rainy season and widely spaced crop, maize gets infested with variety of weeds and subjected to heavy weed competition during the first 4-6 weeks after emergence. Practice of using heavy inputs and intensive cultivation has led to heavy weed infestation which remains to be the most devastating reason for lowering grain yield by 83% (Usman *et al.* 2001). Herbicide used to be a key component in almost all weed management strategies, but indiscriminate use of these herbicides has resulted in serious ecological and environmental problems. A strong need was felt to discover the alternative weed management options in organic agriculture (Economou *et al.* 2002). Integrated weed management includes the combination of cropping practices for efficient and economical weed control (Swanton and Weise 1996). Intercropping within the organic agricultural production has an important role in weed control. The wider row spacing in maize can be used to grow short duration legumes which not only act as smoother crop, but also give additional yield (Shah *et al.* 2011). The increased number of plants per unit area, as in case of intercrops, results in the reduction of weed biomass (Bulson *et al.*1997).

Despite best management practices being adopted, the per hectare yield of *Kharif* crops including maize tends to be low due to the reverse nutrient competition offered by weeds as rains and humidity support luxuriant growth of weeds which can reduce the maize yield up to 60.8% (Gaur *et al.* 1991). Keeping in view the negative effects of herbicides, the present study was undertaken to observe the effect of non-chemical methods of weed management in maize under organic production system.

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MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 2010 and 2011 at the Research Farm of Department of Organic Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The area represents the mid-hill wet temperate zone of Himachal Pradesh. The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 5.6), medium in organic carbon (0.57%), low in available nitrogen (205.0 kg/ha), available phosphorus (9.5 kg/ha) and medium in available potassium (180.0 kg/ha). The experiment was laid out in randomized block design with nine treatment combinations and three replications. The treatments comprised of mechanical weeding (MW) at 20 DAS, 2 mechanical weeding (MW) at 20 and 40 DAS, hand weeding (HW) at 20 DAS, 2 hand weeding at 20 and 40 DAS, soybean intercropping with no weeding, soybean inter-cropping + 1 MW (20 DAS), soybean intercropping + 1 HW (20 DAS), 2 MW at 20 and 40 DAS + mash intercropping (40 DAS) and unweeded check. Weed population was recorded from the unweeded check plots at 120 days after sowing for the purpose of calculating the percent infestation of different weed species. The total dry weight of weeds was recorded at 120 days after sowing.

RESULTS AND DISCUSSION

Effect on weeds

The major weeds were: *Echinochloa* sp. *(E. colona* (L.) Link and *E. crusgalli* (L.) P. Beauv.), *Digitaria sanguinalis* (L.) Scop. and *Panicum dichotomiflorum* Michx. among grasses, *Cyperus* sp. *(C. esculentus* L. and *C. iria* L.*)* among sedges and *Commelina benghalensis* L. among broad-leaved. The grasses, broad-leaved weeds and sedges constituted about 65.4, 21.5 and 13.1% of total weed flora. Under mid-hill conditions of Himachal Pradesh, similar weed flora has been reported earlier in maize fields by Saini and Angiras (1998).

Effect on crop

Different weed control treatments significantly affected number of cobs, cob length, grains/cob and, 1000 grains weight compared to that of unweeded control plot (Table 1). It has been found that two MW (20 and 40 DAS), 1 HW/1 MW (20 DAS), two HW/MW (20 and 40 DAS) and 1 MW (20 DAS) being statistically at par with each other recorded significantly higher number of cobs/ha and higher cob length over the remaining treatments. Soybean inter-cropping (no weeding) was as good as 1 HW in suppressing weeds and producing significantly longer cobs and higher number of cobs/ha over unweeded control. During both the years of study, grains/cob and 1000-grain weight were significantly higher over unweeded check but were statistically at par among the different treatments except grains/cob during 2010. In 2011, 2 MW + mash inter-cropping and soybean inter-cropping +1 HW/1MW (20 DAS) produced significantly higher number of grains/cob over all other treatments. Soybean inter-cropping though resulted in higher grains/ cob over unweeded check but recorded comparatively lower grains/cob over other treatments. Ali (1988) and Ghosh *et al*. (2007) also reported similar results.

Soybean intercropping + 1 MW (20 DAS), 2 MW (20 and 40 DAS) and 2 MW (20 and 40 DAS) + mash inter-cropping being at par with each other resulted in significantly lower weed dry weight and higher maize equivalent yield over all other treatments during both the years of experimentation. This might be due to the weed smothering ability of the legumes due to the profuse canopy which also resulted in higher weed control efficiency. Ali (1988), Ghosh *et al.* (2007) and Nongmaithem *et al.* (2012) also expressed similar opinions, where legumes with good canopy were most efficient for weed control. Hand weeding twice (20 and 40 DAS) being at par with 1 HW/1MW (20 DAS) were the next best treatments in controlling weeds and producing higher yields over the remaining treatments. Soybean inter-cropping though was least effective in suppressing weeds among all the treatments but it produced significantly higher maize equivalent yield and lower weed dry weight over unweeded control. Two mechanical weedings (20 and 40 DAS) being at par with soybean inter-cropping + 1 HW/1 MW (20 DAS) resulted in significantly higher maize/maize equivalent yield and lower weed dry weight over other treatments except 2 MW (20 and 40 DAS) + mash intercropping.

Mechanical weeding (20 DAS) resulted in significantly highest benefit–cost ratio of 4.6 and 4.0 during 2010 and 2011, respectively. This treatment was followed by 2 MW (20 and 40 DAS) and soybean inter-cropping + 1 MW each of which resulted into 2.3 B:C ratio. It was closely followed by 2 MW + mash inter-cropping which gave on an average 2.2 B:C ratio. All the weed

Table 1. Effect of various weed control treatments on yield attributes of maize

Treatment	Number of cobs/ha ($x10^3$/ha)		Cob length (cm)		Grains/cob		1000-grain weight (g)	
	2010	2011	2010	2011	2010	2011	2010	2011
Mechanical weeding (MW) 20 DAS	72.4	65.7	17.5	16.8	311.6	303.2	211.7	212.2
Mechanical weeding (MW) (20 and 40 DAS)	73.9	66.4	17.0	17.1	308.2	315.1	218.6	212.5
Hand weeding (HW) 20 DAS	65.2	62.6	16.5	15.9	302.3	286.4	205.0	198.4
Hand weeding (HW) 20 and 40 DAS	71.5	65.3	17.1	16.6	315.2	315.7	214.7	209.0
Soybean intercropping (no weeding)	64.7	59.5	15.6	16.0	292.5	280.7	206.8	196.4
Soybean intercropping + 1MW (20 DAS)	73.6	67.4	17.5	17.2	333.4	312.5	215.2	211.0
Soybean intercropping + 1 HW (20 DAS)	71.8	65.5	17.6	17.0	329.6	302.5	212.5	208.1
2 MW 20 and 40 DAS + mash intercropping	74.7	68.8	17.9	16.8	340.1	298.5	215.8	210.4
Unweeded check	48.6	45.5	14.8	13.9	182.4	165.4	195.8	188.4
LSD (P=0.05)	3.5	3.8	0.8	0.7	15.1	17.5	15.6	16.2

DAS - Days after sowing, MW - Mechanical weeding, HW- Hand weeding

Table 2. Effect of treatments on weed dry weight, weed control efficiency, maize equivalent yield and benefit: cost ratio

Treatment	Weed dry weight (g/m^2)		Weed control efficiency (%)		Maize grain equivalent Yield (t/ha)		Benefit: cost ratio	
	2010	2011	2010	2011	2010	2011	2010	2011
Mechanical weeding(MW) at 20 DAS	42.8	54.6	58.2	56.6	3.42	2.95	4.6	4.0
Mechanical weeding (MW) at 20 and 40 DAS	24.3	28.7	76.3	77.2	3.65	3.28	2.7	2.6
Hand weeding(HW) at 20 DAS	49.5	62.3	51.7	50.5	3.25	2.64	2.9	1.7
Hand weeding (HW) at 20 and 40 DAS	33.8	35.4	67.0	71.9	3.44	3.02	1.3	1.2
Soybean intercropping (no weeding)	46.4	65.7	54.7	47.8	2.80	2.48	1.5	1.6
Soybean intercropping + 1 MW at 20 DAS	28.4	31.2	72.4	75.2	3.84	3.35	2.4	2.1
Soybean intercropping + 1 HW at 20 DAS	31.5	36.2	69.2	71.2	3.71	3.24	1.7	1.5
2 MW at 20 and40 DAS+ mash intercropping	27.6	21.4	73.0	83.0	3.82	3.56	2.1	2.3
Unweeded check	102.4	125.8	-	-	2.15	1.84	-	-
LSD (P=0.05)	12.5	5.7	-	-	0.24	0.21	-	-

management treatments resulted in significantly lower weed dry weight and higher weed control efficiency over unweeded check during both the years of study (Table 2). Irrespective of number of weedings, the mechanical weedings produced lower weed dry weight as compared to the hand weeding, however, the differences were non-significant. Two mechanical/hand weedings at 20 and 40 DAS being at par with soybean intercropping + 1 mechanical/hand weeding at 20 DAS produced significantly lower weed dry weight and higher weed control efficiency over the remaining treatments during both the years of experimentation.

Soybean intercropping suppressed second flush of weeds to a great extent. Two mechanical weedings (20 and 40 DAS) + mash intercropping gave the highest weed control efficiency due to profuse canopy as has also been observed by Ali (1988) and Ghosh *et al.* (2007). Soybean inter-cropping was as effective as one hand weeding (20 DAS) in suppressing the weeds during both the years. However, it was also at par with one mechanical weeding during first year as was evident from weed dry weight and weed control efficiency (Table 2). Kandasamy and Chandrasekhar (1998) reported that the traditional (non-chemical) methods of weed control effectively minimized weed competition and maximized maize yield.

It was concluded that under organic farming conditions, soybean intercropping + 1 mechanical weeding (20 DAS) or 2 mechanical weedings (20 and 40 DAS) could be the best options for non-chemical management in maize.

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Suitable cropping system and weed management practices for higher fodder oat production

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ABSTRACT

Field experiments were carried out during 2009-10 and 2010-11 at Mountain Livestock Research Institute, Manasbal, Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir, India to find out the suitable weed management practices and cropping system of fodder oat. The green fodder yield and dry matter accumulation of oat was significantly higher under oat sole than oat + vetch (2:1) and oat + vetch (1:1), however was at par to oat + vetch 4:1. The magnitude of increase in green fodder yield with oat sole was 0.96, 12.71 and 15.51% than 4:1, 2:1 and 1:1 cropping system, respectively. Application of pendimethalin 0.75/ha recoded 7.76, 24.46 and 98.6% superiority over application of butachlor 2 kg/ha, wheel hoe and weedy check, respectively. The oat sole with application of pendimethalin 0.75/ha recorded highest gross profit (₹ 76,903/ha), net returns (₹ 49,363/ha) and B:C (2.79) than other treatment combination.

Key words: Butachlor, Cropping system, Fodder oat, Green fodder yield, Pendimethalin, Wheel hoe

The fodder production in India is insufficient to meet the requirements of growing livestock population and country faces a net deficit of 61.1% in green fodder, 21.9% in dry crop residues and 64% in feeds (Agarwal *et al*. 2008). The shortage of feed and fodder has resulted in low productivity of Indian livestock (Tripathi *et al.* 2009). The fodder cultivation is equally or more remunerative than grain, cash or commercial crops (Agarwal *et al*. 2008). In Jammu & Kashmir, 0.6 lakh ha is under cultivated fodder crops (DES 2008) and faces a net deficit of 19% in fodder (Anonymous 2006). Among the cultivated *Rabi* fodder crops, oat is one of the promising fodder crop as it fits well in rice based cropping sequence. In Kashmir valley, a large number of weed species have been reported that are associated with fodder oat crop like *Ranunculus muricatus*, *R. arvensis*, *Fumaria indica*, *Arenaria serpyllifolia*, *Poa annua* among the highly frequent species (Reshi *et al*. 1986 and Singh *et al.* 2007). Besides other factors, weed infestation is one of the significant factors limiting the productivity and quality of fodder oat. Since the information available on weed management practices in fodder oat is limited in Kashmir, the present investigation was initiated to find out appropriate cropping system and weed management practice for higher fodder oat production.

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MATERIALS AND METHODS

The present investigation was conducted during *Rabi* seasons of 2009-10 and 2010-11 at Mountain Livestock Research Institute, Manasbal, Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir to detect suitable cropping system and weed management practice for higher fodder oat production. The study area falls in temperate climatic zone of north western Himalaya. The experimental soil was clay loam in texture, neutral in reaction (pH 7.1), high in organic carbon (2.1%) and medium in available P (17.3 kg/ha), available K (414 kg/ha) and low in available N (156 kg/ha). The experiment was laid out in a split plot design with four cropping systems, *viz.* oat + vetch (4:1), oat (*Avena sativa*) + vetch (*Vicia villosa*) (2:1), oat + vetch (1:1), oat (sole) in main plot and four weed control methods, *viz*. weedy, wheel hoe, pendimethalin 0.75 kg/ha and butachlor 2.0 kg/ha to subplot with three replications having 15 m^2 gross plot size of each treatment. Oat cultivar '*Sabzar*' was sown with row to row spacing of 25 cm in pots receiving sole oat treatment. The winter vetch cultivar '*Golder Tares*' was sown after every four rows of oat in oat + vetch 4:1 treatment. In treatment oat + vetch 2:1, after every two rows of oat, one row vetch was sown and in oat + vetch 1:1, every row of oat was followed by one row of vetch. The spacing between oat and vetch was kept same as that of sole oat treatment (25 cm row-row) in all intercrop treatments.

The wheel hoe was operated twice in the season, one at 30-35 days after sowing and second at 160-165 days after sowing. The pendimethalin 0.75 kg/ha and butachlor 2.0 kg/ha were applied within three days after sowing to respective plots. No weed management practice was done in weedy check plots. The plant samples were taken at the time of harvesting for estimation of dry matter. Oat was harvested at milking stage and at the same time winter vetch was also harvested. The green fodder yield was estimated from 10.4 m^2 net plot area of each treatment.

RESULTS AND DISCUSSION

Weed flora

The weed flora observed in the experimental plots were: *Lamium amplexicaule,Galium aparine, Asperugo procumbense, Bromus japonica, Medicago polymorpha, Lolium perenne, Adonis aestivalis, Fumaria indica, Scandix pecten-veneris, Lithospermum arvense, Ranunculus arvensis, Cynodon dactylon, Arenaria serpyllifolia, Poa annua* and *Capsella bursa.*

Effect on weed biomass

The different cropping system and weed control methods induced significantly distinction in weed biomass, dry matter accumulation and green fodder yield of oat (Table 1). Among the cropping system oat + vetch (4:1) recorded significantly lower weed dry matter than oat + vetch (2:1), oat + vetch (1:1), however was at par to oat sole. Further, the oat sole recorded significantly lower weed dry matter than oat + vetch (2:1), oat + vetch (1:1). The difference between oat + vetch (2:1) and oat + vetch (1:1) was not significant with respect to weed dry matter. This trend may be ascribed to non-smoothening effect of winter vetch in replacement series of oat - vetch intercropping system. Among the weed control methods, application of pendimethalin 0.75 kg/ha recorded significantly lower weed dry weight than butachlor 2.0/ha, wheel hoe and weedy check. Application of butachlor 2.0 kg/ha recorded significantly lower weed dry matter than wheel hoe and weedy. Besides, wheel hoe was significantly superior than weedy with respect to weed dry matter. Pisal and Sagarka (2013) also reported that pre-emergence pendimethalin resulted efficient control of monocot and dicot weeds.

Effect on green fodder yield and dry matter

The green fodder yield and dry matter accumulation of oat was significantly higher under oat sole than oat + vetch (2:1) and oat + vetch (1:1), however was at par to oat + vetch 4:1. Further, oat + vetch 4:1 was superior to oat + vetch (2:1) and oat + vetch (1:1) with respect to green fodder yield and dry matter accumulation, though the difference between oat + vetch (2:1) and oat + vetch (1:1) was not significant. The oat sole recorded 0.96%, 12.71% and 15.51% increase in green fodder yield than 4:1, 2:1 and 1:1 cropping system, respectively. Lower biomass per unit area of winter vetch than oat may be the basis of higher dry matter accumulation and green fodder yield with sole oat. Application of pendimethalin 0.75 kg/ha was significantly superior with respect to green fodder yield and dry matter accumulation than other weed control treatments, and was followed by butachlor 2.0 kg/ha, wheel hoe and weedy. In turn, application of butachlor 2.0 kg/ha recorded significantly higher green fodder yield and dry matter accumulation than wheal hoe and weedy and further, wheel hoe was significantly superior than weedy check. Mishra *et al*. (2012) also found that application of pendimethalin 0.5 kg/ha was good in

Table 1. Effect of intercropping and weed control methods on weed dry matter, green fodder yield, dry matter accumulation of fodder oat

Treatment	Weed dry matter (g/m^2)			Green fodder (t/ha)			Dry matter (t/ha)		
	2009-10	2010-11	Mean	2009-10	2010-11	Mean	2009-10	2010-11	Mean
Cropping system									
Oat+vetch (4:1)	50.1	48.0	49.1	28.89	27.28	28.09	8.99	8.81	8.87
Oat+vetch (2:1)	60.5	58.1	59.3	25.87	24.45	25.16	7.71	7.44	7.57
Oat+vetch (1:1)	57.0	54.7	55.9	25.27	23.84	24.55	7.66	7.24	7.45
Oat sole	50.7	48.7	49.7	29.16	27.55	28.36	9.72	9.14	9.43
LSD (P=0.05)	4.37	4.22	4.26	1.30	0.83	0.85	0.86	0.54	0.65
Weed control method									
Wheel hoe	49.5	47.6	48.6	27.14	25.62	26.36	8.76	8.16	8.46
Pendimethalin 0.75g/ha	35.8	34.4	35.1	33.74	31.88	32.81	10.42	10.07	10.27
Butachlor 2.0g/ha	41.6	40.0	40.8	31.33	29.61	30.47	9.61	9.35	9.48
Weedy check	91.2	87.6	89.4	16.98	16.05	16.52	5.19	5.09	5.14
LSD (P=0.05)	4.62	4.42	4.48	1.36	1.11	1.14	0.52	0.56	0.52

weed control and produced higher grain yield of maize. Application of pendimethalin 0.75/ha recorded 7.8, 24.5 and 98.6% superiority over application of butachlor 2 kg/ ha, wheel hoe and weedy check, respectively. Higher fodder yield with application of pendimethalin 0.75/ha was also reported by Bar *et al.* (1991) and Bhilare *et al*. (2001).

Economics

The oat sole with application of pendimethalin 0.75 kg/ha recorded highest gross profit (₹ 76,903/ha), net return (₹ 49,363/ha) and B:C (2.79) than other treatment combination (Table 2) and was followed by oat sole + butachlor, pendimethalin (4:1), butacholr (4:1) and lowest was recorded with weedy sole and weedy (4:1). It was concluded that fodder oat crop sown as sole with application of pendimethalin 0.75 kg/ha was found superior both with respect to green fodder production and economically.

Table 2. Relative economics of different treatment combinations

Treatment	Cost of cultivation ($x10^3$`/ha)	Gross returns ($x10^3$`/ha)	Net returns ($x10^3$`/ha)
Wheel hoe (4:1)	29.19	60.84	31.65
Pendimethalin (4:1)	28.44	69.41	40.97
Butachlor (4:1)	27.97	66.10	38.13
Weedy (2:1)	28.40	33.89	5.49
Wheel hoe (2:1)	30.27	49.34	19.07
Pendimethalin (2:1)	29.50	59.35	29.85
Butachlor (2:1)	29.43	53.84	24.41
Weedy (1:1)	29.15	43.32	14.17
Wheel hoe (1:1)	30.40	46.93	16.53
Pendimethalin (1:1)	30.65	56.84	26.19
Butachlor (1:1)	30.18	54.23	24.05
Weedy (sole)	26.04	26.55	0.51
Wheel hoe (sole)	28.54	53.83	25.29
Pendimethalin (sole)	27.54	76.90	49.36
Butachlor (sole)	27.07	69.60	42.53
Weedy check (4:1)	26.94	28.38	1.44

Input - Oat seed = ₹16/kg; Vetch seed = ₹ 250/kg; N = ₹ 11.95/kg; P_2O_5 = ₹ 24.0/kg; K_2O = ₹ 9.0/kg; Pendimethalin = ₹ 500/litre; Butachlor = ₹ 30/kg; Output Green fodder = ₹ 2.0/kg

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Water hyacinth for heavy metal scavenging and utilization as organic manure

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ABSTRACT

Study on phytoremedial capability of water hyacinth as a safe organic manure source was done at the Regional Agricultural Research Station, Kumarakom during 2010-12. The heavy metals and other minerals in water hyacinth were Fe (33038 ppm), Al (13075 ppm), Ca (2234.80 ppm), Mn (1440.1 ppm), Mg (1608.3 ppm), Zn (77.08 ppm), Cu (49.80 ppm), Cr (23.37 ppm), As (5.276 ppm), Pb (0.531 ppm), and Hg (0.151 ppm). The heavy metal contents in all the three forms of composts were almost similar, except for Fe, Cr and Cd. The biomass yield of *Amaranthus viridis* in a pot culture study was higher in water hyacinth than ordinary compost during the initial harvest, while yields for the final harvest and total yields were significantly higher for the farmyard waste compost. The heavy metals Pb, Hg and Cd content in *Amaranthus* remained unaltered by the organic sources, while As, Cr and Ni content were enhanced significantly by the water hyacinth treatments.

Key words: *Eichhornia crassipes,* Heavy metal contamination, Nutrient scavenger, Phytoremediation, Vermi compost, Water hyacinth, Wetlands

The Vembanad–Kole wet lands, the largest among the three Ramsar sites in Kerala, is now on the verge of deterioration as there is high concentration of heavy metals and pesticide residues in water and sediment. The heavy metal content in sediments of the Vembanad estuary was reported to be above the critical limits (Varma et al., 2007). Sabitha and Nagaraj (2007) also reported the severe qualitative degradation in wetlands of Kerala.

The high degree of pollution by plant nutrients, *viz.* nitrates, nitrites and phosphates has contributed to prolific growth of *Eichhornia crassipes (*water hyacinth*)*, with coverage of 75% of the water bodies of Kerala state. This weed is widely seen in paddy fields, lakes, streams and channels making large areas inaccessible, non-navigable and uncultivable. Though the ill effects of water hyacinth have been dealt by many workers, its services as a cleansing macrophyte of polluted water bodies has seldom been appreciated. Phytoremedial capability of aquatic macrophytes is a cost effective green technology based on the use of specially selected metal accumulating plants. Wetland plants are preferred over other plants due to their low cost, frequent abundance in aquatic ecosystem and easy handling (Raj 2008). Though the capability of water hyacinth to accumulate plant nutrients and heavy metal contaminants present in water bodies is well known, however, disposal of biomass wiith accumulated heavy metals is a major constraint. The phytoremedial capability of *E. crassipes* and its utility as an organic source of nutrients for crop production has been reported by Sasidharan *et al.* (2012). However, elevated heavy metal content in plant tissues and composts of water hyacinth and the possible contamination of vegetables and agricultural produces through food chain are points of concern. In the present investigation, assessment of the capability of water hyacinth in recovering plant nutrients and heavy metals from polluted water bodies and evaluation of composting techniques for its easy disposal and the possible heavy metal contamination of crops produced are addressed.

MATERIALS AND METHODS

Studies were undertaken up at the Regional Agricultural Research Station, Kumarakom ($9^0$36'46''N; $76^0$25'51''E) during 2010-12. Samples of mature water hyacinth plants were randomly collected from different parts of the Vembanad Lake during March 2011 and January 2012 and were subjected for assessing the mineral composition and compost production. Simultaneously, sediments and water from these locations were collected for assessment the extent of heavy metals. A pot culture experiment with *E. crassipes* compost (EC), water hyacinth vermi compost (EVC), farm yard waste compost (FMC) and a no manure control as treatments with *Amaranthus* (*Amaranthus tricolour*) variety '*Arun*' as the test crop was conducted for two seasons during 2011-

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12. *Eichhornia crassipes* vermi compost and aerobic compost were prepared as per standard practice. Vermi compost was prepared using a mixture of partially dried (50% moisture) water hyacinth and cow dung in 8:1 (V/V basis) ratio. Earth worms (*Eudrillus eugineae*) were introduced 2 weeks later and resulting vermi compost was collected after 45 days. Composts, sand and soils were mixed in 1:1:1 proportion and 2 kg each of the potting mixture was filled in polyethylene pots. The different compost samples (EC, EVC and FMC) and the potting mixture were analysed for various physico- chemical parameters. One month old *Amaranthus* seedlings were transplanted at four seedlings per pot. No extraneous plant nutrients and plant protection chemicals were administered other than the treatments. Soil samples from all the pots were analysed for various physico–chemical properties. Two plants from each pot were uprooted at 20 and 40 days interval after planting and yields was recorded. *Amaranthus* samples were oven dried and analysed for plant nutrients and heavy metals as per the following methods.

Plant samples were washed thoroughly with deionised water and oven dried at 60^{o}C for 48 h and powdered using Wiley mill and analysed for plant nutrients and heavy metals. water hyacinth plants were analysed tissue wise for which the plants were separated to root, stem + petiole and leaf lamina while, whole plants of *Amaranthus* were similarly prepared for chemical analysis. Oven dried plant samples were weighed and placed in teflon vessels and digested by diacid method. The volume of the extract was made up to 50 ml with distilled water and the metal content was estimated using AAS.

The potting mixture was analysed for pH, EC, OC, P_2O_5, K_2O, Ca, Mg, S, Fe, Mn, Cu and Zn as per standard methods. Compost samples were oven dried at 60^{0} C for two days and samples were analysed for pH, EC, moisture (gravimetric method), nitrogen (micro kjeldhal), carbon (Walkey and Black), total potash (diacid extract), total phosphates (vanadomolybdo phosphoric yellow method), Cu, Zn, Fe, Mn, Pb, Cr, Hg, As, Cd, and Ni (diacid extract method) using AAS. The water and sediments of Vembanad lake were collected from different locations and analysed for Cu, Zn, Fe, Mn, Al Pb, Cr, Cd and Ni using AAS. The data for two seasons were pooled and analysed using ANOVA to test the significance level of variations in physico-chemical properties of potting mixture, yield of *Amaranthus*, and chemical composition and heavy metal content of *Eichhornia*, and *Amaranthus*.

RESULTS AND DISCUSSION

Heavy metals composition

Range of different heavy metals in lake sediments and water of lake are given (Table 1). Content wise, heavy metals were in the order of Fe > Al > Mn > Zn > Cu >Cr > As > Pb > Hg > Ni >Cd in their abundance (Table 2). The pattern was almost similar to that of lake water in order of Fe > Al > Mn > Zn > Cr > Pb > Ni > Cu >Cd. Elevated content of Cu in *E. crassipes* compared to the lake water is the most significant variation in heavy metal composition between *E. crassipes* and its habitat. The strong ability of *E. crassipes* to remove Cu from contaminated water bodies and the high bio-concentration factor (BCF) for Cu has been reported by Chaohua *et al.* (2007). Among the heavy metals and secondary nutrients, Fe contributed major share (3.3%) followed by Al (1.3%), Ca (0.23%) and Mg (0.16%). In water hyacinth tissues, Fe, Al and Mn were significantly higher in roots (94.6, 90.7 and 40.8%, respectively) while, Ca and Mg were more in the leaf lamina and stem + petiole (98 and 71%, respectively) and were significantly lesser in roots. The higher content of Fe may be due to the comparatively higher availability of the metal in the sediments and field water of the Vembanad wetlands (Table 1). Similarly, higher content of Al and Mn may also be attributed to the higher concentration of these metals in its habitat. Bio accumulation of these metals has further contributed to the present level in *E. crassipes*.

Tissue wise, concentration of Cu (55.5%) and Zn (55.8%) in the root was evident, while almost 93% of Cr and As were present in the stem + petiole portion. Pb, Hg, and Ni also followed the same trend of higher concentration in the stem + petiole portion. However, Cd revealed to be located differently with 39.5% in leaf lamina, 22.9% in the stem + petiole and the rest in the roots. Among the heavy metals, Cd, Pb and Ni content in the samples were below the safe limits, while that of Cu, Cr and Zn were above the prescribed threshold, revealing the potential of the plant to absorb higher quantities of these heavy metals. Though *E. crassipes* was reported to be an indicator plant of the level of contamination of the water bodies, in the present investigation, the content of all the heavy metals studied were not in proportion to its availability in the lake water (Table 1). While Cd, Pb and Ni concentration in the lake water was higher than Cu and Zn, their content in *E. crassipes* were lesser than Cu, Cr and Zn. This may be due to the differential response of *E. crassipes* to dissolved metals in the growing media. The higher uptake of Cu and Zn might be due to their nutritional role in plants

Table 1. Heavy metal in sediments and lake water in the Vembanad lake during 2010-2012

	Zn	Cu	Mn	Fe	Al	Pb	Ni	Cd	Cr
Sediments (mg/kg)	0.64 -26.21	0.00-4.30	0.19-462.90	210-7581	0.00-222	84-102	34.8-45.4	3.90-7.90	6.90-13.2
Water (mg/l)	0.0-0.05	0.00-0.03	0.00-0.92	0.00-5.78	0.0-2.0	0.14-0.20	0.05-0.70	0.04-0.05	0.31-0.42

Table 2. Composition of heavy metals in water different parts of water hyacinth (mg/kg)

Plant part	Ca	Mg	Al	Cu	Zn	Fe	Mn	Pb	Cr	Hg	As	Cd	Ni
Leaf lamina	3310	1834	1134	33.73	20.9	4248	1095	0.04	1.54	0.094	0.45	0.019	0.021
Stem+petiole	3420.6	1572	1003	32.73	81.3	4961	1463	1.18	65.90	0.229	14.76	0.011	0.083
Root	123.1	1419	37090	82.93	129.0	89906	1762	0.36	2.66	0.130	0.62	0.018	0.043
Mean	2284	1608	13075	49.80	77.0	33038	1440	0.53	23.37	0.151	5.28	0.016	0.049

as essential nutrients. The Cr content in *E. crassipes*plants were higher than Ni and Cd, which can be attributed to its higher concentration in the lake water (Table 1 and 2)

Quality of compost

The *Eichhornia crassipes* aerobic (EC) and *Eichhornia* vermi composts (EVC) were comparable to farmyard waste compost (FMC) in pH, EC, moisture, nitrogen, organic carbon and C: N ratio (Table 3). Total potash was 46% and 28% higher in EVC and EC, respectively compared to FMC. The higher content of potash was due to the elevated level of K in raw *E. crassipes*. Among micronutrients, Cu was available almost equally in all the three forms of composts. Zn content in all forms of composts were considerably higher than Cu. The availability of Zn on the other hand was highest in EC followed by EVC and FMC. Fe and Mn content were considerably higher in EVC than the other two forms of composts. The present findings were in confirmation with that of Waturu (2011). The difference in the composting process might have contributed to the variation in Fe content between the *E. crassipes* based composts.

Among heavy metals, Cr content in both EC and EVC were considerably high. This has been contributed by the higher content of Cr in *E. crassipes* plants (Table 2). It was interesting to note that the content of the heavy metals Pb, As, and Ni were considerably high in FMC than EC and EVC, while the Cd content in FMC was considerably less compared to the ten fold higher content in EC. The As content in *E. crassipes* composts were considerably less compared to the high concentration of this heavy metal in *E. crassipes* plants. The favourable physico chemical characteristics other than the higher Fe and Mn content and lesser heavy metal concentration indicate the suitability of *E. crassipes* composts for crop production. Montoya *et al.* (2012) also reported the suitability of *Eichhornia* biomass for producing quality compost suitable for horticultural crops.

Physico-chemical properties of potting mixture

Significant variation in the physico-chemical properties of the potting mixture (Table-3) could be observed ($P < 0.05$) due to the treatments. FMC and EVC improved the pH of the soil and were significantly superior to the other treatments, which in their turn were at par with each other. Organic carbon and phosphorus content were, however, significantly higher for FMC while the other treatments were at par. The beneficial effect of farm yard manure on physico-chemical and biological properties of soil is an established fact. The higher nitrogen content in FMC and the improved biological properties might have enhanced the organic carbon and available P_2O_5 content of the soil. Potassium was significantly higher for EVC treated soil. This may be attributed to the higher content of potassium in *E. crassipes* based composts. Calcium content was higher in EVC and FMC treated soils, which were at par and significantly superior to soil treated with EC. Iron content in both types of *E. crassipes* composts was significantly higher than the other treatments with significantly lesser Fe in EC than EVC. Among micronutrients all the three composts forms had significantly higher copper content than the control. The over all picture indicated that the soils treated with *Eichhornia* vermi composts (EVC) were equally good as that of the FMC as far as most of the soil physico-chemical properties studied except the higher Fe, Mn content and lesser OC, and available P in EVC.

Yield of *Amaranthus*

The initial harvest of fresh weight of *Amaranthus* indicated significantly higher ($p<0.01$) yields in EC than EVC and no manure control which was at par with FMC.

Table 3. Physico–chemical properties of composts

Parameter	*Eichhornia* compost	*Eichhornia* vermi compost	Farmyard waste compost
pH	6.8	6.8	6.8
EC (dS/m)	0.02	0.02	0.02
Moisture (%)	14.0	15.3	13.4
Nitrogen (%)	2.9	2.8	3.2
Organic carbon (%)	41.4	37.6	41.4
C:N ratio	14.2	13.2	13.1
Total potash (K_2O %)	1.4	1.6	1.1
Total phosphates (P_2O_5 %)	2.72	2.7	2.5
Copper (Cu mg/kg)	63.4	60.7	68.1
Zinc (Zn mg/kg)	180.3	142.0	126.2
Iron (Fe mg/kg)	1405.8	12576.5	7936.8
Manganese (Mn mg/kg)	1041.6	1064.1	541.4
Lead (Pb mg/kg)	0.26	0.20	0.35
Chromium(Cr mg/kg)	20.0	21.5	4.93
Mercury (Hg mg/kg)	0.24	0.20	0.23
Arsenic (As mg/kg)	0.84	0.53	1.75
Cadmium (Cd mg/kg)	0.05	0.02	0.01
Nickel (Ni mg/kg)	0.05	0.04	0.07

The dry weight during the first harvest however, did not differ among the composts. Fresh weight and dry weight corresponding to second harvest and total yield, confirmed the superiority of FMC over *E. crassipes* composts. Among *E. crassipes* composts, aerobic compost (EC) had significantly higher fresh biomass yield than EVC (Table 4). However this superiority was not reflected on the corresponding dry weight. The higher yields from FMC may be due to better soil reaction, higher organic carbon content and other nutrients. The lesser Fe in the soil treated with FMC might also have contributed to the higher yields (Table 3). Similarly the higher content of Fe in EC might be the major yield limiting factor. The role of higher concentration of Fe as a yield limiting factor has been reported by Bridgit (1999). The low yield from *Eichhornia* composts treatments might be due to the higher content of Fe in its composts (Table 3).

Mineral composition of *Amaranthus*

Both the forms of *E. crassipes* composts significantly ($P<0.05$) increased the Ca content of *Amaranthus* (Table 5). EVC and EC recorded 60 and 46% higher Ca content, respectively than FMC. The variation in Ca content might be brought about by differential availability of Ca from the compost sources. However, the uptake of Mg was not seen influenced by the different nutrient sources. Among the micro nutrients differential response could be seen with respect to Fe, Mn, Zn and Cu. Fe content in *Amaranthus* was the highest for FMC which however, was at par with EVC and control treatment. Fe content between the two forms of *Eichhornia* composts , varied significantly with the higher content for EVC than EC. This may be due to the higher Fe content in EVC (Table 3) than EC. The antagonism between Fe and Ni may be another factor that contributed to lesser Fe content in EC than the other treatments. The Ni content of the latter was significantly higher than the former (Table 5).

Shreyakova *et al.* (2011) attributed reduced Fe uptake in *Amaranthus* on account of antagonism between Fe and Ni. Though there was no significant variation due to composts, the Cu content in *Amaranthus* was 4 to 5 fold higher than Zn in the compost treatments. Enhanced uptake of Cu by *Amaranthus* and its utility as a phyto extractor of Cu from industrial soil was reported by Rahman *et al.* (2013). In the present study the effect of the treatments on Zn content in *Amaranthus* was significant ($P<0.05$). The control treatment had the highest Zn content which was 157 % higher than EVC which had the next highest Zn content. The decreased Zn content in the compost treated *Amaranthus* may be due to antagonism between Zn and Cu which was an established fact

The heavy metals Pb, Hg and Cd content in *Amaranthus* did not show any variation due to the treatments. The highest values for Pb (0.445 mg/kg for EVC), Cd (0.022 mg/kg for EC) and Hg (0.055 mg/kg for control) in *Amaranthus* plants were well with in the safe limit prescribed by the Indian Standards (Awashthi 2000). Among the other heavy metals, differential response to Cr, As and Ni were evident as revealed by significantly ($P<0.01$) higher concentration of these metals in *Amaranthus*. Cr content was the highest in EVC, which was at par with all the other forms of composts and superior to no manure control. Though the Cr content in *E. crassipes* composts were high (Table 3), the same was substantially less in FMC. Since Cr content in *Amaranthus* treated with all the three forms of composts did not vary significantly it is inferred that the manure sources didn't influence the Cr content. The availability of all essential nutrients in the desired level in the composts and the consequent synergetic action might have contributed to the elevated Cr status in *Amaranthus*. Shreyakova *et al.* (2011) also reported enhanced heavy metal uptake of *Amaranthus* when industrial soils were treated with fertilizer nitrogen.

The As content in *Amaranthus* was the highest for EC with significantly lower content for the other two forms of composts. Since the control treatment enjoyed significant higher content of As than EVC, the possibility of

Table 4. Physico-chemical properties of soil treated with different composts

Treatment	pH	EC dS/m	OC (%)	P_2O_5 (mg/kg)	K_2O (mg/kg)	Ca (ppm)	Mg (ppm)	S (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
EC	5.87^{b*}	0.15	0.72^{b}	80.1^{c}	327.7^{c}	409.2^{b}	8.8	99.9	114.2^{a}	104.3^{b}	1.96	8.72^{a}
EVC	6.32^{a}	0.027	0.99^{b}	129.9^{b}	493.2^{a}	426.0^{a}	8.7	143.4	93.6^{b}	148.7^{a}	2.62	11.90^{a}
FMC	6.45^{a}	0.185	1.89^{a}	171.4^{a}	424.1^{a}	428.2^{a}	9.0	103.7	2.2^{c}	106.9^{b}	2.19	11.01^{a}
Control	5.73^{b}	0.457	0.74^{b}	87.9^{c}	226.1^{c}	368.2^{c}	8.6	149.8	1.7^{c}	65.5^{c}	1.66	3.31^{b}
LSD (P=0.05)	0.362	NS	0.545	27.81	138.84	3.286	NS	NS	16.46	32.84	NS	4.305

*Values followed by the same alphabet do not differ significantly, EC - *Eichhornia crassipes,* EVC - *E. crassipes* vermicompost, FMC Farmyard waste compost

Table 5. Biomass yield of *Amaranthus* (g/plot)

Treatment	20 days after planting		40 days after planting		Total	
	Fresh weight	Dry weight	Fresh weight	Dry weight	Fresh weight	Dry weight
EC	41.25^{a*}	3.55^{a}	49.15^{b}	4.88^{b}	90.40^{b}	8.43^{b}
EVC	20.23^{b}	2.83^{a}	23.53^{b}	2.40^{b}	43.76^{c}	5.23^{bc}
FMC	32.96^{ab}	3.20^{a}	86.76^{a}	9.17^{a}	119.72^{a}	12.37^{a}
Control	10.25^{c}	1.12^{b}	18.0^{b}	1.98^{b}	28.25^{c}	3.1^{c}
LSD (P=0.05)	16.54	2.03	31.38	3.55	27.92	3.58

*Values followed by the same alphabet do not differ significantly

Eichhornia as the source of As can be ruled out. Similarly the As content in raw *E. crassipes* (Table 2) and in its composts were considerably higher than in the *Amaranthus* plants and hence transfer of As from *E. crassipes* and its biomagnification is a very distant possibility. Ni content was also the highest for EC which was significantly superior to the other two forms of composts. Similar to As, the Ni content in *Amaranthus* was very much less than the *E. crassipes* plant tissues and its composts. Hence the transfer of Ni to *Amaranthus* plants beyond the permissible limit did not taken place. The content of all the heavy metals in *Amaranthus* studied were well with in the permissible limit prescribed by Indian/WHO Standards.

Table 6. Mineral composition of *Amaranthus* at 40 DAS (mg/kg)

Treatment	*Ca*	*Mg*	*Cu*	*Zn*	*Fe*	*Mn*	*Pb*	*Cr*	*Hg*	*As*	*Cd*	Ni
EC	3504^{a*}	1625	32.8	6.3^{b}	2079^{b}	188	0.150	1.053^{a}	0.053	0.020^{a}	0.022	0.0146^{a}
EVC	3870^{a}	1664	37.6	8.8^{b}	6594^{ab}	303	0.445	1.249^{a}	0.053	0.002^{c}	0.013	0.0009^{b}
FMC	2404^{b}	1551	36.5	7.2^{b}	7545^{a}	147	0.179	1.059^{a}	0.024	0.001^{c}	0.011	0.0009^{b}
Control	2548^{b}	1490	27.3	22.6^{a}	4686^{ab}	192	0.101	0.538^{b}	0.055	0.009^{b}	0.006	0.0005^{b}
LSD (P=0.05)	956.6	NS	NS	8.9	4622	NS	NS	0.374	NS	0.007	NS	0.0005

*Values followed by the same alphabet do not differ significantly

Water hyacinth absorbed very high levels of dissolved plant nutrients and heavy metals from the Vembanad wetland system, which had dissolved plant nutrients and heavy metals in concentrations exceeding the prescribed safe limit. The pattern of heavy metal content in their abundance in *E. crassipes* resembled that of the concentration of the heavy metals in the lake water except that of Cu. The enormous quantities of plant nutrients and heavy metals accumulated by *E. crassipes* made it an ideal aquatic macrophyte for scavenging mineral pollutants from water bodies. The large volume of biomass obtained from *E. crassipes* could be converted as composts, comparable in quality with farm yard waste compost. *E. crassipes* composts were of less Pb, As and Ni and almost similar Hg concentration and considerably higher Cr and Cd content than farm yard waste compost. Significant increase in yield of *Amaranthus*, a green leaf vegetable crop could be obtained by *E. crassipes* compost application compared to the control. The heavy metals Zn, Cu, Pb, Cr, Hg, As, Cd and Ni in *Amaranthus* were well below the safe limit prescribed by Indian/WHO standards. Thus the aquatic macrophyte, *E. crassipes* could be used as a phytoremedial agent capable of cleansing the water bodies off plant nutrients and heavy metals and the biomass generated could be converted to composts. *E. crassipes* composts were effective as organic manure source for production of green-leaved vegetables devoid of heavy metal contamination.

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Short communication

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Evaluation of herbicides alone and in combination for weed control in wheat

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Wheat is the world's most widely cultivated food crop. Average yield losses due to weeds are 20-30%, however, heavy infestation of the formidable weeds can inflict huge crop losses (Singh *et al*. 1999). Grassy weeds like *Phalaris minor* and *Avena ludoviaciana* are dominant in rice-wheat rotation in north west plain zone. Continuous use of a particular herbicide may develop resistance in weeds. Herbicide mixtures may be an alternative for management or delay of cross resistance development against these herbicides (Dhawan *et al*. 2009). Keeping in view the above facts, the present investigation was undertaken to test the performance of herbicides alone or in combination to control weeds in wheat.

A field experiment was conducted during 2011-12 on research farm of CCS Haryana Agricultural university, Hisar situated is at 29^0 10'N latitude and 75^0 46' E longitudes with an elevation of 215.2 m above the mean sea level. The soil of the experimental field was sandy loam in texture with 210 t/ha available N, 15.6 kg/ha available P, 410 t/ha available K, 0.34% organic carbon and soil pH of 8.3. The experiment was done with 14 treatments (Table 1). Wheat was sown on 7^{th} November 2011 with a row spacing of 20 cm in randomized block design with three replications. The herbicides were applied at 35 days after sowing using knapsack sprayer. In weed free treatment, weeds were removed as and when they appeared. The data on weeds was taken from 0.25 m^2 area. The data on crop growth parameters, yield attributes and yields were recorded as per standard parameters.

Among single herbicide application, metribuzin 210 g/ha resulted significantly lower population of *Phalaris minor* than application of clodinafop 60 g/ha, pinoxaden 40 g/ha and sulfosulfuron 25 g/ha because it controlled grassy weeds more efficiently. Singh *et al*. (2011) have also reported that metribuzin was effective in controlling grassy weeds in wheat. Among various combinations, the population of *P. minor* was minimum in sulfosulfuron + metribuzin 25 + 210 g/ha which might be due to synergistic effect of these herbicides in controlling grassy weeds particularly *P. minor*. Application of sulfosulfuron + metsulfuron 32 g/ha resulted in significantly lower plant population of *Phalaris minor* because of combined effect of sulsufuron + metsulfuron. Isoproturon + 2,4-D (1000 + 500 g/ha) application resulted in more number of *P. minor* plant as compared to other mixed herbicides application which might be due to resistance of *P. minor* to isoproturon (Table 1). Resistance of *P. minor* to isoproturon has already been established and reported by Malik and Singh (1995).

Initially up to 30 DAS, no significant difference in population of *Chenopodium album* was recorded because no herbicide treatments were imposed in different plots of the experiment. At 60 and 90 DAS, application of metribuzin 210 g/ha and sulfosulfuron 25 g/ha resulted in significantly less plant population of *Chenopodium album* than clodinafop 60g/ha and pinoxaden 40 g/ha (Table 2). Singh *et al*. (2005) also reported that alone application of sulfosulfuron 25 g/ha or metribuzin 210 g/ha provided reduction in density of broadleaf weeds. Application of sulfouslfuron + metribuzin 25 + 210 g/ha resulted in lower plant population of *C. album* at 60, 90, 120 DAS and at maturity which may be due to more control of broadleaf weeds by sulfosulfuron 25 g/ha and metribuzin 210 g/ha. These results are in conformity with Sharma (2012).

Weed control efficiency (WCE) was significantly higher with application of sulfosulfuron 25 g/ha among single application of herbicides. This may be due to better control of *C. album* (Table 3) which led to less dry matter accumulation by weeds. Application of sulfosulfuron + metsulfuron 32 g/ha resulted in 89.2% WCE which was at par with sulfosulfuron+metribuzin 25 + 210 g/ha may be due to more control of grassy and broadleaf weeds.

Number of spikes in single applied herbicides were not influenced significantly, however, sulfosulfuron applied 25 g/ha produced the higher number of spike which may be due to the better control of weeds by this herbicides as compared to metribuzin 210 g/ha, clodinafop 60 g/ha and pinoxaden 40 g/ha as evident from the lower weeds dry matter (Table 3) in this herbicide. Application of metribuzin 210 g/ha in combination with clodinafop 60

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g/ha, sulfosulfuron 25 g/ha and fenoxaprop 120 g/ha produced more number of spikes as compared to its alone application which was attributed to the superior control of weeds in herbicide mixtures as evident from the better weed control efficiency of herbicide mixtures. The positive effect of herbicide mixtures in controlling complex weed flora have also been reported by Singh *et al*. (2005).

Different herbicide treatments resulted in significantly higher 1000-grain weight as compared to weedy check but at par with weed free. This may be due to less competition for different resources in herbicide treatments being efficient in controlling weeds which resulted in more translocation of food from source to sink. Similar result had also been reported by Singh *et al*. (2012).

Herbicide mixture of metribuzin 210 g/ha with clodinafop 60 g/ha, pinoxaden 40 g/ha, sulfosulfuron 25 g/ha and fenoxaprop 120 g/ha resulted more straw yield of wheat, as compared to the alone application of metribuzin 210 g/ha. Application of mixed herbicides produced similar straw yield as compared to weed free. This may be due to non-significant difference in dry matter accumulation by wheat in herbicide mixture which resulted in non-significant different in straw yield.

Weed control treatments produced significantly higher grain yield as compared to weedy check. Sulfosulfuron 25 g/ha being significantly superior to alone application of metribuzin 210 g/ha, clodinafop 60 g/ha and pinoxaden 40 g/ha produced higher wheat grain yield,

Table 1. Effect of different weed control treatments on population (no./m^2) of *Phalaris minor* in wheat

Treatment	Dose (g/ha)	30 DAS	60 DAS	90 DAS	120 DAS	At maturity
Metribuzin	210	6.3(38.6)	1.8(2.3)	1.6(1.7)	1.5(1.4)	1.3(0.7)
Clodinafop	60	6.1(35.6)	3.3(2.3)	2.4(1.7)	1.9(10.7)	1.7(4.3)
Pinoxaden	40	6.2(37.3)	3.5(2.7)	2.4(1.3)	1.9(11.0)	1.7(4.7)
Sulfosulfuron	25	6.1(36.6)	4.3(18.0)	3.5(11.7)	2.9(7.7)	2.4(4.7)
Clodinafop + metribuzin	60+210	6.2(37.6)	2.9(7.3)	2.1(3.4)	1.8(2.4)	1.6(1.7)
Pinoxaden + metribuzin	40+210	6.0(35.0)	2.7(6.3)	2.1(3.4)	1.8(2.4)	1.6(1.7)
Sulfosulfuron + metribuzin	25+210	6.2(37.6)	2.2(3.6)	1.8(2.4)	1.3(1.0)	1.3(0.7)
Fenoxaprop + metribuzin	120+210	5.8(33.3)	2.6(6.0)	1.9(2.7)	1.6(1.7)	1.5(1.3)
Sulfosulfuron + metsulfuron	32	6.0(35.3)	2.1(3.4)	1.6(1.7)	1.3(0.7)	1.1(0.3)
Mesosulfuron + iodosulfuron	14.4	6.0(35.0)	2.2(4.0)	1.8(2.4)	1.6(1.7)	1.5(1.3)
Clodinafop + metsulfuron	60+4	6.4(40.3)	2.1(3.4)	1.7(2.0)	1.6(1.7)	1.5(1.3)
Isoproturon + 2,4-D	1000+500	6.2(38.0)	4.6(7.3)	3.5(4.7)	2.9(20.0)	2.4(11.3)
Weedy check		6.4(40.3)	5.7(32.0)	5.1(26.0)	4.9(23.6)	4.5(20.0)
Weed free		1.0(0.00)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)
LSD (P=0.05)		0.3	0.21	0.21	0.35	0.30

DAS - Days after sowing; Original data given in parentheses

Table 2. Effect on different weed control treatments on population (no./m^2) of *Chenopodium album* in wheat

Treatment	Dose (g/ha)	30 DAS	60 DAS	90 DAS	120 DAS	At maturity
Metribuzin	210	7.1(50.0)	2.9(18.7)	2.2(15.7)	1.8(8.0)	1.5(3.7)
Clodinafop	60	6.8(44.7)	5.4(28.0)	4.7(21.4)	4.2(17.4)	4.1(15.7)
Pinoxaden	40	6.9(47.7)	5.3(27.6)	4.6(20.7)	4.3(17.7)	4.0(15.3)
Sulfosulfuron	25	6.8(43.7)	2.9(2.3)	2.1(1.7)	1.8(7.3)	1.5(3.3)
Clodinafop + metribuzin	60+210	7.1(48.7)	2.6(1.70	1.8(0.7)	1.6(5.7)	1.3(2.3)
Pinoxaden + metribuzin	40+210	6.8(44.7)	2.1(1.3)	1.6(0.7)	1.5(3.3)	1.3(1.7)
Sulfosulfuron + metribuzin	25+210	6.6(42.7)	2.1(1.0)	1.5(0.3)	1.4(3.3)	1.1(1.3)
Fenoxaprop + metribuzin	120+210	6.8(45.6)	2.9(1.7)	2.1(1.3)	1.6(7.3)	1.5(3.3)
Sulfosulfuron + metsulfuron	32	6.6(42.0)	2.2(1.3)	1.6(0.7)	1.5(3.7)	1.3(1.7)
Mesosulfuron + iodosulfuron	14.4	6.7(43.3)	3.1(1.7)	2.1(1.0)	1.6(8.3)	1.4(3.3)
Clodinafop + metsulfuron	60+4	6.7(43.7)	2.3(4.4)	1.6(1.7)	1.5(1.4)	1.4(1.0)
Isoproturon + 2,4-D	1000+500	7.1(49.3)	3.5(2.7)	2.5(1.7)	1.9(11.3)	1.6(5.3)
Weedy check		7.1(50.0)	6.7(30.7)	6.3(28.0)	5.6(44.3)	5.4(38.6)
Weed free		1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)	1.0(0.0)
LSD (P=0.05)		0.32	0.29	0.23	0.19	0.18

DAS - Days after sowing, Original data given in parentheses was subjected to square root $\sqrt{(x+1)}$ tansformation before analysis

Table 3. Effect of different weed control treatments on dry matter of *C. album* at different crop stages and weed control efficiency

Treatment	Dose (g/ha)	Dry matter (g/m^2)					Weed control efficiency (%)
		30 DAS	60 DAS	90 DAS	120 DAS	At maturity	
Metribuzin	210	4.0	17.8	28.1	43.3	47.8	70.5
Clodinafop	60	3.5	21.8	35.3	62.3	66.4	59.9
Pinoxaden	40	4.0	20.9	33.2	59.8	63.3	61.8
Sulfosulfuron	25	3.4	14.3	22.2	35.7	40.4	76.4
Clodinafop + metribuzin	60+210	4.1	8.4	12.4	20.5	28.3	82.9
Pinoxaden + metribuzin	40+210	3.9	7.8	10.3	18.2	26.1	84.2
Sulfosulfuron + metribuzin	25+210	3.8	6.2	9.5	17.1	23.3	85.9
Fenoxaprop + metribuzin	120+210	3.5	9.3	14.4	23.3	26.2	84.1
Sulfosulfuron + metsulfuron	32	3.8	6.0	8.3	14.4	17.7	89.2
Mesosulfuron + iodosulfuron	14.4	3.9	9.0	12.8	22.6	25.4	84.6
Clodinafop + metsulfuron	60+4	3.8	9.9	17.4	26.3	29.4	82.2
Isoproturon + 2,4-D	1000+500	3.4	9.6	15.3	25.3	28.3	82.9
Weedy check		3.8	45.2	85.6	134.5	166.5	0.0
Weed free		0.0	0.0	0.0	0.0	0.0	100.0
LSD (P=0.05)		NS	5.5	5.9	8.1	7.4	3.79

DAS - Days after sowing

Table 4 . Effects of different weed control treatments on yield attributes and yield of wheat

Treatment	Dose (g/ha)	Spikes/m^2	Grains/ spikes	1000-grain wt.(g)	Straw yield (t/ha)	Grain yield (t/ha)	HI (%)
Metribuzin	210	383	33.8	41.1	8.13	5.34	39.7
Clodinafop	60	376	32.5	41.6	7.73	5.08	39.7
Pinoxaden	40	378	34.2	41.1	7.70	5.19	40.3
Sulfosulfuron	25	402	34.1	41.5	8.33	5.70	40.7
Clodinafop + metribuzin	60+210	440	33.9	41.9	9.0	6.24	40.9
Pinoxaden + metribuzin	40+210	443	34.3	41.6	9.08	6.32	41.1
Sulfosulfuron + metribuzin	25+210	450	34.0	41.9	9.12	6.41	41.3
Fenoxaprop + metribuzin	120+210	432	34.0	41.8	9.07	6.16	40.5
Sulfosulfuron + metsulfuron	32	452	33.8	42.0	9.04	6.42	41.5
Mesosulfuron + iodosulfuron	14.4	435	34.0	41.9	8.91	6.19	41.0
Clodinafop + metsulfuron	60+4	422	34.6	41.3	8.75	6.04	40.8
Isoproturon + 2,4-D	1000+500	425	34.3	41.6	8.78	6.07	40.9
Weedy check		332	31.9	39.0	6.44	4.14	39.2
Weed free		453	33.8	42.2	9.03	6.46	41.7
LSD (P=0.05)		44	2.7	2.0	1.15	0.59	NS

which may be due to the better weed control as is evident from the higher WCE *i.e.* 76.4 as compared to other herbicides. Moreover, the number of spikes in this treatment was higher than metribuzin 210 g/ha, clodinafop 60 g/ha and pinoxaden 40 g/ha, which attributed to the higher yield in this treatment.

Ready mix application of sulfosulfuron + metsulfuron 32 g/ha produced the highest grain yield (6.42 t/ha) among different herbicide treatments but it was statistically at par with weedy free. Non-significant differences in number of spikes, grain number and 1000 grain weight of ready mix herbicides lead to non-significant variation in grain yield of wheat. Moreover, rapid growth of wheat plant efficiently utilized the resources in absence of weeds.

SUMMARY

Metribuzin alone 210 g/ha resulted in significantly lower population of *Phalaris minor* than alone application of clodinafop 60 g/ha, pinoxaden 40 g/ha and sulfosulfuron 25 g/ha. Application of sulfosulfuron + metsulfuron 32 g/ha and 25 + 210 g/ha resulted in significantly lower population of *P. minor* and *C. album*, respectively. Sulfosulfuron + metsulfuron 32 g/ha resulted

in 89.2% WCE which was at par with sulfosulfuron + metribuzin 25 + 210 g/ha. Weed control treatments produced significantly higher grain yield as compared to weedy check. Sulfosulfuron 25 g/ha being significantly superior to alone application of metribuzin 210 g/ha, clodinafop 60 g/ha and pinoxaden 40 g/ha produced higher wheat grain yield, which was evident from the higher WCE as compared to other herbicides. Ready-mix application of sulfosulfuron + metsulfuron at 32 g/ha produced the highest grain yield (6.42 t/ha) among different herbicide treatments but it was statistically at par with weed free.

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Effect of integrated weed management on seed yield of fodder maize

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Mostly fodder varieties of maize are shy-seeders and have low yield potential for seed. The seed production of fodder maize has much concern, because fodder varieties of maize are mostly bred for high vegetative growth and the crops are harvested before maturity of seeds.To meet the demand of seeds, it is imperative to develop suitable agro-techniques to enhance the seed production of forage maize. The season-long weed competition causes considerable yield losses in maize (Dalley *et al.* 2006). World-wide yield losses in maize due to weeds are estimated to be around 37% (Oerke and Dehne 2004). The predominant weed flora were *Echinochloa crusgalli* L. and *Cynodon dactylon* L. among monocots; *Cyperus rotundus* L. among sedges; and *Amaranthus viridis* L., *Digera arvensis* L., *Portulaca oleracea* L., *Alternenthara sessili* L. and *Trianthema* spp. among dicots (Arvadiya *et al* 2012). The infestation of these weeds were found increased in the maize growing belt of the state especially where the farmers were using atrazine year after year. So, tank mix combinations of two herbicides having different mode of action and integrated weed management practices for better weed control were investigated.

Field experiment was conducted at Research Farm, AICRP on Forage Crops, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh) during *Kharif*, 2012. The soil of the experimental field was sandy clay loam in texture, neutral in reaction (pH 7.2), and low in organic carbon (0.53%) as well as with low available N (232 kg/ha), medium in available P (17.2 kg/ha) and medium in available K (315 kg/ha) contents with normal electrical conductivity (0.32). Ten treatments consisted with pre-emergence application of atrazine 1.0 kg/ha, pendimethalin 1.0 kg/ha and alachlor 2.5 kg/ha alone and with hand weeding at 30 DAS, combined application of atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha and atrazine 0.75 kg/ha + alachlor 2.25 kg/ha, hand weeding twice at 20 and 40 DAS and weedy check were tested in a randomized block design with three replications. Sowing of maize cv. '*African Tall*' was sown on 13th July, 2012 by using seed rate 40 kg/ha in the rows 60 cm apart. A uniform dose of 80 kg/ha N + 40 kg P_2O_5 + 20 kg K_2O/ha was applied in all the plots. Half quantity of N as per treatment along with full quantity of P and K fertilizers were given as basal application at the time of sowing and remaining N was top-dressed at 25 DAS and 45 DAS. Various observations were recorded on weed parameters and crop parameters. In studies on intensity of weeds and dry matter accumulation by weeds were made species wise and transformed values were statistically analyzed at 60 DAS. Finally, the grain and stover yields were determined.

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The predominant weeds under monocot were *Echinochloa colona* (15.4%), *Digiteria sanguinalis* (13.1%), *Cyperus rotundus* (16.2%) and *Commelina communis* (14.0%). *Phyllanthus niruri* (14.4%) and *Eclipta alba* (13.6%) were prominent among dicot weeds. Many other minor weeds in small intensity (13.3%) were also present in maize ecosystem at 60 DAS stage.

The weed management practices significantly influenced the weed density and dry weight at 60 DAS (Table 1). In weedy check, the total weed population was significantly higher than all the herbicidal treatments atrazine 1.0 kg/ha, pendimethalin 1.0 kg/ha and alachlor 2.5 kg/ha including hand weeding at 30 DAS and weed free treatments. The weed menace was minimum under hand weeding done at 20 and 40 DAS, but it was marginal at 60 DAS due to emergence of weeds during later part of crops growth. Among the pre-emergence herbicides treatments, activity of atrazine 1.0 kg/ha, pendimethalin 1.0 kg/ha and alachlor 2.5 kg/ha alone was not well marked against most of weeds but when all these herbicide applied with integration of one hand weeding at 30 DAS and combined application of atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha and atrazine 0.75 kg/ha + alachlor 2.25 kg/ha, controlled most of the associated weeds. Weedy check had the highest weed biomass and it had reduced significantly when weeds were controlled either by use of herbicides or hand weeding (20 and 40 DAS). The lowest weed biomass was recorded under weed free treatment closely followed by atrazine 1.0 kg/ha + hand weeding at 30 DAS, alachlor 2.5 kg/ha + hand weeding, combined application of atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha and atrazine 1.0 kg/ha + alachlor 2.25 kg/ha, found significant to reduced the weed biomass over pre-emergence application of atrazine 1.0 kg/ha, pendimethalin 1.0 kg/ha and alachlor 2.5 kg/ha alone. Similar views were also endorsed by Mandal *et al.* (2004). The WCE was maximum with 2 hand weeding closely followed by alachlor 2.5 kg/ha + hand weeding at 30 DAS, atrazine 1.0 kg/ha + hand weeding at 30 DAS, combined application of atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha and atrazine 0.75 kg/ha + alachlor 2.25 kg/ha but lowest WCE found with pre-emergence application of atrazine 1.0 kg/ha, pendimethalin 1.0 kg/ha and alachlor 2.5 kg/ha alone. These results are in agreement with findings of Walia *et al.* (2007).

Seed and stover yields were lowest in the plots receiving no weed control measures (weedy check) due to severe competition stress right from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally the seed yield. All the treated plots receiving either manual weeding or herbicidal treatments and integration with hand weeding produced higher yield over weedy check plots (Table 2). The maximum seed and stover yields was noted in hand weeding at 20 and 40 DAS followed by atrazine 1.0 kg/ha + hand weed at 30 DAS than other treatments. The crop under weed free plots attained lush growth due to elimination of weeds from inter and intra row spaces besides better aeration due to manipulation of surface soil, which resulted into superior yield attributes and development, and consequently the highest yield. Malviya and Singh (2007) also reported that, hand weeding as an effective method of weed control for achieving the maximum yield. Maximum yield loss of 49.5% was recorded under weedy check where, weeds were not controlled in the entire crop season. The weed index was lowest (2.20) in plots receiving pre-emergence application of atrazine 1.0 kg/ha + hand weeding at 30 DAS followed by T_6 and T_5. The lower weed index values under aforesaid treat-

Table 1. Effect of different treatments on weed density and dry weight at 60 DAS in fodder maize

Treatment	*Echinochloa colona*		*Digiteria sanguinalis*		*Cyperus rotundus*		*Commelinacommunis*		*Phyllanthus niruri*		Others	
	Density /m²	Dry weight (g/m²)	Density /m²	Dry weight (g/m²)	Density /m²	Dry weight (g/m²)	Density /m²	Dry weight (g/m²)	Density /m²	Dry weight (g/m²)	Density /m²	Dry weight (g/m²)
T_1- Atrazine 1.0 kg/ha	3.45 (11.5)	4.14 (16.7)	3.22 (9.9)	4.19 (17.1)	3.50 (11.8)	4.18 (17.0)	3.46 (11.5)	4.19 (17.1)	3.66 (13.3)	4.19 (17.1)	3.47 (12.1)	4.22 (17.3)
T_2- Pendimethalin 1.0 kg/ha	4.18 (17.0)	4.81 (22.7)	3.87 (14.5)	4.86 (23.1)	4.18 (17.0)	4.85 (23.0)	4.10 (16.3)	4.85 (23.0)	4.13 (17.0)	4.85 (23.0)	3.97 (15.8)	4.88 (23.3)
T_3- Alachlor 2.5 kg/ha	3.67 (13.0)	4.38 (18.7)	3.45 (11.4)	4.40 (18.8)	3.72 (13.3)	4.41 (19.0)	3.67 (13.0)	4.43 (19.1)	3.79 (14.0)	4.43 (19.1)	3.61 (12.8)	4.45 (19.3)
T_4- Atrazine 1.0 kg/ha + hand weeding at 30 DAS	2.61 (6.3)	3.44 (11.3)	2.22 (4.4)	3.39 (11.0)	2.61 (6.3)	3.49 (11.7)	2.48 (5.7)	3.51 (11.8)	3.07 (9.6)	3.51 (11.8)	2.69 (8.0)	3.54 (12.1)
T_5- Pendimethalin 1.0 kg/ha+ Hand weeding at 30 DAS	2.91 (8.0)	3.85 (14.3)	2.58 (6.2)	3.81 (14.0)	3.03 (8.7)	3.89 (14.7)	2.92 (8.0)	3.90 (14.7)	3.22 (10.3)	3.90 (14.7)	2.88 (8.6)	3.94 (15.1)
T_6- Alachlor 2.5 kg/ha + hand weeding at 30 DAS	2.54 (6.0)	3.53 (12.0)	2.37 (5.1)	3.49 (11.7)	2.67 (6.7)	3.58 (12.3)	2.54 (6.0)	3.59 (12.4)	3.16 (10.0)	3.59 (12.4)	2.86 (8.5)	3.60 (12.5)
T_7- Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha tank mixed	2.97 (8.3)	4.02 (15.7)	2.81 (7.4)	4.00 (15.5)	3.34 (10.7)	4.06 (16.0)	3.05 (8.8)	4.07 (16.1)	3.22 (10.3)	4.07 (16.1)	2.99 (9.1)	4.07 (16.1)
T_8- Atrazine 0.75 kg/ha + alachlor 2.25 kg/ha tank mixed	3.08 (9.0)	3.89 (14.7)	2.60 (6.4)	3.87 (14.5)	3.13 (9.3)	3.94 (15.0)	3.08 (9.0)	3.94 (15.1)	3.24 (10.6)	3.94 (15.1)	3.01 (9.5)	3.94 (15.0)
T_9- Hand weeding at 20 and 40 DAS	2.48 (5.7)	3.29 (10.3)	2.06 (3.7)	3.29 (10.3)	2.54 (6.0)	3.39 (11.0)	2.41 (5.3)	3.39 (11.0)	0.88 (0.3)	3.39 (11.0)	0.79 (0.1)	3.19 (9.7)
T_{10}- Weedy check	5.67 (31.7)	7.62 (57.6)	5.24 (27.0)	7.85 (57.0)	5.81 (33.3)	7.69 (58.6)	5.40 (28.7)	7.67 (58.3)	5.49 (29.7)	7.67 (58.3)	5.27 (27.3)	7.54 (56.3)
LSD (P=0.05)	0.29	0.21	0.35	0.23	0.33	0.21	0.28	0.20	0.75	0.20	0.97	0.23

Original values are given in parentheses

Table 2. Effect of different treatments on yield, WCE and economics in fodder maize

Treatment	Cob length (cm)	Cob weight (g)	Cob girth (cm)	Seeds/ cob	Seed index	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Weed index (%)	WCE (%) at 60 DAS	Gross monetary returns (x10^{3}` /ha)	Net monetary returns (x10^{3}` /ha)	B:C ratio
T_1	14.6	130.3	3.70	323.0	25.2	1.76	13.38	11.6	21.7	70.5	37.42	14.38	1.62
T_2	14.4	125.8	3.60	278.7	25.3	1.71	12.94	11.7	23.7	60.3	36.34	13.26	1.57
T_3	14.2	128.3	3.70	320.0	25.3	1.74	13.25	11.6	22.3	67.2	37.09	13.58	1.58
T_4	16.3	142.6	3.90	331.0	26.2	2.20	13.83	13.7	2.2	80.1	43.14	16.35	1.61
T_5	14.8	137.7	3.80	326.0	26.7	1.95	13.63	12.5	13.2	74.7	39.99	13.15	1.49
T_6	15.2	139.0	3.90	329.0	26.0	2.08	13.72	13.2	7.2	79.0	41.69	14.43	1.52
T_7	14.6	136.0	3.70	324.0	26.1	1.93	13.43	12.6	14.2	72.5	39.47	16.20	1.69
T_8	14.7	135.0	3.70	324.7	26.0	2.02	13.54	13.0	9.9	74.1	40.75	17.02	1.71
T_9	17.5	145.0	3.90	332.3	26.7	2.25	14.09	13.8	0.0	81.9	44.05	13.91	1.46
T_{10}	14.0	120.5	3.60	228.0	25.5	1.13	12.03	8.6	49.5	0.0	28.39	5.75	1.25
LSD (P=0.05)	1.1	3.8	0.25	2.3	NS	0.20	0.15	0.4	-	0.8	-	-	-

Treatment details are given in Table 1.

ments are attributed to the reduced competitional stress by weed. Therefore, the yield attributes in crop were superior which ultimately resulted into increased seed yield. Weed free treatment received two hand weeding required maximum investment (₹ 30,083/ha) to control weeds while expenditure incurred under pre-emergence application of atrazine 1.0 kg/ha, pendimethalin 1.0 kg/ha and alachlor 2.5 kg/ha ranged from (₹ 22,983 to 23,458/ha), indicating that control of weed through hand weeding was more expensive than the use of herbicides in maize. Maximum gross returns (₹ 44,054/ha) was obtained under weed free treatment closely followed by T_4 -atrazine 1.0 kg/ha + hand weeding (₹ 43,140/ha) and T_6 -alachlor 2.5 kg/ha + hand weeding (₹ 41,699/ha). Though GMR was maximum in weed free treatments, but the net monetary returns and B:C ratio were also the highest under combined application of atrazine 0.75 kg/ha + alachlor 2.25 kg/ha closely followed by atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha and atrazine 1.0 kg/ha + hand weeding at 30 DAS, respectively.

SUMMARY

A field experiment was conducted at Research Farm, JNKVV, Jabalpur, Madhya Pradesh during *Kharif* 2012 to see the effect of integrated weed management on growth, development and seed yield of fodder maize. The lowest weed density and weed biomass was recorded under weed free treatment closely followed by atrazine 1.0 kg/ha + hand weeding. All the treated plots receiving either manual weeding or herbicidal treatments and integration with hand weeding produced higher yield over weedy check plots. The maximum seed and stover yields were noted in hand weeding at 20 and 40 DAS followed by atrazine 1.0 kg/ha + hand weed at 30 DAS. The B: C ratio (1.71) was higher in the tank mixed application of atrazine 0 .75 kg/ha + alachlor 2.25 kg/ha.

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Short communication

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Comparative efficacy of different herbicides in summer pearlmillet

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Key words: Pearlmillet, Herbicide, Weed control efficiency

Pearlmillet (*Pennisetum glaucam* L.) is one of the major coarse grain crops and is considered to be a poor man's food. Weed management in pearl millet during early growth period of crop is most important. On an average, 55% yield reduction due to heavy weed infestation in pearl millet was observed by Banga *et al*. (2000). The predominant methods of weed management are inter-culturing and hand weeding in pearlmillet crop. The use of herbicides has revolutionized weed management and reduces the cost of cultivation. therefore integrated approach for weed management using chemical and manual methods were evaluated for weed management pearlmillet.

A field experiment was conducted during summer season of the year 2012-13 at the farm of B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). The soil of the experimental area was loamy sand in texture, low in N (140 kg/ha), medium in available P (40 kg/ha) and high in available K (300 kg/ha) with slightly alkaline in reaction (pH 7.50). The experiment was laid out in randomized block design with four replications and with twelve treatments. Herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using 500 liter of water/ha. The weed count and dry weight of weeds were recorded at 20 and 40 DAS and at harvest.

Table 1. Effect of practices on density, dry weight and weed control efficiency

Treatment	Weed density (no./m^2)				Weed dry weight (g/m^2)				Weed index (%)	Weed control efficiency (%)	
	Dicot		Monocot		Dicot		Monocot				
	20 DAS	At harvest	20 DAS	At harvest	20 DAS	At harvest	20 DAS	At harvest		20 DAS	At harvest
Atrazine 1000 g/ha PE	4.16^{e} (17.00)	1.78^{e} (2.75)	6.60^{bc} (43.25)	5.19^{b} (26.50)	1.64^{e} (2.23)	1.34^{e} (1.33)	3.73^{de} (2.23)	2.41^{de} (5.38)	11.18	54.3	50.1
Atrazine 1000 g/ha PE *fb* HW at 30 DAS	4.05^{e} (16.00)	1.18^{f} (1.25)	5.33^{ef} (28.00)	2.72^{d} (7.00)	1.34^{f} (1.33)	1.05^{f} (0.48)	3.61^{e} (1.33)	1.83^{g} (2.88)	2.21	61.7	63.5
Atrazine 1000 g/ha10 DAS	4.23^{e} (17.50)	2.05^{de} (3.75)	6.95^{b} (48.00)	5.12^{b} (26.00)	1.66^{e} (2.30)	1.36^{e} (1.38)	4.99^{b} (2.30)	2.68^{d} (6.75)	11.93	40.8	45.5
Atrazine 1000 g/ha at 10 DAS *fb* HW at 30 DAS	4.10^{e} (16.50)	1.32^{e} (2.50)	6.54^{bc} (42.50)	3.19^{d} (9.75)	1.36^{f} (1.38)	1.03^{f} (0.63)	4.30^{c} (18.02)	1.85^{g} (2.95)	4.38	49.4	62.6
Oxyfluorfen 80 g/ha PE	8.35^{b} (69.50)	3.44b^{c} (11.50)	6.01^{cd} (35.75)	5.19^{b} (26.50)	3.56^{b} (12.25)	2.68^{b} (6.73)	4.15^{cd} (16.75)	3.38^{b} (10.95)	15.82	38.4	20.8
Oxyfluorfen 80 g/ha PE *fb* HW at 30 DAS	6.76^{cd} (45.50)	2.34^{d} (5.00)	4.26^{g} (18.00)	3.03^{d} (8.75)	2.81^{c} (7.45)	1.38^{e} (1.43)	3.74^{de} (13.62)	2.52^{d} (5.90)	7.51	47.4	48.1
Oxyfluorfen 100 g/ha PE	6.21^{d} (52.00)	3.23^{bc} (10.00)	5.72^{de} (32.50)	4.40^{c} (19.00)	3.34^{b} (10.73)	2.11^{d} (3.98)	3.52^{e} (11.97)	3.08^{c} (9.03)	14.68	45.4	31.7
Oxyfluorfen 100 g/ha PE *fb* HW at 30 DAS	6.51^{cd} (42.50)	1.85^{e} (3.00)	4.37^{g}(18. 75)	2.86^{d} (7.75)	2.57^{d} (6.15)	1.35^{e} (1.35)	3.48^{e} (11.65)	2.17^{ef} (4.23)	5.36	51.5	54.2
Pendimethalin 750 g/ha PE	6.71^{cd} (45.00)	3.56^{b} (12.25)	4.70^{fg} (21.75)	4.68^{bc} (21.50)	2.91^{c} (8.00)	2.29^{c} (4.83)	3.01^{f} (8.60)	3.31^{bc} (10.53)	24.55	53.1	26.2
Pendimethalin 750 g/ha PE *fb* HW at 30 DAS	7.19^{c} (52.00)	3.11^{c} (9.25)	4.27^{g} (18.00)	3.02^{d} (8.75)	2.87^{c} (7.80)	2.08^{d} (3.85)	2.67^{f} (7.80)	2.12^{f} (4.08)	16.23	56.1	46.0
Interculturing*fb* HW at 20 and 40 DAS	0.70^{f} (0.00)	0.70^{g} (0.00)	0.70^{h} (0.00)	0.07^{e} (0.00)	0.70^{g} (0.00)	0.70^{g} (0.00)	0.70^{g} (0.00)	0.07^{h} (0.00)	-	92.0	86.9
Weedy check	10.63^{a} (113.00)	5.37^{a} (28.50)	9.88^{a} (97.25)	8.64^{a} (74.25)	4.87^{a} (23.33)	3.64^{a} (12.78)	7.36^{a} (53.82)	4.23^{a} (17.43)	37.05	-	-
LSD (P=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.			

Figures in the parenthesis are original values. All figures are subjected to transformed values to square root ($\sqrt{x + 0.5}$). DAS- Days after sowing; *fb*- Followed by, Different alphabets dinote significant difference among treatments.

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Table 2. Effect of weed management practices on growth and yield attributing characters of pearl millet

Treatment	Initial Plant population (no./m row length)	Crop dry matter accumulation (g/plant)		Effective tillers/ plant	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Protein content (%)	Plant height at harvest (cm)	CBR
		30 DAS	At harvest							
Atrazine 1000 g/ha PE	10.37[a]	4.01[bcd]	33.66[abc]	4.02[bc]	11.05[bcd]	6.95[bcd]	18.20[ab]	10.32[de]	179[bc]	4.84
Atrazine 1000 g/ha PE *fb* HW at 30 DAS	10.50[a]	4.27[b]	35.72[ab]	4.35[b]	11.92[ab]	7.65[a]	18.97[ab]	11.48[ab]	181[bc]	5.04
Atrazine 1000 g/ha10 DAS	10.50[a]	3.99[bcde]	33.51[abc]	4.05[bc]	11.06[bcd]	6.88[bcd]	18.24[ab]	10.58[bcde]	185[ab]	4.81
Atrazine 1000 g/ha at 10 DAS *fb* HW at 30 DAS	10.25[a]	4.09[bc]	35.38[ab]	4.27[b]	11.30[abc]	7.53[ab]	18.45[ab]	11.40[abc]	189[ab]	4.92
Oxyfluorfen 80 g/ha PE	9.85[ab]	3.71[cde]	29.60[def]	3.85[bc]	10.43[cde]	6.58[d]	15.79[cde]	10.43[cde]	174[bc]	4.50
Oxyfluorfen 80 g/ha PE *fb* HW at 30 DAS	9.85[ab]	3.66[de]	32.62[bcd]	3.95[bc]	11.06[bcd]	7.23[abc]	17.05[bcd]	11.30[abc]	179[bc]	4.70
Oxyfluorfen 100 g/ha PE	9.77[ab]	3.65[de]	29.97[cde]	3.75[bc]	10.77[cde]	6.67[cd]	17.03[bcd]	11.18[abcd]	178[bc]	4.58
Oxyfluorfen 100 g/ha PE *fb* HW at 30 DAS	9.55[ab]	3.61[de]	33.20[abc]	4.25[b]	11.27[abc]	7.40[ab]	17.96[abc]	11.40[abc]	180[bc]	4.80
Pendimethalin 750 g/ha PE	6.60[c]	3.63[de]	27.65[ef]	3.80[bc]	10.25[de]	5.89[e]	15.13[de]	10.47[cde]	174[bc]	3.97
Pendimethalin 750 g/ha PE *fb* HW at 30 DAS	6.85[c]	3.65[de]	28.88[ef]	4.25[bc]	10.05[e]	6.55[d]	15.18[de]	11.10[abcd]	180[bc]	4.14
Interculturing *fb* HW at 20 and 40DAS	10.59[a]	4.85[a]	37.00[a]	5.55[a]	12.10[a]	7.81[a]	19.44[a]	11.72[a]	201[a]	5.01
Weedy check	10.50[a]	3.60[e]	26.08[f]	3.35[c]	9.89[e]	4.92[f]	14.27[e]	10.02[e]	164[c]	3.73
LSD (P=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Different alphabets dinote significant diffenrence among treatments.

Treatment of interculturing *fb* HW at 20 and 40 DAS recorded the lowest number of monocot and dicot weeds at 20 DAS and at harvest. Among the different chemical weed management practices atrazine 1000 g/ha PE *fb* HW at 30 DAS recorded minimum number of monocot and dicot weeds (Table 1). These results are in accordance with the Singh *et al*. (2001). Among different weed management practices, interculturing *fb* HW at 20 and 40 DAS recorded the lowest dry weight of monocot and dicot weeds at 20 DAS and at harvest. Application of atrazine 1000 g/ha PE *fb* HW at 30 DAS recorded lower monocot and dicot weed dry weight at different intervals followed by atrazine 1000 g/ha at 10 DAS *fb* HW at 30 DAS. The highest WCE and lowest weed index was registered under treatment of interculturing *fb* HW at 20 and 40 DAS. (Sharma and Jain 2003).

Plant height, crop dry matter accumulation/plant, effective tillers/plant, protein content recorded higher under treatment of interculturing *fb* HW at 20 and 40 DAS followed by atrazine 1000 g/ha PE *fb* HW at 30 DAS. Pendimethalin treated plots showed poor germination which might be due to the phytotoxic effect of herbicide. Further, interculturing *fb* HW at 20 and 40 DAS registered higher grain (7.82 t/ha) and stover yields (19.44 t/ha) which was closely followed by atrazine 1000 g/ha PE *fb* HW at 30 DAS (Table 2). While the highest Cost benefit : ratio (CBR) value was achieved under application of atrazine 1000 g/ha PE *fb* HW at 30 DAS. These results are in line with Kaur and Singh (2006).

SUMMARY

Among the different chemical weed management practices atrazine 1000 g/ha PE *fb* HW at 30 DAS recorded minimum number of monocot and dicot weed. Pendimethalin treated plots showed poor germination which might be due to the phytotoxic effect of herbicide. Further, interculturing *fb* HW at 20 and 40 DAS registered higher grain (7.82 t/ha) and stover yields (19.44 t/ha) which was closely followed by atrazine 1000 g/ha PE *fb* HW at 30 DAS

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Short communication

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Effect of post-emergence herbicides on growth and yield of soybean

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Key words: Chemical control, Herbicide mixture, Soybean, Weed management, Yield attributes

Soybean [*Glycine max* (L.) Merrill] is an important oilseed crop of the twentieth century. In India, it is cultivated in 9.60 million ha area with the annual production of 12.74 million tones. Madhya Pradesh contributes nearly 5.56 million ha and 6.67 million tones to the total area and production of soybean in the country, respectively (Anonymous 2011). Being a rainy season crop, it has high yielding capacity but weed infestation is one of the major constraints in the cultivation of soybean. It weeds, are not controlled during critical period of weed-crop competition, there is reduction in the yield of soybean from 35 to 50% depending upon the weed flora and density. Hand-weeding is a traditional and effective method of weed control, but untimely and continuous rains as well as unavailability of labour during peak period of demand, are the main limitations of manual weeding. Mostly, farmers are using pre-plant incorporated or pre-emergence herbicides for weed control in soybean, but their efficacy is reduced due to variation in climatic and edaphic factors. Therefore, need was felt to explore the possibility of post-emergence herbicides for effective control of weed.

An experiment was conducted at JNKVV, Jabalpur during *Kharif* 2008. The total rainfall received during crop period was 1380 mm. The maximum and minimum temperature was 38.6^{0}C and 33.6^{0}C, respectively. The soil of the experimental field was clay in texture, having pH 7.3, organic carbon 0.63% and low in available N (246 kg/ha), medium in P (16 kg/ha) and high in K (298 kg/ha). The experiment was laid out in randomized block design with three replications. The experiment consisted of ten treatments. All the herbicides were applied as post-emergence (PoE) *i.e.* 20 DAS by using a knapsack sprayer fitted with flat fan nozzle with volume of 600 l/ha water. The sowing was done on 16 July, 2008 at the rate of 70 kg/ha at 45 cm of row spacing and was harvested on 1 November, 2008. The recommended dose of N, P_2O_5 and K_2O (20, 80 and 20 kg/ha), respectively were applied as basal at the time of sowing. Before sowing, soybean seed (*'JS 93-05'*) were treated with Thiram 2.5 g/kg of seed followed by inoculation with rhizobium culture 5 g/kg of seed. Weed data on species wise weed density and dry weight were recorded at 40 DAS and at harvest using 0.25 m^2 quadrate randomly at two places in a plot. While observations on grain yield and yield attributing parameters, *viz*. pods/plant and seed/pods were recorded at harvest. The economics of treatment was computed with minimum support price or prevailing market rate of products. All the data were subjected to analyses with standard statistical procedure. The data of weed density and dry weight were subjected to square root transformation $\sqrt{x+0.5}$ before statistical analysis. Net assimilation rate (NAR) was calculated as per formula given.

Echinochloa colona (22.6 and 17.6%) was the most dominant weed followed by *Dinebra retroflexa* (18.7 and 18.8%) and *Cyprus iria* (17.0 and 16.5%) among the monocot weed at 40 DAS and harvest, respectively. Dicot weeds like *Eclipta alba* (22.3 and 24.7%) and *Alternanthera philoxeroides* (19.2 and 20.2%) (Fig.1) were less dominant in soybean ecosystem at 40 DAS and harest, resprctivly. The highest weed infestations were recorded in weedy check plot.

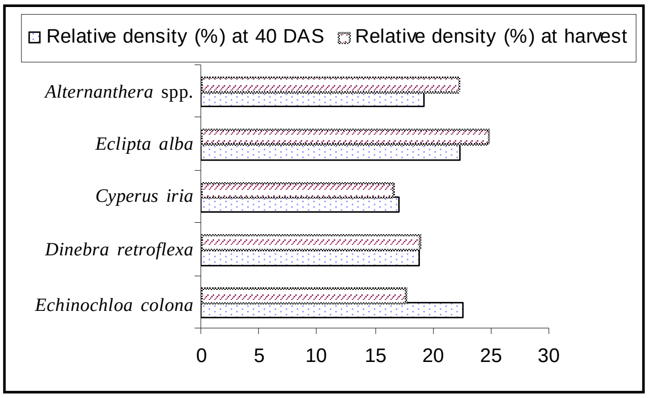

Fig. 1. Relative density of weeds at 40 DAS and harvest

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Application of quizalofop-p-ethyl at 37.5 g/ha marginally reduced density and dry weight of monocot weeds but result was more pronounced at higher rate (50 and 62.5 g/ha). Combined application of quizalofop-p-ethyl + chlorimuron (37.5 + 24 g/ha) effectively controlled both monocot and dicot weeds. The presence of quizalofop-p-ethyl molecule in non lethal concentration at the site of action could be the reason for poor activity of quizalofop-p-ethyl when applied at the lower rate (37.5 g/ha) but the reverse was true when it was applied at higher rate (50 and 62.5 g/ha) or when quizalofop-p-ethyl 37.5 g/ha was applied along with chlorimuron (24 g/ha). On the other hand, imazethapyr 75 g/ha and fenoxaprop-ethyl 100 g/ha caused more reduction in density and dry weight of monocot weeds. These results were in conformity with Jadhav (2013) (Table 1 and 2).

Two hand weeding (20 and 40 DAS) reduced the density and dry weight of weeds to the maximum extent over herbicidal treatments due to elimination of all sort of weeds. Similar views were endorsed by Pal *et al* (2013).

Crop biomass and NAR

Two hand weeding (20 and 40 DAS) gave significantly higher crop biomass (Table 3) as compared to other treatments and it was at par with quizalofop-p-ethyl + chlorimuron (37.5 + 24 g/ha). Application of imazethapyr 75 g/ha was comparable with quizalofop-p-ethyl + chlorimuron (37.5 + 24 g/ha) and significantly superior over weedy check in respect of crop biomass. These findings were in close agreement with Kelly *et al*. (1998). The higher crop biomass might be due to better weed control by herbicidal mixture. Whereas, lower rates of quizalofop-p-ethyl at (37.5 and 50 g/ha) were ineffective in curbing the weed menace and thereby produced inferior crop biomass. Application of different herbicides did not influence significant effect on net assimilation rate (NAR).

Yield attributes and yield

The yield and yield attributes, *viz.* pods/plant, seed yield and stover yield were recorded significantly higher under two hand weeding (20 and 40 DAS) as compared to other treatments (Table 3) due to elimination of weeds

Table 1. Effect of post-emergence herbicides on weed density (no./m^2) in soybean

Treatment	Rate (g/ha)	*Echinochloa colona*		*Eclipta alba*		*Dinebra retroflexa*		*Cyperus iria*		*Alternanthera philoxeroides*	
		40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest
Quizalofop-p-ethyl	37.5	5.04 (20.7)	3.16 (7.3)	5.18 (22.0)	5.18 (22.0)	4.97 (20.0)	3.84 (11.3)	4.39 (15.3)	3.41 (8.7)	5.11 (21.3)	5.11 (21.3)
Quizalofop-p-ethyl	50	4.41 (15.3)	2.65 (4.7)	4.88 (19.3)	4.88 (19.3)	3.75 (10.7)	2.93 (6.0)	3.44 (8.7)	2.65 (4.7)	5.04 (20.7)	5.04 (20.7)
Quizalofop-p-ethyl	62.5	3.94 (11.4)	2.58 (4.3)	4.74 (18.0)	4.74 (18.0)	3.08 (6.7)	2.65 (4.7)	2.93 (6.0)	1.74 (2.7)	4.81 (18.7)	4.81 (18.7)
Quizalofop-p-ethyl + vit-o-vit	37.5 +750	4.89 (19.3)	3.08 (6.7)	5.10 (21.3)	5.10 (21.3)	3.81 (11.3)	2.93 (6.0)	3.96 (12.0)	3.05 (6.7)	5.04 (20.7)	5.04 (20.7)
Fenoxaprop-ethyl	100	3.41 (8.7)	2.65 (4.7)	4.96 (20.0)	4.96 (20.0)	3.44 (8.7)	2.50 (4.0)	3.05 (6.7)	1.85 (2.7)	4.49 (16.0)	4.49 (16.0)
Imazethapyr	75	4.32 (14.7)	2.93 (6.0)	3.65 (10.0)	2.65 (4.7)	3.31 (8.0)	2.93 (6.0)	2.78 (5.3)	1.83 (2.7)	2.50 (4.0)	1.17 (1.3)
Imazaquin	93.75	5.66 (26.7)	5.66 (26.7)	3.96 (12.0)	2.80 (5.3)	5.79 (28.0)	5.91 (29.3)	5.72 (27.3)	5.72 (27.3)	3.44 (8.7)	2.50 (4.0)
Quizalofop-p-ethyl + chlorimuron	37.5 + 24	3.75 (10.7)	2.55 (4.3)	3.41 (8.6)	2.78 (5.3)	3.31 (8.0)	2.41 (3.6)	3.05 (6.7)	1.17 (1.3)	2.96 (6.2)	1.83 (2.7)
Hand weeding	20 and 40 DAS	0.70 (0.0)	2.50 (4.0)	0.70 (0.0)	2.60 (5.2)	0.70 (0.0)	2.93 (6.0)	0.70 (0.0)	2.93 (6.0)	0.70 (0.0)	2.93 (6.0)
Weedy check	-	7.28 (46.0)	7.43 (48.0)	6.92 (41.3)	7.03 (42.7)	7.13 (44.0)	7.43 (48.0)	7.13 (44.0)	7.38 (47.3)	6.15 (32.0)	6.50 (36.0)
LSD (P=0.05)		0.59	0.53	0.63	0.57	0.51	0.57	0.58	1.28	0.47	0.99

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

Table 2. Effect of post-emergence herbicides on weed dry weight (g/m^2) in soybean

Treatment	Rate (g/ha)	*Echinochloa colona*		*Eclipta alba*		*Dinebra retroflexa*		*Cyperus iria*		*Alternanthera philoxeroides*	
		40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest	40 DAS	Harvest
Quizalofop-p-ethyl	37.5	7.24 (45.6)	4.59 (17.5)	8.70 (67.5)	9.08 (73.7)	8.31 (61.2)	6.37 (35.9)	6.27 (33.7)	4.65 (17.7)	8.91 (70.8)	9.70 (85.0)
Quizalofop-p-ethyl	50	6.27 (33.4)	3.67 (10.1)	8.35 (61.8)	8.46 (63.6)	6.17 (32.3)	4.51 (16.2)	4.70 (17.8)	3.52 (9.1)	8.83 (69.5)	9.48 (80.9)
Quizalofop-p-ethyl	62.5	5.81 (28.4)	3.44 (8.6)	8.04 (57.1)	8.25 (60.1)	4.98 (20.2)	3.26 (11.4)	4.14 (13.4)	2.50 (6.0)	8.53 (64.5)	9.08 (73.9)
Quizalofop-p-ethyl + vit-o-vit	37.5 +750	6.83 (40.3)	4.23 (14.0)	8.63 (66.4)	8.73 (68.0)	6.36 (34.9)	5.56 (26.1)	5.63 (26.4)	4.12 (13.5)	8.81 (69.2)	9.44 (80.2)
Fenoxaprop-ethyl	100	4.79 (18.8)	3.31 (7.9)	8.38 (62.3)	8.51 (64.5)	4.26 (14.2)	2.29 (9.6)	4.31 (18.8)	2.37 (5.2)	7.88 (54.5)	8.50 (64.2)
Imazethapyr	75	6.16 (32.1)	3.98 (12.3)	6.10 (31.6)	4.11 (13.2)	5.48 (25.2)	4.94 (19.9)	3.83 (11.5)	1.46 (2.8)	5.01 (20.9)	3.03 (9.6)
Imazaquin	93.75	8.04 (57.0)	8.12 (58.2)	6.65 (38.0)	4.29 (14.4)	8.85 (70.0)	10.4 (99.7)	8.03 (56.8)	8.40 (62.6)	5.71 (27.3)	4.49 (16.0)
Quizalofop-p-ethyl + chlorimuron	37.5 + 24	5.43 (24.6)	3.87 (11.4)	5.71 (27.7)	4.31 (14.8)	5.42 (25.1)	5.28 (23.2)	4.09 (13.3)	2.33 (5.0)	4.22 (13.8)	2.86 (5.5)
Hand weeding	20 and 40 DAS	0.70 (0.0)	2.88 (5.7)	0.70 (0.0)	3.47 (8.9)	0.70 (0.0)	5.43 (24.7)	0.70 (0.0)	4.18 (13.8)	0.70 (0.0)	3.78 (10.9)
Weedy check	-	10.36 (97.4)	10.52 (100.6)	11.84 (128.7)	11.91 (130.3)	11.72 (125.9)	15.13 (214.1)	10.24 (94.9)	10.74 (104.9)	10.73 (105.)	11.77 (127.3)
LSD (P=0.05)		0.90	0.85	0.86	0.78	0.98	0.98	0.90	1.89	0.79	1.90

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

Table 3. Effect of post-emergence herbicides on yield attributes, yield and economic of soybean

Treatment	Rate (g/ha)	NAR (g/m^2/day) at 30-60DAS	Crop biomass (g/m^2)	Pods/ plant	Seeds/ pod	Seed yield (t/ha)	Stover yield (t/ha)	GMR (x10^3 `/ha)	NMR (x10^3 `/ha)
Quizalofop-p-ethyl	37.5	0.20	472.4	14.2	2.39	1.05	2.66	20.99	5.17
Quizalofop-p-ethyl	50	0.21	512.8	15.5	2.43	1.17	2.97	23.41	7.25
Quizalofop-p-ethyl	62.5	0.22	520.2	17.6	2.43	1.35	3.27	27.00	10.48
Quizalofop-p-ethyl + vit-o-vit	37.5 + 750	0.20	492.2	16.4	2.41	1.22	3.18	24.57	8.46
Fenoxaprop-ethyl	100	0.21	542.3	17.7	2.45	1.36	3.39	27.27	11.16
Imazethapyr	75	0.22	556.6	19.2	2.51	1.52	3.64	30.41	14.71
Imazaquin	93.75	0.19	454.3	14.0	2.41	1.01	2.58	20.23	4.53
Quizalofop-p-ethyl +chlorimuron	37.5 + 24	0.22	591.9	19.4	2.56	1.59	3.74	31.85	15.92
Hand weeding	20 & 40 DAS	0.23	609.9	21.0	2.65	1.87	4.31	37.36	15.59
Weedy check	-	0.17	315.8	12.0	2.28	0.81	2.11	16.09	1.33
LSD (P=0.05)		NS	42.1	0.9	NS	0.15	0.40	-	-

NAR: Net assimilation rate; GMR: Gross monetary returns; NMR: Net monetary returns from inter and intra row spaces besides better aeration due to manipulation of surface soil and thus, more space, water, light and nutrients were available for the better growth and development. Pal *et al.* (2013) also reported hand weeding as an effective method of weed control for achieving the maximum yield of soybean.

In herbicidal treatments, application of quizalofop-p-ethyl + chlorimuron (37.5 + 24 g/ha) and imazethapyr 75 g/ha were at par with each other and significantly superior to rest of other treatments in respect of pods/plant, seed and stover yield due to effectively control of monocot and dicot weeds. These results were in close agreement with the findings of Jadhav (2013). Kelly *et al*. (1998) reported that imazethapyr as post-emergence effectively controlled gassy as well as broad leaf weeds in soybean. Application of fenoxaprop 100 g/ha produced better pods/plant, seed and stover yield as compared to quizalofop-p-ethyl 62.5 g/ha because of relatively low competition stress and better yield attributes. Whereas, lower rates of quizalofop-p-ethyl at 37.5 and 50 g/ha were ineffective in controlling broad leaved weeds thereby produced lower yield attributes leads to lower seed yield. The seed yield was lowest in the plots receiving no weed control (weedy check) due to severe competition stress right from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally the minimum seed yield. The seeds/pod of soybean showed marked difference due to application of post-emergence herbicides.

Economics

The gross and net returns were minimum in weedy check because of lowest economic yield *i.e.* grain yield. The plots receiving combined application of quizalofop-p-ethyl (37.5 g/ha) + chlorimuron (24 g/ha) fetched the higher gross and net returns followed by imazethapyr 75 g/ha and fenoxaprop-ethyl 100 g/ha. However, the gross return was maximum under 2 Hand-weeding (20 and 40 DAS) but lowest net returns due to higher cost of manual labour for weeding.

SUMMARY

The field was mainly infested with monocot weeds like *Echinochloa colona, Dinebra retroflexa* and *Cyperus iria, w*hereas dicot weeds *Eclipta alba* and *Alternanthera philoxeroides* were less dominant in soybean. The application of quizalofop-p-ethyl 37.5 g/ha + chlorimuron 24 g/ha gave satisfactory control of weeds and it gave highest crop biomass (592 g/m^2), seed yield (1.59 t/ha) and net monetary returns (₹15,918/ha) followed by imazethapyr 75 g/ha which registered the crop biomass (557 g/m^2), seed yield (1.52 t/ha) and net monetary returns (₹14,712/ha). However, 2 hand weedings checked the weed growth and recorded significantly higher seed yield (1.87 t/ha) over rest of the treatments, but net monetary return (₹15,594/ha) were lower than application of quizalofop-p-ethyl 37.5 g/ha + chlorimuron 24 g/ha.

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Short communication

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

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Chickpea (*Cicer arietinum* L.) is one of the important grain legume of the world which is grown in 44 countries across five continents. India is the largest producer of chickpea accounting to 75% of the world production. The major chickpea growing states in India are Maharashtra, Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Rajasthan, Uttar Pradesh and Gujarat. It grows on a very light sandy loam to heavy textured clay soils. Chickpea can fix up to 140 kg N/ha in a growing period. Potential yield losses in chickpea due to weeds range from 22 - 100%. Bhalla *et al*. (1998) reported that herbicide treatment gave 50 - 64% weed control with an increase in yield. Weed growth was significantly reduced by the use of herbicides and resulted in 50% increase in yield over untreated fields (Hosseini *et al*. 1997). But after emergence of weeds, suitable post-emergence (POE) herbicide are not available. Keeping in view, the present experiment was designed to investigate the efficacy of different per-and post-emergence herbicides for broad-spectrum weed management and their effects on the growth and yield of the chickpea crop. Parasitic weed, *Cuscuta* was also becoming a problem in some parts of the country. There is urgent need to identify more effective herbicides with broad-spectrum of weed control and wider adaptability in chickpea (Singh and Sharma 2013).

An experiment was carried out at research farm of Junagarh Agricultural University, Junagadh located in south Saurashtra region of Gujarat during *Rabi* season 2012-13. This region receives an average rainfall of 680 mm with a variability of 61%. The average monthly temperature during the growing period in the experimental year was 33.0 °C, lower than climatic data of long-term period (33.5 °C). The soil was medium black clay having 252 kg/ha N, 97.3 kg/ha P, 319 kg/ha K, and 0.87% organic carbon. The experiment was laid out with nine treatment combinations in randomized block design with three replications (Table 1). Crop was grown in *Rabi* 2012-13 at 45×10 cm spacing having six rows of five meter row length. The net plot size was 4.0×1.8 m (7.2 m^2) at harvest time. Each plot had two rows at the beginning and at the end of the plot for protection which were removed before harvest.

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The dominant weed flora of the experimental field comprised of *Cyperus rotundus*, *Elurops vellosus*, *Eleusine indica*, *Dactyloctenium aegyptium* and *Asphodelus tenuifolius* among monocots. Among dicot, *Chenopodium album*, *Chenopodium murale*, *Melilotus indica*, *Boerhavia diffusa*, *Portulaca oleracia*, *Euphorbia hirta* and *Digera arvensis* were found dominant weeds.

Unweeded check plot produced significantly maximum weed density at all the stages except at 30 DAS (Table 1). At 30 days crop growth, application of pendimethalin (1.0 kg/ha) PE + HW at 25-30 DAS produced significantly maximum weed density (3.46 weeds/m^2) but remained at par with fenoxaprop-ethyl (60 g/ha) POE at 25-30 DAS (3.16 weeds/m^2) and unweeded check (3.07 weeds/m^2). Application of pendimethalin + imazethapyr 1.0 kg/ha PE recorded significantly lower weed density at 30 DAS (1.65 weeds/m^2), 60 DAS (1.44 weeds/m^2), 90 DAS (1.63 weeds/m^2) and at harvest (1.49 weeds/m^2). At 60 DAS, the same treatment was found significantly superior over all herbicide applications and one hand weeding in production of minimum weed density. However, one hand weeding was found inadequate for reducing the weed density. Application of pendimethalin + imazethapyr 1.0 kg/ha + one hand weeding at 30-35 DAS significantly produced minimum weed dry weight (38.0 kg/ha) which remained at par with fenoxaprop-ethyl (60 g/ha) as post-emergence at 25-30 DAS and pendimethalin + imazethapyr 2% 1.0 kg/ha P as PE at 30 days crop growth. At 60 days crop growth, the same treatment produced minimum weed dry weight (48.3 kg/ha). At harvest the minimum weed dry weight (50.3 kg/ha) was produced by one hand weeding which remained at par with application of oxyfluorfen 23.5% EC (0.25 kg/ha) as PE at 20 DAS + hoeing at 30-35 DAS, fenoxaprop-ethyl 10% EC (60 g/ha) as POE at 25-30 DAS, pendimethalin 30% EC + imazethapyr 2% 1.0 kg/ha as PE + hand weeding. Significantly the maximum weed dry

Table 1. Effect of weed management practices on density and dry weight of weeds

Treatment	Weed count* (m^2)				Weed dry weight (kg/ha)			
	30	60	90	Harvest	30	60	90	Harvest
Pendimethalin 30% EC (1.0 kg/ha) PE + HW at 25-30 DAS	2.55 (6.56)	1.93 (3.81)	1.60 (2.60)	1.70 (2.93)	98.1	94.0	73.3	91.7
Pendimethalin 38.7% CS (1.0 kg/ha) PE	2.60 (6.78)	2.05 (4.22)	1.76 (3.17)	1.90 (3.60)	113.7	106.0	100.7	104.0
Pendimethalin 38.7% CS (1.0 kg/ha) PE+ hoeing at 30-35 DAS	3.46 (12.04)	1.64 (2.71)	1.56 (2.43)	1.50 (2.27)	106.3	79.3	81.7	84.0
Oxyfluorfen 23.5% EC (0.25 kg/ha) PE at 20 DAS + hoeing at 30-35 DAS	2.40 (5.81)	1.92 (3.76)	1.94 (3.83)	1.77 (3.17)	89.3	55.3	61.7	67.7
Fenoxaprop-ethyl 10% EC (60 g/ha) POE at 25-30 DAS	3.16 (10.05)	2.20 (4.91)	1.84 (3.40)	2.07 (4.33)	42.8	46.2	54.7	63.7
Pendimethalin 30% EC + imazethapyr 2% (1.0 kg/ha) PE	1.65 (2.80)	1.44 (2.18)	1.63 (2.70)	1.49 (2.23)	44.7	61.0	47.3	55.0
Pendimethalin 30% EC + imazethapyr 2% (1.0 kg/ha) PE + hoeing at 30-35 DAS	1.97 (3.94)	1.94 (3.75)	1.80 (3.30)	1.76 (3.13)	38.0	48.3	51.7	55.7
One hand weeding at 30-35 DAS	2.38 (5.75)	1.95 (3.84)	1.82 (3.33)	2.00 (4.03)	74.0	62.0	47.7	50.3
Unweeded control	3.07 (9.50)	3.26 (10.66)	2.99 (8.92)	3.13 (9.84)	119.1	121.3	114.3	133.0
LSD (P=0.05)	0.52	0.46	0.40	0.33	35.0	24.2	31.1	26.8

***** Figures given in the parentheses are original means

weight was produced under unweeded control plot (133.0 kg/ha). Application of pendimethalin 30% EC + imazethapyr 2% 1.0 kg/ha with or without hand weeding gave good results on parameters of weed density and dry weight of weeds but found phytotoxic on chickpea.

At Ludhiana (north-west plain zone) and Kota (central zone) both fenoxaprop-ethyl and oxyfluorfen herbicides gave poor control of weeds and their application showed phytotoxic effect on germination of the chickpea crop (Anon. 2013) but at Junagadh both were found safer for chickpea. Application of pendimethalin 38.7% CS formulation was found at par with pendimethalin 30% EC formulation but slightly better over EC formulation at harvest in production of weed density and dry weight of weeds. This may be due to the longer herbicidal activity with CS formulated chemicals which control newly emerged weeds upto longer period. Singh and Sharma (2013) reported that pendimethalin is an effective pre-emergence herbicide (0.50-0.75 kg/ha) for control of annual broad-leaved and grassy weeds in chickpea. They also reported that application of oxyfluorfen (0.25 kg/ha) as pre-emergence is effective for managing broad-leaved weeds especially for *Medicago hispida* in central India.

The maximum herbicidal efficiency index (Table 2) was achieved under pendimethalin 38.7% CS (1.0 kg/ha) PE + hoeing at 30-35 DAS (100.9%) followed by pendimethalin 30% EC (1.0 kg/ha) as PE + HW at 25-30 DAS (96.5%) and oxyfluorfen 23.5% EC (0.25 kg/ha) as PE at 20 DAS + hoeing at 30-35 DAS. Pendimethalin 38.7% CS formulation when applied with one HW was found better compared to its EC formulation with one hoeing in herbicide efficiency index.

Application of different dosage of pre-and-post emergence herbicides influenced significant effect on number of branches/plant and pods/plant while on plant population and plant height, it was found non-significant (Table 2). Significantly maximum number of pods/plant (37.3) was produced with application of pendimethalin 30% EC (1.0 kg/ha) PE + HW at 25-30 DAS over unweeded control plot (24.3) and remained at par with all the treatments except application of fenoxaprop-ethyl 10% EC (60 g/ha) as POE at 25-30 DAS. Weeds in unweeded check reduced chickpea seed yield by 101.3% over the best treatment pendimethalin 38.7% CS as PE + hoeing at 30-35 DAS. Significantly maximum seed yield (1387 kg/ha) was recorded with application of pendimethalin 38.7% CS (1.0 kg/ha) PE + hoeing at 30-35 DAS over unweeded check (689 kg/ha) and remained at par with pendimethalin 30% EC (1.0 kg/ha) PE + HW at 25-30 DAS and oxyfluorfen 23.5% EC (0.25 kg/ha) PE at 20 DAS + hoeing at 30-35 DAS by producing 1356 and 1207 kg/ha seed yield of chickpea, respectively. The maximum straw yield (1511 kg/ha) was produced with application of pendimethalin 38.7% CS (1.0 kg/ha) PE + hoeing at 30-35 DAS and

Table 2. Effect of broad spectrum weed management practices on growth and yield of chickpea

Treatment	Plant stand ($x10^5$/ha)	Plant height (cm)	Branches/ plant	Pods/ plant	Seed yield (t/ha)	Straw yield (t/ha)	Herbicide efficiency index (HEI)
Pendimethalin 30% EC (1.0 kg/ha) PE + HW at 25-30 DAS	2.38	38.6	4.13	37.3	1.36	1.51	96.5
Pendimethalin 38.7% CS (1.0 kg/ha) PE	2.43	34.1	4.73	29.1	1.18	1.35	71.7
Pendimethalin 38.7% CS (1.0 kg/ha) PE+ hoeing at 30-35 DAS	2.42	38.5	4.20	33.7	1.39	1.45	100.9
Oxyfluorfen 23.5% EC (0.25 kg/ha) PE at 20 DAS + hoeing at 30-35 DAS	2.38	38.1	4.53	31.8	1.21	1.41	74.8
Fenoxaprop-ethyl 10% EC (60 g/ha) POE at 25-30 DAS	2.39	35.2	4.00	27.5	1.10	1.20	59.6
Pendimethalin 30% EC + imazethapyr 2% (1.0 kg/ha) PE	2.39	36.5	5.93	31.5	0.85	0.99	23.0
Pendimethalin 30% EC + imazethapyr 2% (1.0 kg/ha) PE + hoeing at 30-35 DAS	2.39	32.7	7.07	29.4	0.93	1.01	35.4
One hand weeding at 30-35 DAS	2.37	37.2	4.73	41.2	1.07	1.26	54.5
Unweeded control	2.40	32.6	3.80	24.2	0.69	0.82	-
LSD (P=0.05)	NS	NS	1.8	9.2	0.20	0.27	-

minimum with unweeded check (817 kg/ha). However, due to its phytotoxic effect on chickpea, application of pendimethalin + imazethapyr 1.0 kg/ha as PE without hand weeding reduced the straw yield significantly when compared with unweeded check.

Higher seed yield of chickpea under pendimethalin 38.7% CS (1.0 kg/ha) PE + hoeing at 30-35 DAS was due to better herbicidal efficiency index (100.9%) and less weed count throughout the growing season. Application of pendimethalin + imazethapyr1.0 kg/ha as PE proved phytotoxic with poor chickpea seed yield but results in enhanced branching in chickpea. However, results showed that one hand weeding gave more yield over unweeded control plot but was found inadequate for getting higher seed yield. Application pendimethalin 30% EC (1.0 kg/ha) PE + HW at 25-30 DAS and pendimethalin 38.7% CS (1.0 kg/ha) PE + hoeing at 30-35 DAS were found superior over one hand weeding during the investigation. Weedy situation prevailing throughout the crop period caused 54.7% reduction in yield of chickpea over one hand weeding. Hence, one hand weeding was found inadequate for getting higher chickpea seed yield under irrigated conditions of south Gujarat.

Pendimethalin 38.7% CS (1.0 kg/ha as PE) + 1 hoeing at 30-35 DAS was found best weed management practice and may be recommended for irrigated conditions for south Gujarat, however, application enhanced branching significantly but found phytotoxic in the chickpea.

SUMMARY

A field experiment was conducted at Junagadh during 2012-13 to evaluate bio-efficacy of pre-and post-emergence herbicides under irrigated conditions of south Gujarat (India). Significantly higher chickpea seed yield (1.39 g/ha) was recorded with application of pendimethalin 38.7% CS at 1.0 kg/ha as pre-emergence (PE) + 1 hoeing at 30-35 DAS and remained at par with pendimethalin (1.0 kg/ha) as PE + 1 HW at 25-30 DAS (1.36 g/ha) and oxyfluorfen 23.5% EC (0.25 kg/ha) as PE at 20 DAS + hoeing at 30-35 DAS (1.21 g/ha). Pre-application of pendimethalin 30% EC + imazethapyr 2% (Velor 32 at 1.0 kg/ha) significantly enhanced branching in chickpea but proved phytotoxic under south Gujarat conditions. One hand weeding was found inadequate for getting higher chickpea seed yield as weedy situation prevailing throughout the crop period caused 54.7% reduction in seed yield of chickpea.

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Short communication

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Persistence of imazethapyr residues in soybean and soil

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Imazethapyr belonging to imidazolinone group is a systemic pre-plant incorporated, pre-emergence and post emergence herbicide. Imazethapyr is mainly used in soybean, however, it is also used in crops like corn, oilseed rape and vegetables for control of many major annual and perennial grasses and broad-leaved weeds (Sondhia and Varshney 2010). It inhibits acetolactate synthatase (ALS), a key enzyme in the biosynthesis of the branched chain amino acids isoleucine, leucine and valine, leading to disruption of protein and DNA synthesis.

Microbial degradation and photodegradation have been suggested as major dissipation mechanism for imazethapyr (Stougaard *et al.* 1990). Imazethapyr incorporated in the soil persisted longer than imazethapyr applied to the soil surface (Patel *et al.* 2009). Hollaway *et al.* (2004) reported that 10% residues of applied imazethapyr persisted for 24 and 5 months after treatment in clay soil and sandy soil respectively. Soil pH affects its sorption-desorption, which in turn may affect its persistence and bioavailability

Venktesh *et al.* (2008) found post-emergence application of herbicide imazethapyr most effective in minimizing weed growth and enhancing the grain yield of soybean. At the recommended dose of herbicide application, generally the problem does not arise and it selectively kill the weeds. But when the dose is more than recommended rates due to indiscriminate use and improper calibration and method of application, there is possibility of residual hazards in soil and crop produced. Therefore an experiment was conducted to study the persistence of imazethapyr residues applied to soybean in soil, grain and straw of soybean.

A field experiment was conducted in *Kharif* 2006 at research farm, College of Agriculture, Gwalior in randomized block design with 14 treatments replicated thrice. The treatments consisted of recommended and double the recommended doses of imazethapyr, alachlor, pendimethalin, fenoxaprop, chlorimuron-ethyl and quizalofop with weedy check and weed free (two hand weeding). The experimental soil was sandy clay loam with 55.2% sand, 19.4% silt, 25.4% clay and 0.34% organic carbon, having 7.5 pH. The soil samples from the imazethapyr 200 g/ha (double the recommended dose) applied 20 days after sowing and control (weed free) plots were collected at 15, 30, 45, 60 and 75 days after herbicide application and after harvest of crop. The samples (0-15 cm depth) were bulked, air dried, powdered and passed through 2 mm sieve. The soybean grains and straw were sampled at harvest. The straw samples were cut in small pieces and air dried. The grain and straw samples were then ground in mechanical shaker. The residues of imazethapyr in soil, grain and straw samples were extracted and analysed by HPLC method as per Sondhia (2008), in residue laboratory of Directorate of Weed Science Research, Jabalpur.

The samples were extracted with 0.5 N NaOH solution for 1 h on a horizontal shaker. Methanol was added to the solution and shaken vigorously. The pH was adjusted to 2 with 6 N HCl and partitioned with methylene chloride. The lower methylene chloride layer was collected, dried on anhydrous Na_2SO_4, passed through activated charcoal and evaporated to dryness at 40^0C.

No clean up was required for soil samples. Soybean grains and straw sample extracts were cleaned on a glass adsorption column packed with a mixture of celite (1g) and activated charcoal (0.25 g) between anhydrous sodium sulfate (2 g) at each end. The concentrated extract was added to the top after pre-washing with methanol and eluted with methanol and water (60:40). Elutes were collected and solvent of elutes was evaporated to dryness at 40^0C. Finally residues were dissolved in 2 mL of methanol. lmazethapyr residues were analyzed on a Shimadzu high-performance liquid chromatography equipped with diode array detector at 250 nm using Phenomenex C-18 (ODS) column (250 x 4.6 mm). The mobile phase was mixture of methanol and water (70:30) at a flow rate of 0.8 mL/min. 20 µl of the aliquot of sample and standard was injected using micro syringe. The retention time of imazethapyr was found to be 3.5 minutes.

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The residue level of imazethapyr in soil, soybean grain and straw are presented. The concentration of imazethapyr in soil decreased with time and at harvest, residues were below the detectable limit. The residue level of imazethapyr in soil was found 0.017, 0.016, 0.015, 0.012 and 0.011 µg/g at 15, 30, 45, 60 and 75 days after herbicide application. At harvest the residue was below detectable limit. However the residue level of 0.082 and 0.023 µg/g were detected in soybean grains and straw, respectively which were below the maximum residue limit of 0.1 mg/kg (Anonymous 2006). Sondhia (2008) reported 0.008, 0.102 and 0.301 µg/g residues in post harvest soil, grains and straw of soybean crop respectively at 100g/ha application rate.

SUMMARY

A field experiment was conducted to study the persistence of imazethapyr applied to soybean in sandy clay loam soil. The herbicide was applied as post-emergence 20 days after sowing at 100 and 200 g/ha. The residue analysis of imazethpyr 200 g/ha applied as post-emergence 20 days after sowing was carried out in soil samples collected at 15, 30, 45, 60 and 75 days after application and in soil, grain and plant samples after harvest. The residue level of imazethapyr in soil was found 0.017, 0.016, 0.015, 0.012 and 0.011 µg/g at 15, 30, 45, 60 and 75 days after herbicide application. At harvest the residue was below detectable limit. However the residue level of 0.082 and 0.023 µg/g were detected in soybean grains and straw, respectively which were below the maximum residue limit

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