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Bioefficacy of penoxsulam against broad-spectrum weed control in transplanted rice

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ABSTRACT

Comparative efficacy of penoxsulam against weed control in transplanted rice was studied at Agricultural Research Station, Ummedganj, Kota (Rajasthan). The experiment was laid out in randomized block design with 7 treatments and 4 replications. Results revealed that the major weed flora associated with the transplanted rice were grasses like*Echinochloa colonum* and *Echinochloa crusgalli*; sedges like *Cyperus rotundus*, *Cyperus difformis* and *Cyperus iria*; and broad-leaved weeds like *Eclipta alba* and *Ammenia baccifera*. Penoxsulam at 0.0250 kg/ha applied at 0-5 days after transplanting was most effective to check all types of weed growth. This treatment also gave the maximum grain yield and straw yield, resulting in the lowest weed index, dry weight of weeds, weed persistence index and highest herbicidal efficiency index

Key words: Herbicide, Chemical control, Rice, Transplanted

In India, rice is the staple food for millions of people and plays a pivotal role in the economy. Weeds are regarded as one of the major limiting factors of crop production. Weeds share light, nutrients and water with the crop and thus interfere with rice growth in many ways. Living or decaying weeds can secrete toxic root exudates or leaf leachates that lower the normal growth of rice plant. Weed infestation provides a habitat for growth of various pest organisms (insects, nematodes and pathogens), which adversely affect the production of rice and other crops. The productivity of wet season rice is very low as weeds pose serious menace as compare to other rice ecosystems. This is because of aerobic soil conditions, high temperature and dry tillage practices. With the introduction of short-statured high-yielding rice varieties with erectophylic leaves, the weed menace becoming more acute (Mishra *et al.* 2006). The weed flora under transplanted condition is very much diverse and consists of grasses, sedges and broad leaf weeds causing yield reduction of rice up to 76% (Singh *et al*. 2004). The effective control of weeds at initial stages (0-40 DAT) can help in the improving productivity of this crop. Therefore, evaluation of new herbicides for wide spectrum control of weed flora is imperative. Recent trend of herbicide use is to find out an effective weed control measure by using low dose high efficiency herbicides which will not only reduce the total volume of herbicide use but also increase grain production (Kathiresan 2001). Therefore, the present study was undertaken to evaluate the performance of penoxsulam in transplanted *kharif* rice and associated weeds.

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* season of 2006 and 2007 at the Agriculture Research Station, Ummedganj, Kota (Rajasthan). The soil was clayey in texture, slightly alkaline in reaction (pH 7.5), low in organic C (0.56%) and medium in available N (278 kg/ha), P (12.3 kg/ha) and high in available K (305 kg/ha). The experiment was laid out in randomized block design with 7 treatments comprises of butachlor 1.5 kg/ha at 5-7 DAT, penoxsulam 0.0225 kg/ha at 0-5 DAT, penoxsulam 0.0250 kg/ha at 0-5 DAT, penoxsulam 0.0200 kg/ha at 8-12 DAT, penoxsulam 0.0225 kg/ha at 8-12 DAT, Weed-free check (where weeds were completely removed from the plot at 10 days interval until harvest), two hand weedings at 20 and 40 days after transplanting (DAT) and non weeded control replicated four times. Fertilizers were applied to the plots as N-P_2O_5-K_2O 150-60-40 kg/ha through urea, SSP, MOP respectively. The whole amount of P and K was applied as basal dose during final land preparation. N was top-dressed in three equal installments at 20, 40 and 55 DAT, respectively The variety '*PHB-71*' was used as the test crop. Thirty-day old rice seedlings were transplanted 20 cm x 10 cm apart on 29 July, 2006 and 25 July, 2007 at the seed rate of 25 kg in nursery for one hectare. Two sprays of monocrotophos 1 l/ha were applied as pro-

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phylactic measure against insects-pests. The crops were kept under constant observation from transplanting till harvesting. The data on weed infestation and weed density were collected from each unit plot at 30, 60, 90 DAT and at harvest. A quadrate of 0.25 m^2 was placed randomly at three different spots outside an area of 12 m^2 in the middle of the plot. The infesting species of weeds within each quadrate were identified and their number was counted species-wise. The average number of three samples was then multiplied by 4 to obtain the weed density per m^2. The weeds inside each quadrate were uprooted, cleaned. The collected weeds were first dried in the sun and then in an electric oven for 72 hours maintaining a constant temperature of 80°C. After drying, weight of weeds was taken and expressed in g/m^2. Weed control efficiency was calculated using standard formula. Results of both the years were analysed statistically and data which did not show the homogeneity hence were given individual year-wise least significant differences was used for means verification and for discussion of the results under probability level of 0.05.

RESULTS AND DISCUSSION

The major weeds observed in the experimental plots were grasses like *Echinochloa colona* and *Echinochloa crusgalli*, sedges like *Cyperus rotundus*, *Cyperus difformis* and *Cyperus iria*, and broad-leaved weeds like *Eclipta alba* and *Ammenia baccifera*.

The weed density was higher during 2007 than 2006. Density and biomass of weeds were significantly higher in non-weeded control treatment. In contrast, hand weeding (twice at 20 and 40 DAT) treatment recorded lower weed density (5 and 4/m^2) and biomass of weeds (3.15 and 3.7 g/m^2) than rest of the weed management practices (Table 1) respectively in both the years. Among the tested herbicides, penoxsulam 0.0250 kg/ha applied at 0-5 days after transplanting (DAT) was most effective to check all types of weeds and their growth resulting in lowest biomass (7.3 and 10.6 g/m^2) of weeds due to its higher weed control efficiency (59.8 and 76.0%) in both the years, respectively. Among the tested herbicides, penoxsulam at 0.0250 kg/ha applied at 0-5 days after transplanting (DAT) recorded highest herbicidal efficiency index (3.51 and 3.46) and lowest weed persistence index (0.01 and 0.01), respectively in both the years. The lower density and biomass of weeds were due to the fact that penoxsulam inhibited the plant enzyme acetolactate synthase (ALS), which was involved in biosynthesis of the branched-chain amino acids. The ALS compounds inhibit the production of the amino acids valine, leucine, and isoleucine in plants by binding to the ALS enzyme (Tranel and Wright 2002). Without these amino acids, protein synthesis and growth are inhibited, ultimately causing plant death (WSSA 2007).

Increasing rates of herbicides did not influence the weed density by markedly increase the dry matter of weeds (Table 2). Hand weeding twice showed the maximum control of weeds, which was significantly superior to other treatments. Weed control measures brought about measurable improvement in growth and yield attributes and yield of transplanted rice compared with the weedy check. Among all the herbicide treated plots produced grain and straw yields significantly more than the non-weeded plots. The highest grain yield of rice (6.4 and 6.2 t/ha) was obtained with hand weeding twice at 20 and 40 DAT and among the herbicide tested penoxsulam at 0.0250 kg/ha applied at 0-5 DAT gave significantly higher gain yield (6.1 and 5.8 t/ha) in both the years respectively. Similar trend of result was also found in case of straw yield of rice. Among different tested herbicides, lowest weed index (5.0-7.4%) was recorded with the application of penoxsulam at 0.0250 kg/ha (at 0-5 DAT) resulting in 36-41% increase

Table 1. Effect of penoxsulam on weed growth in transplanted rice

Treatment	Doses (kg/ha)	Weeds (no./m^2)		Dry weight of weeds (g/m^2)		Weed control efficiency (%)		Weed persistence index		Weed index (%)		Herbicide efficiency index	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Butachlor at 3-5 DAT	1.5000	12	21	9.5	20.3	56.7	65.1	0.02	0.05	9.4	12.3	2.25	1.49
Penoxsulam at 0-5 DAT	0.0225	18	25	14.8	23.8	49.1	61.0	0.05	0.07	13.1	14.3	1.18	1.15
Penoxsulam at 0-5 DAT	0.0250	10	9	7.3	10.6	59.8	76.0	0.01	0.01	5.0	7.4	3.51	3.46
Penoxsulam at 8-12 DAT	0.0200	35	45	26.6	43.3	32.3	38.9	0.16	0.24	23.0	23.6	0.28	0.35
Penoxsulam at 8-12 DAT	0.0225	22	29	18.3	25.8	44.2	58.8	0.07	0.09	17.4	16.6	0.72	0.94
Two hand weedings at 20 and 40 DAT	-	5	4	3.15	3.7	65.7	83.9	0.00	0.00	0.0	0.0	-	-
Weedy check	-	81	92	70.2	88.1	-	-	-	-	30.5	34.7	-	-
LSD (P=0.05)		2.6	3.0	5.44	2.9								

Table 2. Effect of penoxsulam on yield attributes and yield of transplanted rice

Treatment	Dose (kg/ha)	No. of panicles/m^2		Panicle weight (g)		Grain yield (t/ha)		Straw yield (t/ha)		Harvest Index (%)	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Butachlor at 3-5 DAT	1.5	275	257	3.63	3.50	5.85	5.48	7.94	7.47	42.4	42.3
Penoxsulam at 0-5 DAT	0.0225	266	251	3.51	3.46	5.61	5.35	7.91	7.21	41.5	42.6
Penoxsulam at 0-5 DAT	0.0250	284	276	3.74	3.71	6.13	5.79	8.64	8.29	41.5	41.1
Penoxsulam at 8-12 DAT	0.0200	250	232	3.32	3.30	4.97	4.77	7.09	6.81	41.2	41.2
Penoxsulam at 8-12 DAT	0.0225	258	248	3.45	3.42	5.33	5.21	7.30	6.96	42.2	42.8
Two hand weedings at 20 and 40 DAT	-	293	293	4.06	3.96	6.46	6.25	8.73	8.46	42.5	42.5
Weedy check	-	236	204	8.17	3.12	4.49	4.08	6.73	5.61	40.0	42.1
LSD (P=0.05)		18.21	9.35	0.17	0.13	0.35	0.21	0.45	0.48	2.3	2.3

in grain yield of rice over non-weeded control. The effective control of weeds starting from the early crop growth stage might have resulted in better growth and yield of rice. The variation in grain yield under different treatments was the result of variation in weed density and weed biomass. Application of herbicides under test did not show any phytotoxic symptoms on rice plant. All these findings were in close conformity with the findings of Mishra *et al.* (2004), Bond *et al.* 2007 and Pal *et al.* (2009). Based on the results of present investigation, it can be concluded that penoxsulam 0.0250 kg/ha applied at 0-5 days after transplanting was most effective to check all types of weed population which may be recommended to replace the tedious, time consuming and expensive hand weeding practice of weed control in transplanted rice.

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Changes in biochemical properties of rice rhizosphere as influenced by tillage and herbicide application

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ABSTRACT

A field study was conducted during 2009 at Raipur in an inceptisol with rainy season rice to evaluate the effect of herbicides application on biochemical characteristics of rhizosphere soil under different tillage systems. Four different types of tillage system were evaluated *viz*. (i) conventional-conventional (ii) conventional-zero (iii) zero-conventional and (iv) zero-zero. Among weed control measures, comparative effects of hand weeding and recommended herbicides application (butachlor as pre-emergence and fenoxaprop-p-ethyl + ethoxysulfuron as post-emergence herbicide 1.5 kg, 56.25 g and 15 g/ha, respectively) were tested compared with a weedy check (control). The conventional-conventional tillage system was found most effective to improve the biochemical characteristics of soil. Under this system, maximum organic C content was accumulated in rhizosphere soil and also found maximum enzyme activity (dehydrogenase activity, acidic phosphatase activity and alkaline phosphatase activity). Application of pre- and post- emergence herbicide reduced the biochemical activities in soil after its application (3 and 22 days after sowing, respectively) to 35 days of sowing of the crop thereafter it became normalize due to degradation of applied herbicides.

Key words: Dehydrogenase activity, Organic C, Phosphatase activity, Recommended herbicide, Tillage

In India, rice is cultivated in an area of about 44 million ha with a production of over 100 million tonnes. are one of the major constraints for increasing rice production. Hence, it is essential to eradicate weeds which are the main competitor for nutrients, sunlight, moisture and space. Besides, the weeds are also sink of different pests and disease causing organisms, and may also induce allelopathic effect. Different tillage practices have been shown to alter the chemical and microbiological properties of soils (Ferreira *et al*. 2000). Tillage systems alter the organic matter content in soil, which ultimately affects the microbial population and their activity.. Generally herbicides are not harmful when applied at recommended rates(Selvamani and Sankaran 1993) but some reports showed that herbicidal application may have adverse effect on bacterial (Rajendran and Lourduraj 1999) and fungal population (Shukla 1997). Nonetheless, some herbicides may even stimulate the growth and activities of microflora. In the present study, the microbiological parameters of rice rhizosphere under varying tillage and weed control practices were studied.

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MATERIALS AND METHODS

Rice-wheat cropping system was rotated for five continuous years (2005 -2009) in Instructional-cum-research farm of Indira Gandhi Agricultural University, Raipur, Chhattisgarh. In the fifth year, a study was conducted to find out the effect of different tillage systems vis-à-vis different weed control practices on enzymatic activity (dehydrogenase, acidic and alkaline phosphatase activity) and organic C content in rhizosphere soil. The soil was inceptisol with pH 6.78, EC 0.16 milimhos/cm, organic C 0.60%, available N 205.5 kg/ha, available P 14.8 kg/ha and available K 345.0 kg/ha. Four tillage systems in main plots, *viz*. conventional–conventional (CT-CT), conventional–zero (CT-ZT), zero–conventional (ZT-CT), and zero–zero (ZT-ZT); and weed control, *viz.* and weeding and recommended herbicideand weedy check in sub-plots were laid out in split plot design with 3 replications. For *Kharif* rice, butachlor was applied as pre-emergence and fenoxaprop-p-ethyl and ethoxysulfuron as post-emergence 1.5 kg, 56.25 g and 15.00 g/ha, respectively. Soil samples from rhizosphere were collected from 7.5-15.0 cm soil depth at 0, 7, 14, 21, 28, 35, 42, and 50 days after sowing and harvest. The samples were analyzed for organic C and hydrogenase activity. Acid and alkaline phosphatase activity of collected soil samples was also determined.

RESULTS AND DISCUSSION

There was a little change in organic C content in rhizosphere soil during the crop growth stages. Significantly higher organic C was quantified in zero-zero over conventional-conventional tillage system at initial, 7, 14 and 21 DAS (Table 1). However, other three systems were found at par with each other Saffigna *et al.* (1989) reported that microbial biomass and soil organic matter was influenced by soil management practices.

There was slight inhibition of acid phosphatase activity (APA) from 0-7 DAS, followed by a continuous increase from 7-DAS. The activity of acid phosphatase enzyme again showed a declining trend from 50 DAS up to harvest. Maximum APA was found under conventional-conventional and minimum in zero-zero tillage system. The conventional - conventional and conventional- zero tillage systems significantly augmented APA over zero-zero tillage system, except at harvest when the differences were at par. There was a slight inhibition of alkaline phosphatase activity (AlPA) from 0-7 DAS, followed by a continuous increase up to 50 DAS and decline thereafter. Conventional- conventional and conventional-zero tillage systems significantly increased the AlPA in rhizosphere soil over zero-zero tillage at all the growth stages except 0, 50 DAS and at harvest (Table 3). There was an increase in dehydrogenase activity (DA) in rice rhizosphere soil from 0-50 DAS, followed by a decrease up to harvest in conventional-conventional and conventional-zero plots. The conventional-conventional and conventional-zero system significantly increased the DA over zero-zero system from 7-0 DAS. Maximum DA was measured in conventional-conventional system and minimum in zero-zero system.

At 50 DAS, maximum APA, AlPA and DA were recorded, which might be due to maximum rhizosphere effect of the root system which augmented the native microflora of the root system.

Organic C in hand-weeded, herbicide-applied and

Table 1. Effect of tillage practices and weed control measures on organic C (%) of rhizosphere soil of rice

Treatment	Days after sowing								
	0	7	14	21	28	35	42	50	At harvest
Tillage									
CT-CT	0.59	0.59	0.59	0.59	0.59	0.60	0.61	0.63	0.65
CT-ZT	0.60	0.59	0.59	0.60	0.60	0.60	0.61	0.62	0.64
ZT-ZT	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.62	0.62
ZT-Ct	0.60	0.60	0.60	0.60	0.60	0.60	0.61	0.62	0.62
LSD (P=0.05)	0.01	0.01	0.01	0.01	NS	NS	NS	NS	NS
Weed management									
Hand weeding	0.60	0.60	0.60	0.60	0.60	0.60	0.61	0.62	0.63
Herbicide	0.59	0.59	0.59	0.59	0.59	0.59	0.60	0.61	0.61
Weedy check	0.61	0.61	0.61	0.61	0.60	0.62	0.63	0.64	0.66
LSD (P=0.05)	NS	NS	NS	NS	NS	0.02	0.03	0.02	0.01

Table 2. Effect of tillage and weed control practices on enzume activities of rhizosphere soil of rice

Treatment	Days after sowing								
	0	7	14	21	28	35	42	50	At harvest
Tillage									
CT-CR	104.8	101.6	107.7	117.6	126.7	137.3	156.6	229.3	133.8
CT-ZT	101.6	98.1	101.4	109.8	116.9	125.0	151.4	229.4	132.8
ZT-ZT	94.0	86.8	88.6	95.8	102.2	108.3	138.2	206.5	130.6
ZT-CT	100.1	96.5	99.3	107.1	114.3	119.7	144.1	210.3	131.6
LSD (P=0.05)	5.2	9.5	9.0	9.2	12.3	11.5	12.8	20.3	NS
Weed management									
Hand weeding	99.0	100.03	112.7	132.4	147.3	161.3	184.9	217.6	130.7
Herbicide	98.7	82.03	69.7	54.7	45.7	39.8	63.6	207.4	131.9
Weedy check	102.7	103.05	115.3	135.6	152.1	167.8	193.3	231.7	134.0
LSD (P=0.05)	NS	9.8	8.5	2.0	11.5	12.4	13.7	21.4	NS

Table 3. Effect of tillage practices and weed control measures on alkaline phosphatase activity (mg *p*-NP/h/g soil) status of rhizosphere soil of rice

Treatment	Days after sowing								
	0	7	14	21	28	35	42	50	At Harvest
Tillage									
CT-CT	88.9	88.1	92.8	101.7	106.3	117.4	142.1	199.7	110.6
CT-ZT	86.2	79.9	84.6	91.8	95.6	105.3	134.3	192.5	109.2
ZT-ZT	83.4	68.7	71.7	76.3	79.8	86.0	116.9	183.6	106.3
ZT-CT	84.7	76.5	77.9	83.8	87.6	95.7	125.5	181.9	107.8
LSD (P=0.05)	NS	7.1	7.8	8.4	8.2	11.0	11.9	NS	NS
Weed management									
Hand weeding	83.7	81.7	91.6	103.1	111.5	127.2	160.7	187.9	106.2
Herbicide	85.8	68.4	58.4	53.6	47.1	40.7	60.2	183.2	108.2
Weedy check	88.0	84.9	95.3	108.5	118.3	135.5	168.3	197.1	111.1
LSD (P=0.05)	NS	7.8	7.9	2.2	7.9	11.8	12.7	NS	NS

Table 4. Effect of tillage practices and weed control measures on dehydrogenase activity (mg TPF/h/g soil) status of rhizosphere soil of rice

Treatment	Days after sowing								
	0	7	14	21	28	35	42	50	At harvest
Tillage									
CT-CT	26.5	31.3	33.7	36.6	39.6	42.6	51.8	87.7	37.7
CT-ZT	25.2	28.7	30.8	32.7	35.0	37.6	46.1	82.3	35.5
ZT-ZT	23.4	21.7	23.1	23.9	27.9	28.9	36.2	70.6	31.1
ZT-CT	24.8	23.1	25.3	26.5	30.7	32.0	41.4	73.4	33.4
LSD (P=0.05)	NS	2.9	2.7	2.8	3.4	3.1	5.2	7.5	NS
Weed management									
Hand weeding	23.7	27.9	33.1	36.8	42.7	46.9	53.2	79.1	33.6
Herbicide	24.8	17.5	12.6	9.1	7.6	4.5	18.3	74.2	33.7
Weedy check	26.4	33.2	39.1	44.2	49.5	54.8	60.1	82.1	36.1
LSD (P=0.05)	NS	1.3	3.2	1.4	3.6	3.5	4.6	7.8	2.0

weedy check did not vary significantly up to 28 DAS. However from 35 DAS to harvest, significantly higher organic C was recorded in weedy check in comparison to herbicide-treated plots (Table 1). At harvest, significant quantity of organic matter accumulated in weedy check and hand-weeded conditions over herbicide application. This might be due to higher crop-weed density these treatments in comparison to herbicide-treated plots.

Recommended herbicide application decreased the acid phosphatase activity from initial stage (98.7) to 35 DAS (39.8), but thereafter the APA recovered and increased up to 50 DAS (207.4 mg *p*-NP/h/g soil). The APA was found significantly higher in hand-weeded and weedy check plots over herbicide-treated plots, excluding initial and harvest stage of the crop. These observations are in close agreement with Shukla and Mishra (1997). Recommended herbicide application inhibited the alkaline phosphatase activity from 0-35 DAS, followed by an increment up to 50 DAS. In rhizospere of hand-weeded and weedy check plots, the AlPA increased from 0-50 DAS, followed by decreased up to harvest. The hand weeding and weedy check conditions significantly increased AlPA in soil over recommended herbicide application except 0, 50 DAS and at harvest (Table 3). In recommended herbicide treated plots, the dehydrogenase activity decreased from 0-35 DAS (4.5), then recovered and reached its highest value at 50 DAS. There was an increase in DA under hand-weeded and weedy check plots from 0-50 DAS, followed by a decrease up to harvest. The DA was found significantly higher in hand-weeded and weedy check plots over herbicides-treated plot except at 0, 50 DAS and harvest.

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Growth, weed control and yield of direct-seeded rice as influenced by different herbicides

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ABSTRACT

A field experiment was conducted at Varanasi to study the effect of different rates of carfentrazone-ethyl for controlling weeds in rice. Major weed flora were: *Echinochloa colona, Echinochloa crussgalli, Dactyloctenium aegyptium, Caesulia axillaris, Ammania baccifera, Eclipta alba* and *Phyllanthus niruri*. Application of carfentrazone-ethyl at 35 g/ha effectively reduced the density, dry matter accumulation and N, P, K depletion by weeds, and recorded the highest weed control efficiency. It also enhanced the growth parameters, grain and straw yield, nutrient uptake by the crop. Herbicides ethoxysulfuron at 15 g/ha, metsulfuron at 4 g/ha and carfentrazone at 15-35 g/ha applied as post-emergence and pendimethalin at 1.0 kg/ha as pre-emergence recorded higher values of yield attributes and yield.

Key words: Carfentrazone-ethyl, Direct-seeded rice, nutrient uptake, weed management

About 90% of the world rice is produced and consumed in Asia. India is the second largest producer of rice next to china where it is grown in an area of 45 million ha annually with a production of 90 million tonnes and accounts for about 45% of food grain production in the country. In eastern Uttar Pradesh, it is a key source for the rural livelihoods where growing rice during *Kharif* season is prominent. Dry seeding has been the principal method of rice establishment since the 1950s in the developing countries (Pandey and Velasco 2005). Studies have revealed that direct-seeded rice (DSR) has the potential to replace the traditional transplanted rice (Balasubramaniam and Hill, 2000 and Singh *et al*. 2008) and is becoming popular as it eliminates many farm operations like nursery raising, puddling and transplanting and hence it reduces the cost of production. High weed infestation is the major bottleneck in the success of direct-seeded rice and deters productivity and sustainability (Rao *et al*. 2007). Weeds cause heavy damage to direct-seeded rice (DSR) crop which may be to the tune of 50-100%. Weeds also deteriorate the quality of grain and enhance the cost of production. Continuous application of same herbicide leads to shift in weed flora and development of resistance to herbicides. Carfentrazone is a new herbicide which inhibits proto-porphyrinogen, has a broad spectrum of weed control and is rapidly degraded in the environment (Duke *et al.* 1991). It is difficult to raise weed free DSR with the application of only one herbicide. Therefore, an effective and economical weed control strategy needs to be implemented to meet the demand of staple food for increasing population of India. Keeping these facts in view, the present investigation was undertaken to study the effect of carfentrazone-ethyl on weeds, yield, nutrient uptake and economics of direct seeded rice.

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MATERIALS AND METHODS

An investigation was conducted to evaluate the efficacy of different herbicides on complex weed flora of rice field at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during the *Kharif* season of 2010 and 2011. The experimental site was situated at 23.2 ÚN latitude, 83.03ÚE longitude and at an altitude of 129 m above sea level in the north-eastern Gangetic plain and has a typical sub-tropical climate characterized by hot, dry summer and cool winter. The soil tested was sandy clay loam in texture, neutral in reaction (pH 7.4), low in organic C (0.35%), available P (28.1 kg/ha), available K (204.5 kg/ha) and low in available N (210.5 kg/ha). Rice-wheat rotation was being followed in the field from the previous five seasons. The experiment was laid out in randomized block design with ten treatments replicated thrice. Promising rice variety '*NDR-359*' was sown on 1 July at 25 x 10 row and plant to plant spacing with a seed rate of 100 kg/ha in a plot size of 5.0 x 3.6 m during 2010 and 2011. The required quantity of herbicides as per treatment was applied. A uniform dose of 120+60+40 kg/ha of N, P, and K was applied through urea, diammonium phosphate, muriate of potash respectively. Full dose of P and K and half dose of N were applied at the time of sowing and remaining half dose of N was applied in two equal splits at tillering and panicle initiation stage. The crop was raised with recommended package of practices. Herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle with water as a carrier at 600 litres/ha. Pre-emergence herbicide was applied just after sowing and post-emergence herbicide was applied at 25 days after sowing of crop. The data on weed population were recorded at different growth stages of crop with the help of quadrate (0.5 x 0.5 m) at two randomly selected places in each plot and then converted into per square metre. Weeds were cut at ground level, washed with tap water, sun dried and thereafter oven dried at 75 C for 48 hr and then weighed. These were subjected to square root transformation to normalize their distribution before statistical analysis. Data on grain yield of rice was recorded at harvest. Weed control efficiency was calculated as per standard formula.

RESULTS AND DISCUSSION

Weed growth

Major weed species observed in the experimental field were: *Echinochloa colona* (L). Link, *Echinochloa crusgalli* (L.). Beav, *Dactyloctenium aegyptium* (L.), among grasses, sedges included *Cyperus* spp. and broad-leaf weeds dominated by *Caesulia axillaris*(L.), *Ammania baccifera* (L.), *Eclipta alba* (L.), *Phyllanthus niruri* (L.). The composition of grasses, broad-leaf and sedges was 35.5, 33.5 and 30.9% in 2010 and 37.7, 32.0 and 30.1% during 2011, respectively. Relative composition of narrow and broad-leaved weeds in weedy check recorded at 30 days stage of crop growth revealed that average weed population of narrow leaved weed species was more in comparison to broad-leaved weed species in both the years. It corroborates with the findings of Saini and Angiras (2002) who also reported dominance of grassy weeds over other species in direct seeded rice. Application of carfentrazone-ethyl effectively controlled broad-leaf weeds but failed to check grasses.

All the weed control treatments significantly suppressed both monocot and dicot weeds over weedy check during both the years (Table 1). During 2010, all the carfentrazone-ethyl based treatments significantly reduced the density and dry weight of broad-leaf weeds and were at par with metsulfuron 4 g/ha and 2,4-D 500 g/ha. During 2011, almost similar trend was observed (Table 2).The efficiency of various treatments with respect of weed control efficiency fluctuated to a greater extent under the influence of various weed control treatments. Among the various treatments, weed control efficiency was highest under the application of carfentrazone-ethyl at 30 g/ha (51.0 and 50.5%). In general, the control of weeds increased with increase in the dose of carfentrazone ethyl.

Table 1. Effect of different doses of carfentrazone-ethyl on weed population (no./m^2) at 60 DAS of direct-seeded rice

Treatment	*Echinochloa*		*Cyperus*		*Caesulia*		*Ammania*	
	2010	2011	2010	2011	2010	2011	2010	2011
Carfentrazone-ethyl 5 g/ha	5.24 (27.00)	4.60 (20.67)	6.57 (42.67)	3.89 (14.67)	3.24 (10.00)	1.87 (3.00)	2.86 (7.67)	2.74 (7.00)
Carfentrazone-ethyl 20 g/ha	4.45 (19.33)	4.34 (18.33)	6.12 (37.00)	4.67 (21.33)	2.97 (8.33)	1.78 (2.67)	2.55 (6.00)	2.42 (5.33)
Carfentrazone-ethyl 25 g/ha	4.06 (16.00)	4.14 (16.67)	6.15 (37.33)	4.45 (19.33)	2.92 (8.00)	1.68 (2.33)	2.35 (5.00)	2.20 (4.33)
Carfentrazone--ethyl 30 g/ha	3.98 (15.33)	4.10 (16.63)	5.99 (35.33)	3.89 (14.67)	2.86 (7.67)	1.58 (2.00)	2.35 (5.00)	2.20 (4.33)
Carfentrazone-ethyl 35 g/ha	3.94 (15.00)	4.02 (15.67)	5.93 (34.67)	4.56 (20.33)	2.74 (7.00)	1.47 (1.67)	2.20 (4.33)	2.04 (3.67)
Ethoxysulfuron 15 g/ha	5.24 (27.00)	4.85 (23.00)	5.90 (34.33)	4.18 (17.00)	3.24 (10.00)	2.12 (4.00)	2.48 (5.67)	2.35 (5.00)
2,4-D Na salt 500 g/ha	5.61 (31.00)	5.34 (28.00)	5.79 (33.00)	4.14 (16.67)	3.54 (12.00)	1.78 (2.67)	2.04 (3.67)	1.87 (3.00)
Metsulfuron 4 g/ha	5.02 (24.67)	4.85 (23.00)	5.49 (29.67)	3.94 (15.00)	3.85 (14.33)	1.68 (2.33)	2.35 (5.00)	2.27 (4.67)
Pendimethalin	5.12 (25.67)	4.78 (22.33)	7.58 (57.00)	4.88 (23.33)	3.44 (11.33)	1.58 (2.00)	2.74 (7.00)	2.61 (6.33)
Weedy Check	6.67 (44.0)	6.39 (40.33)	5.79 (33.00)	4.92 (23.67)	4.78 (22.33)	2.68 (6.67)	3.44 (11.33)	3.29 (10.33)
LSD (P=0.05)	1.40	1.59	2.36	2.26	1.08	1.47	1.51	1.23

Table 2. Effect of different rates of carfentrazone-ethyl on weed growth , nutrient depletion by weeds and uptake by direct-seeded rice

Treatment	Weed dry weight (g/m^2)		Nutrient depletion by weeds (kg/ha)						Nutrient uptake by rice (kg/ha)					
			N		P		K		N		P		K	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Carfentrazone-ethyl 5 g/ha	135.9	137.9	22.8	24.1	10.2	10.7	22.8	21.7	20.7	21.0	4.6	4.9	8.3	8.8
Carfentrazone ethyl 20 g/ha	121.5	122.8	20.2	21.2	9.5	9.9	21.9	20.8	22.8	23.2	5.3	5.7	11.0	11.1
Carfentrazone ethyl 25 g/ha	111.8	113.1	18.9	19.8	9.1	9.4	21.0	20.4	23.0	23.3	5.9	6.3	12.0	12.1
Carfentrazone-ethyl 30 g/ha	109.0	113.9	17.6	18.6	8.4	8.6	20.7	20.4	23.3	23.7	6.1	6.4	12.6	12.9
Carfentrazone-ethyl 35 g/ha	112.9	111.0	16.1	16.8	7.3	7.7	20.5	19.8	23.5	24.5	6.3	6.5	13.7	13.9
Ethoxysulfuron 15 g/ha	168.1	169.4	29.0	30.3	11.7	12.3	19.7	19.0	18.0	18.4	4.2	4.4	9.2	9.1
2,4-D Na salt 500 g/ha	147.2	148.5	28.2	29.9	11.1	11.7	19.1	18.9	18.0	18.2	4.2	4.4	8.3	8.6
Metsulfuron 4 g/ha	161.9	163.6	24.3	25.4	11.9	12.3	17.5	16.7	19.3	19.9	4.3	4.5	8.5	8.5
Pendimethalin	152.1	153.8	24.5	25.6	11.4	11.8	21.6	21.1	20.1	20.3	4.3	4.6	9.1	9.2
Weedy check	222.6	224.6	39.6	40.7	17.9	18.5	31.3	30.2	12.8	13.3	2.0	2.1	4.6	4.7
LSD (P=0.05)	2.4	2.6	1.7	1.1	0.9	1.5	1.7	2.9	1.9	2.1	0.4	0.4	0.9	1.8

Table 3. Effect of different rates of carfentrazone-ethyl on growth and yield of direct seeded rice

Treatment	Dose (g ha)	Plant height (cm)		Grains/ panicle		Panicles/m^2		1000-grain weight (g)		Grain yield (t/ha)		Straw yield (t/ha)	
		2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Carfentrazone-ethyl 5 g/ha	15	85.5	86.3	65.0	66.3	231.0	234.6	20.3	20.3	3.04	3.12	4.28	431
Carfentrazone-ethyl 20 g/ha	20	86.4	87.2	67.0	67.6	244.0	247.0	20.9	21.0	3.51	3.52	4.73	4.78
Carfentrazone-ethyl 25 g/ha	25	87.0	86.9	67.3	68.0	245.3	247.6	21.5	22.0	3.67	3.73	4.88	4.93
Carfentrazone-thyl 30 g/ha	30	87.9	87.0	67.6	68.3	246.6	248.3	21.6	21.7	3.68	3.71	4.80	4.95
Carfentrazone-thyl 35 g/ha	35	87.6	87.5	68.3	68.6	247.3	249.0	22.1	22.1	3.69	3.75	4.81	5.01
Ethoxysulfuron 15 g/ha	15	84.0	86.1	59.6	60.6	226.3	227.3	19.4	18.0	2.57	2.60	3.80	3.86
2,4-D Na salt 500 g/ha	500	83.9	85.1	60.3	62.0	228.6	230.6	20.0	20.0	2.90	3.02	4.05	4.10
Metsulfuron 4 g/ha	4.0	84.8	85.6	63.0	63.6	231.0	232.6	20.2	20.5	2.98	3.04	4.08	4.15
Pendimethalin	1000	84.5	84.8	61.6	62.3	227.3	229.0	20.0	20.0	2.78	2.86	4.00	4.10
Weedy Check	-	82.1	82.8	46.67	47.3	194.6	196.0	18.9	17.7	2.49	1.64	2.61	2.68
LSD (P=0.05)		1.6	NS	2.8	4.4	4.6	5.5	0.9	1.6	0.18	0.19	0.18	0.14

Nutrient depletion by weeds

Depletion of nutrients from soil is function of dry weight and nutrient content in weed plants. Weeds usually grow faster than crop plants and thus absorb mineral nutrients quicker, resulting in inadequate supply of nutrients to the crop plants. Application of carfentrazone-ethyl 35 g/ha recorded the lowest nutrient removal by weeds. Unweeded control resulted in highest depletion of nutrients by weeds throughout the crop growth period.

Crop growth and yield

Herbicidal treatments had a favourable effect on the growth attributes, *viz*. plant height, tillers/plant and DMP of rice crop compared to un weeded check during both the years (Table 3). Application of carfentrazone-ethyl at 20 g/ha significantly increased plant height and was at par to carfentrazone-ethyl at 25, 30 and 35 g/ha. In general, number of effective tillers increased with corresponding increase in the dose of carfentrazone-ethyl. However, carfentrazone-ethyl 35 g/ha produced less number of tillers during 2011, while all other carfentrazone treatments remained at par with metsulfuron and pendimethalin.

Adoption of different weed control practices significantly influenced the yield attributes, *viz*. panicles/m^2, grains/panicle and 1000 grain weight during both the years. The enhanced yield attributes recorded may be due to lower density and dry weight of weeds and higher weed control efficiency which resulted in better growth of rice crop. Application of carfentrazone-ethyl 35 g/ha recorded maximum yield attributes *viz*., panicles/m^2, panicle length, filled grains per panicle and 1000-grain weight but it was comparable to other rates of carfentrazone-ethyl.

Rice grain yield increased with increase in dose of carfentrazone-ethyl but was statistically at par with other doses of carfentrazone ethyl. Among carfentrazone treatments, maximum yield was obtained under carfentrazone-ethyl 35 g/ha during 2010 and 2011. During both the years, all the herbicidal treatments produced significantly higher rice grain yield weedy check. However, unweeded control recorded lesser yield which might be due to higher weed competition and lesser availability of nutrients to the crop plants which resulted in lower grain and straw yield in control plots and this was in conformity with the findings of Singh *et al*. (1998) and Thakur *et al*. (2011).

Nutrient uptake being a function of dry matter production and partly due to increase in its concentration, carfentrazone-ethyl 35 g/ha gave more total dry matter and registered significantly higher uptake of NPK.

Based on the present investigation, it can be concluded that carfentrazone-ethyl 35 g/ha applied 25 DAS can be used for satisfactory weed control in rice fields that is pre-dominated with broad-leaved weeds. It can also be used to realize better rice yields without any residual toxicity. However, more specifically it was poor against grassy weeds but excellent against broad-leaved weeds. Further, from this research it is clear that it is effective in controlling annual weeds at very low application rates, whereas higher concentrations are required for controlling perennial weeds. Future research efforts are required to evaluate this herbicide in combination with other herbicides against broad-spectrum weed control in dry direct-seeded rice.

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Compatibility of herbicides against grassy weeds in wheat

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ABSTRACT

Field and pot studies were conducted to determine the compatibility of dicamba in tank mix combination with sulfosulfuron and clodinafop against weeds of wheat (*Triticum aestivum*). Dicamba alone was effective against broad-leaf weeds only. No significant difference for broad-leaf weed control was observed between dicamba doses of 240 and 360 g/ha. Dicamba in combination with clodinafop and sulfosulfuron controlled the broad spectrum weed flora. The efficacy of dicamba in combination with clodinafop and sulfosulfuron was not affected for broad-leaf weed control. However, *Phalaris minor* control with clodinafop was reduced when dicamba applied as tank mix combination. The efficacy of sulfosulfuron was not affected by dicamba when applied as tank mixture and as a result this mixture (sulfosulfuron + dicamba 25 + 120 g/ha) had the highest wheat grain yield (4.99 t/ha). *P. minor* dry weight reduction with clodinafop 60 g/ha alone and in tank mix combination with dicamba 240 g/ha was 97.3 and 58.3%, respectively. In pot studies also, the tank mixing of dicamba did not affect the sulfosulfuron efficacy but clodinafop efficacy was significantly reduced against *P. minor*. The *P. minor* biomass reduction with clodinafop 30 and 60 g/ ha was 84.8 and 99.6%, respectively and when dicamba 240 g/ha was added, the fresh weight reduction reduced to 62.6 and 78.6%, respectively, compared to untreated control.

Key words: Antagonism, Broad-leaved weed, Herbicide mixture, *Phalaris minor*, wild oat

Weed infestation is one of the major constraints in achieving potential yield of wheat. The losses caused by weeds vary depending on the weed species, their abundance, crop management practices and environmental factors. Under extreme cases, losses can be complete crop failure (Malik and Singh 1993). The higher cost and less efficacy of manual weeding in wheat made chemical weed control popular. Generally, both grass and broad-leaf weeds infest wheat (Singh *et al.* 1995, Chhokar and Malik 2002). Among grassy weeds, littleseed canary grass (*Phalaris minor*) and wild oat (*Avenaludoviciana*) are major troublesome weeds under irrigated conditions in wheat crop (Singh *et al.* 1995). Broad-leaf weeds become a problem, where herbicides alone are used for combating the grass weed problem. Dicamba (3,6-dichloro-2-methoxybenzoic acid) an auxin type herbicide was found quite effective against broad-leaf weeds (Chhokar *et al.* 2007a).

Clodinafop and sulfosulfuron are two major herbicides being used by wheat grower in north western Indian plains (Chhokar and Malik 2002, Chhokar and Sharma 2008). Clodinafop controls grasses and not effective against broad-leaved weeds, whereas, sulfosulfuron controls several grasses and broad-leaved weeds. Sulfosulfuron is also not effective against some of the broad-leaved weeds like *Rumex* spp. and *Convolvulus arvensis* Linn. (Chhokar *et al.* 2007a). *Rumex dentatus* was highly competitive and drastically reduced wheat yield (Chhokar *et al.* 2007b). Dicamba, besides controlling *Rumex dentatus* and *Convolvulus arvensis*, also controlled many other broad-leaf weeds (Chhokar *et al.* 2007a). To control diverse weed flora, applications of two or more herbicides are needed. To save time and cost, instead of sequential application of herbicides, it is advantageous to tank mix broad-leaf weed herbicide with graminicide to control broad spectrum weed flora. However, the major requirement is that they should be compatible and the chances of herbicide compatibility in poaceae (grasses) is very less (20%) (Zhang *et al.* 1995). There are some reports of reduced efficacy of sulfonylurea and aryloxyphenoxy propionate herbicides when tank mixed with dicamba. However, the compatibility of dicamba with sulfosulfuron and clodinafop for *P. minor* control have not been evaluated. Keeping these in view, the present study was undertaken with the aim to determine the compatibility of dicamba with sulfosulfuron and clodinafop for control of weeds in wheat.

MATERIALS AND METHODS

Field study

Field studies were conducted for two consecutive *Rabi* seasons of 2006-07 and 2007-08 at Resource Man-

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agement Block, Directorate of Wheat Research, Karnal, Haryana, India. Wheat CV. *'PBW-343'* was sown on 20th and 21st November during 2006 and 2007, respectively at a row spacing of 20 cm using 100 kg seed/ha keeping three replications in randomized block design. The soil of the experimental field was sandy clay loam with pH of 8.0 and organic carbon content 0.39%. A recommended dose of fertilizer (150 kg N, 60 kg P, 40 kg K and 25 kg Zn/ha) was applied at sowing except nitrogen, which was applied in three splits, (1/3rd basal, 1/3rd at first and 1/3rd at second irrigation). The field was infested with weed flora dominated by *Phalaris minor, Avena ludoviciana, Melilotus indica. Medicago denticulata, Rumex dentatus, Anagallis arvensis* and *Coronopus didymus* (Table 1). First irrigation was applied at CRI stage *i.e* 21 days after sowing (DAS). The weed control treatments comprised of dicamba alone (240 and 360 g/ha) and in combination with clodinafop and sulfosulfuron along with untreated weedy control (Table 1). In combination, treatments consisted of dicamba + clodinafop at 120 + 60 and 240 + 60 g/ha and dicamba + sulfosulfuron at 120 +25 g/ha. Cationic surfactant was used 1250 ml/ha with sulfosulfuron. The herbicides were sprayed at 38-40 DAS with knapsack sprayer fitted with two flat fan nozzles boom using 350 l. water/ha. Dry weight of grass and broad-leaved weeds was recorded at 120 DAS by placing a quadrant (50 x 50 cm) at two places in each plot. The crop was manually harvested in the second week of April and net plot threshed using small plot thresher.

Pot study

Pot experiment was conducted to confirm the field study results on compatibility of clodinafop and sulfosulfuron with dicamba. About fifty seeds of *P. minor* were sown in pots (4.5 kg soil capacity having 20 cm top diameter) filled with soil : FYM in ratio of 6:1 (v/v). At 20 DAS, ten plants per pot were kept for herbicide evaluation. Herbicides, clodinafop (30 and 60 g/ha) and sulfosulfuron (12.5 and 25 g/ha) were applied without and with dicamba (240 g/ha). The cationic surfactant at 1000 ml/ha was used with sulfosulfuron treatments. At the time of herbicide spraying, *P. minor* was at 3-4 leaf stage and for spraying a solution of 350 l/ha was delivered using knapsack sprayer fitted with flat fan nozzles. Four week after herbicide spray, fresh weight of *P. minor* was recorded and based on fresh weight of control pots, the relative per cent fresh weight reduction under various treatments was calculated. Experiment was repeated with three replications in CRD and significance was compared using "paired t test" at P = 0.05 level.

RESULTS AND DISCUSSION

The major weed flora infested the experimental field comprised of grassy weeds (*P. minor* and *A. ludoviciana)* and among broad-leaf weeds, major were *Medicago denticulata, Melilotus alba, Rumex dentatus* and *Coronopus didymus.* Dicamba alone was effective against broad-leaved weeds only (Table 1). Dicamba at 240 and 360 g/ha provided good control of broad-leaved weeds and was significantly better compared to sulfosulfuron, clodinafop and weedy control. No significant difference for broad-leaf weed control was observed between dicamba doses of 240 and 360 g/ha. The tank mix application of dicamba with clodinafop and sulfosulfuron provided significant reduction in dry weight of grasses and broad-leaf weeds compared to untreated control. The ineffectiveness of dicamba against grass weeds resulted in poor wheat grain yield due to strong competition from grassy weeds. The yield recorded under dicamba in combination with clodinafop and sulfosulfuron application was significantly better as compared to weedy check and dicamba application alone due to control of complex weed flora. The presence of weeds throughout the crop season reduced the grain yield by 54.2% in comparison to tank mix application of sulfosulfuron + dicamba. The efficacy of sulfosulfuron was not affected by dicamba when applied as tank mixture (sulfosulfuron + dicamba 25 + 120 g/ha) resulting in the highest grain yield (4.99 t/ha). The total weed dry weight under this treatment was only 21.9 g/m^2. Dicamba efficacy against broad-leaf weeds was not affected by tank mix combination with clodinafop and sulfosulfuron.

Clodinafop 60 g/ha alone application reduced the *P. minor* dry weight by 97.3% and the tank mix application of clodinafop 60 g/ha with dicamba 240 g/ha reduced the *P. minor* dry weight by 58.3% compared to untreated control. The antagonistic effect of tank mix application of dicamba and clodinafop for *P. minor* control was also confirmed under pot studies (Fig. 1).The application of clodinafop at 30 and 60 g/ha reduced the fresh biomass of *P. minor* by 84.8 and 99.6%, respectively compared to weedy control. The addition of dicamba as tank mix combination with clodinafop resulted in significantly less reduction of *P. minor* biomass compared to sole clodinafop. The reduction in *P. minor* fresh biomass with clodinafop + dicamba at 30 + 240 and 60 + 240 g/ha was 62.6 and 78.6%, respectively. The reduction in efficacy of ACCase inhibitor herbicides on grasses with tank mixing of dicamba has been reported earlier (Dernoeden and Fidanza 1994, Olson and Nalewaja 1981). Dernoeden and Fidanza (1994)

Table 1. Effects of dicamba alone and in combination against weeds in wheat (pooled data of two years)

Herbicide	Dose g/ha	Weed dry weight (g/m^2)					Wheat grain Yield (t/ha)
		P. minor	Wild Oat	Broad-leaved	Total grassy weeds	Total weeds	
Dicamba	240	14.1(200)*	10.8(120)	1.03(0.1)	17.8(321)	17.9(321)	2.54
Dicamba	360	13.7(191)	11.5(133)	1.00(0.0)	17.9(325)	18.0(325)	2.59
Dicamba + clodinafop	120+60	7.4(59)	1.5(2.0)	1.22(0.6)	6.62(61)	7.89(62)	4.72
Dicamba + clodinafop	240+60	8.4(73)	2.0(5.9)	1.05(0.1)	8.73(79)	8.90(79)	4.70
Dicamba + sulfosulfuron + S**	120+25	2.5(6.9)	3.7(15.0)	1.03(0.1)	4.61(21)	4.68(22)	4.98
Clodinafop	60	2.1(4.7)	1.0(0.0)	11.36(128)	2.10(4.7)	11.5(133)	4.45
Sulfosulfuron + S **	25	1.6(2.1)	2.5(6.0)	5.15(27.4)	2.93(8.1)	6.04(35)	4.77
Weedy Check	-	13.1(175)	11.2(128)	7.59(57.6)	17.3(303)	19.00(361)	2.28
LSD (=0.05)		1.33	1.50	0.88	1.54	1.39	0.24

* Original values given in parentheses are square root transformed {($\sqrt{x+1}$)} for statistical analysis, **S= Cationic surfactant (Leader mix) 1250 ml/ha

demonstrated that auxin herbicides (2,4-D + mecoprop + dicamba) reduced the efficacy of fenoxaprop when applied as tank mixture or when these broad-leaf herbicides were applied 14 days before fenoxaprop application. However, efficacy was not affected when applied either 3 weeks before or >3 days after fenoxaprop application. Similarly, Olson and Nalewaja, 1981 reported that wild oat control with diclofop at 1.0 kg/ha was reduced from 96% to 14% when tank mixed with dicamba. They also reported that MCPA antagonism of wild oat control with diclofop increased as the post treatment temperature increased from 10 to 30°C. Antagonism of tank mix combinations of grass herbicides (clodinafop or fenoxaprop) with broad-leaf herbicides (2, 4-D or metsulfuron) is also reported by Mathiassen and Kudsk (1998) and Yadav *et al.*(2009).

Sulfosulfuron efficacy was not affected by dicamba tank mix combination (Fig.1). Contrary to it, many research workers (Damalas and Eleftherohorinos 2001, Hart and Wax 1996) have reported reduced efficacy of sulfonyl urea (rimsulfuron and primisulfuron and imidazolinone (imazethapyr) herbicides with tank mixing of dicamba. This differential response might be due to difference in the nature of weed or herbicide or use of surfactant or environmental conditions.

Damalas and Eleftherohorinos (2001) observed 17 and 43%, lower control of Johnsongrass with tank mix application of dicamba (280 g/ha) with rimsulfuron and primisulfuron compared to their application alone. Hart and Wax, (1996) also reported dicamba antagonizing grass weed control with imazethapyr by reducing foliar absorption. Using MSO (methylated seed oil) instead of NIS (non-

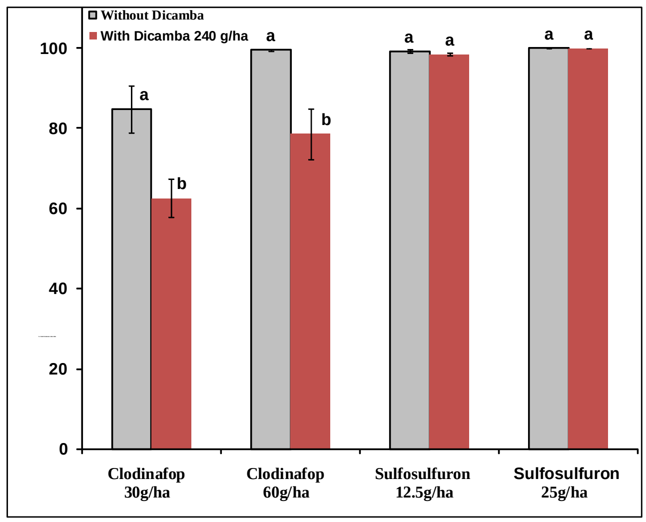

Fig. 1. Reduction in fresh biomass of *P. minor* in comparison to untreated control with clodinafop and sulfosulfuron alone and in tank mix combination with dicamba. Vertical bars represent ± SEM (6 observations). Means having the same letter were not significantly different at P=0.05 using the "paired t-test".

ionic surfactant) prevented antagonism when Na- dicamba was applied at 70 and 140 g/ha and reduced the severity of the antagonism at greater application rates by greatly increasing absorption compared to NIS. The addition of AMS (ammonium sulfate) to spray mixture, maintained imazethapyr at normal absorption and retention rates, and thus prevented any antagonism of grass control. It has also been reported that AMS overcomes the decreased herbicide activity due to antagonism caused by the presence of metal cations (Ca, Na, K and Mg) in water used as spray solution (Nalewaja and Matysiak 1993, McMullen, 1994, Nalewaja *et al*. 1995).

Based on this study, dicamba alone was effective against broad-leaved weeds and in combination with sulfosulfuron provided broad-spectrum weed control. Dicamba antagonized the grass weed control with clodinafop. However, in tank mix combination, the efficacy against broad-leaf weeds was not affected. Damalas (2004) also reported that antagonism is generally observed more often than synergism, occurs more frequently in grass weeds rather than broad-leaved weeds and also in mixtures where the companion herbicides belong mainly to different chemical families. For effective management of diverse weed flora, combination of herbicides, either as ready mixture or tank mixture, if compatible or as sequential application, if not compatible, are needed (Singh *et al.* 2005, Yadav *et al.* 2009, Singh *et al.* 2010). To avoid antagonism clodinafop with dicamba should be used in sequential application. However, further research is needed to identify the optimum time interval between the sequential applications to effectively control the grass weeds as herbicide application timing and sequence may also alter the herbicide compatibility (Dernoeden and Fidanza 1994).

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Bio-efficacy of carfentrazone-ethyl + sulfosulfuron in wheat

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ABSTRACT

An experiment was conducted during *Rabi* season of 2008-09 and 2009-10 at Varanasi (Uttar Pradesh) to evaluate the boiefficacy of carfentrazone-ethyl + sulfosulfuron in wheat. The experimental field was infested with *Phalaris minor, Rumex dentatus, Chenopodium album, Anagalis arvensis and Melilotus spp* during both the years of study. The result indicated that post-emergence application of carfentrazone + sulfosulfuron with surfactant at 45 g/ha recorded minimum density and dry weight of weeds and it was at par to 54 and 90 g/ha, without any phytotoxicity symptoms on the crop. Significant variation in wheat yield was recorded due to application of different herbicides when compared with control. Carfentrazone-ethyl + sulfosulfuron with surfactant at 45 g/ha recorded significantly the highest grain yield over its rate of 36 g/ha and it was at par to 54 and 90 g/ha. The regration equation indicated that extent of reduction could be 26.5 kg/ha for weed dry weight. The evaluation of weed dry weight and weed control efficiency of the different treatments and the regression of yield on it reveled that reduction in grain yield could be 0.025 t/ha for weed dry weight and 1% increase in the weed control efficiency increased the grain yield by 0.020 t/ha, respectively.

K**ey word:** Carfentrazone, Sulfosulfuron, Weeds, Wheat yield, Yield attributes

Wheat is most important winter season cereal crop of India. Cultivation of semi-dwarf input responsive wheat cultivars with slow initial growth, provide favorable environment for weeds. It suffers from severe weed competition which reduces its yield to the tune of 25-55% (Singh *et al*. 2009) and 43.6% (Verna *et al*. 2008) or even more, if not managed effectively. Further, in wheat, a number of weed species belonging to narrow and broad-leaf morphology infest the crop. Hand weeding has been the most widely practiced method of weed control by farmers in our country. However, in recent years, its practical and economic feasibility is often limited by unfavourable climatic and soil conditions, unavailability of labourer during critical period of weeding and also high wages of labour (Pandey *et al*. 2008). The most widely used herbicide isoproturon, which is being used as post-emergence for weed control in wheat, controls only grassy weed like *Phalaris minor* in wheat. Whereas, 2,4-D, has activity only against broad-leaf weeds. Development of resistance in *P. minor* against isoproturon and ear-head deformities in wheat due to 2,4-D, raised serious concern about their use in wheat. Thus, it became important to evaluate new herbicide molecules for management of weeds in wheat. Since, no single herbicide controls both narrow and broad-leaved weeds in wheat, therefore, mixing of herbicides have shown great promise in controlling complex weed flora of wheat (Walia *et al*. 2010). Carfentrazone-ethyl is new herbicide which is effective against BLW including other problematic weeds (Singh *et al*. 2004 and Walia and Singh 2006). Hence, compatibility of carfentrazone-ethyl with sulfosulfuron was studied for making any sound recommendation regarding their use as tank mix application against important weeds in wheat.

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MATERIALS AND METHODS

A field experiment was conducted during winter (*Rabi*) season 2008-09 and 2009-10 at the Agronomy research farm, BHU, Varanasi, which is geographically situated at 23.2^0 N latitude, 83.03^{0}E longitude and at an altitude of 113 msl in the north-eastern Gangetic Plains. This location has a typical sub tropical climate characterized by hot, dry summer and cool winter. The soil of experimental site was sandy clay loam in texture with slightly saline in reaction (pH-7.4). It was low in organic C (0.32%) and available N (150.9 kg/ha), medium in available P (24.6 kg/ha) and K (232.5 kg/ha) in soil surface. The total rainfall received during 2008-09 and 2009-10 was 68.9 and 151.2 mm, respectively, of which 24. 5 and 52.6, 18.4 and 70.4, 26.4 and 28.2 mm, respectively was received during December, January and February. The field was kept under rice-wheat rotation for the last ten years. The experiment consisted of 15 treatments was done in complete randomized block design with three replications. The wheat variety '*HUW 234*' was sown with the help of ferti-seed drill at 22 cm row spacing using 100 kg seed/ha on 2[nd] December 2008 and 5[th] December 2009 in 4.6 x 5.5 m^2 gross plot size. All the herbicides were applied with the help of flat fan nozzle attached to the foot sprayer using volume of spray 500 l/ha, at 30 days after sowing. Urea, diammonium phosphate and murate of potash were used as sources of nitrogen, phosphorus and potassium, respectively. An uniform dose of 40: 60: 40, N:P: K kg/ha was applied uniformly at the time of sowing and remaining 80 kg N was top-dressed in two equal splits, each at after first irrigation and flowering time. Four irrigations were given to critical growth stages of crop and 6cm water were applied per irrigation. Density, dry weight and weed control efficiency of weeds were observed at 45 days after sowing of crop. Weed control efficiency was calculated using standard formula. Data on weed density was recorded from an area enclosed in the quadrate of 0.25/m^2 randomly selected at four places in each plot. Weed species were separately counted from each sample and their density was recorded. Oven dry weight of weeds was recorded at 70^0C for 48 hr. Data on yield contributing characters, grain and straw yield at harvest were studied for both the years. The crop was harvested on 8[th] April 2009 and 15[th] April 2010. Data collected on various parameters were analyzed statistically for valid conclusion.

RESULTS AND DISCUSSION

Effect on weeds

The experimental crop was infested by *Phalaris minor* L. (narrow leaf-weed) and *Rumex dentatus* L., *Chenopodium album* L., *Anagallis arvensis* L., and *Melilotus* sp. (broad-leaf weeds). Tnfestation of BLWs was lower during both the years of study. The density of different narrow and broad-leaf weeds was significantly affected by herbicides treatments. The data revealed that test sample carfentrazone + sulfosulfuron (premix) with surfactant at 45 g/ha recorded significantly the lowest density of all the dominant weed species and was at par to 55 and 90 g/ha (Table 1). Alone application of carfentrazone and sulfosulfuron were effective only against broad-leaf and narrow-leaf weeds during both the years, respectively.

The dry weight of weeds differed significantly due to different treatments (Table 1). Test sample of carfentrazone + sulfosulfuron (premix) at 45 g remained at par with its higher rates (54 and 90 g/ha) and significantly superior to its lower rates and also to other herbicide treatments. However, all the herbicides were significantly superior to untreated control. These results are conformity with the finding of Walia and Singh (2006), Bharat and Kachroo (2007), Pandey *et al.* (2007) and Yadav *et al.* (2009). No phytotoxicity symptoms appeared in crop even at higher rate 90 g/ha (Table 3).

Yield attributes and yield

All the weed control measures recorded significantly the highest yield attributes and grain yield over control (Table 2). The maximum ear heads/m^2, grains/ear head, 1000-grain weight and grain yield was recorded in carfentrazone + sulfosulfuron at 45 g/ha remained at par with its higher rates (54 and 90 g/ha) and were significantly superior to its rate of 36 g/ha. The test herbicide molecule carfentrazone + sulfosulfuron at 45 g/ha with and without surfactant remained at par with each other, but proved significantly superior over carfentrazone-ethyl 40% DF and isoproturon. Sulfosulfuron 75% + metsulfuron 5% WG + surfactant recorded maximum yield attributes and grain yield of wheat but was statistically at par with carfentrazone + sulfosulfuron at 45 g and 54 g/ha. Higher grain yield under carfentrazone + sulfosulfuron at 45 g/ha

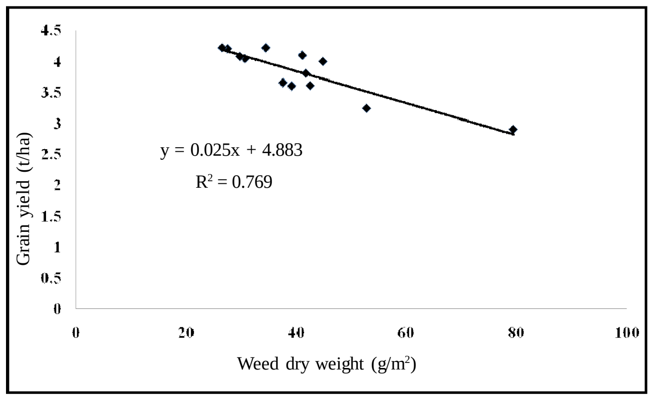

Fig. 1. Relationship between total weed dry weight and grain yield (pooled data of two year)

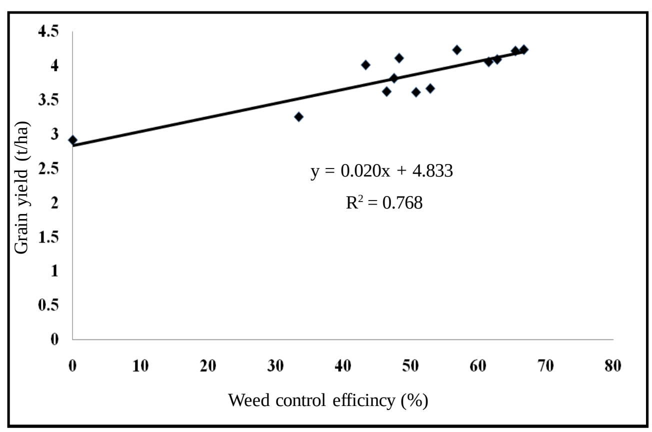

Fig. 2. Relationship between weed control efficiency and grain yield (pooled data of two year)

Table 1. Effect of carfentrazone-ethyl 20% + sulfosulfuron 25% (PREMIX) WDG on weeds in wheat

Treatment	Weed population (no./m^2) at 45 DAS										Weed dry weight at 45 DAS (g/m^2)		WCE (%)	
	Phalaris minor		*Rumex dentatus*		*C. album*		*Anagallis arvensis*		*Melilotus* spp.					
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
T_1	18.6	19.7	9.0	13.0	9.0	8.0	8.6	7.7	8.9	10.7	46.2	43.4	39.2	47.5
T_2	16.0	23.7	7.0	12.0	11.2	8.3	6.0	9.7	9.0	16.3	33.8	44.6	55.5	46.1
T_3	14.1	22.3	8.0	12.7	6.0	4.7	4.1	8.3	6.3	13.0	32.4	42.7	57.4	48.4
T_4	12.6	13.3	6.0	8.7	0.0	0.0	0.0	0.0	0.0	0.0	24.6	36.8	67.6	55.5
T_5	11.9	11.7	5.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	23.9	35.6	68.6	57.0
T_6	11.0	9.7	3.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	22.3	32.8	70.7	60.3
T_7	10.2	8.4	8.0	8.7	0.0	0.0	0.0	0.0	0.0	0.0	21.9	31.2	71.2	62.3
T_8	32.8	31.4	9.0	7.0	5.6	3.7	8.8	6.3	12.0	5.0	38.8	46.3	48.9	44.0
T_9	17.9	19.2	26.0	23.7	6.9	10.7	13.9	15.6	17.6	16.0	37.4	44.8	50.8	45.8
T_{10}	20.6	18.0	10.0	15.0	5.8	12.4	24.6	14.0	13.9	11.3	26.9	42.1	64.6	49.1
T_{11}	22.9	23.0	13.0	14.7	8.2	15.3	18.9	18.7	15.7	14.3	36.7	46.8	51.7	43.4
T_{12}	17,8	22.3	31.0	29.0	15.8	15.7	21.6	23.7	24.6	20.3	51.9	53.6	31.7	35.2
T_{13}	57.9	44.0	49.0	58.0	46.9	31.3	67.9	41.3	35.7	35.7	76.0	82.7	0.0	0.0
T_{14}	10.2	10.3	9.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	22.7	29.6	70.1	64.2
T_{15}	9.8	8.4	10.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	21.6	28.8	71.6	65.2
LSD (P=0.05)	1.82	7.3	0.88	5.2	0.9	3.62	3.6	4.9	4.8	4.0	3.5	3.0		

T_1- Carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% premix, 20 + 25 g/ha), T_2- carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% Premix, 16 + 20 g/ha) + cationic surfactant (625 g/ha), T_3- carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% Premix, 16 + 20 g/ha) + cationic surfactant (750 g/ha), T_4- carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% Premix, 20 + 25 g/ha) + cationic surfactant (625 g/ha), T_5- carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% Premix, 20 + 25 g/ha) + cationic surfactant (750 g/ha), T_6- carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% Premix, 24 + 30 g/ha) + cationic surfactant (625 g/ha), T_7- carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% Premix, 24 + 30 g/ha) + cationic surfactant (750 g/ha), T_8- carfentrazone – ethyl 40% DF (20 g/ha), T_9- sulfosulfuron 75% WDG (leader 25 g/ha) + cationic surfactant, T_{10}- total (sulfosulfuron 75% (32 g/ha) + metsulfuron 5% WG + surfactant, T_{11}- Atlantis (metsulfuron-methyl 3% , 12 g/ha + iodosulfuron-methyl-sodium 0.6%WG, 2.24 g/ha) + surfactant, T_{12}- isoproturon 75% WP (1000 g/ha), T_{13}- untreated control T_{14}- carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% Premix, 40 + 50 g/ha + 750 g/ha) and T_{15}- carfentrazone–ethyl 20% + sulfosulfuron 25% WDG (45% Premix, 40 + 50 g/ha) + cationic surfactant (750 g/ha)

Table 2. Effect of carfentrazone-ethyl 20% + sulfosulfuron 25% (Premix) WDG on yield attributes and yield of wheat

Treatment	Ear head/m^2		1000-grain weight (g)		Grains/ear head		Grain yield (t/ha)	
	2009	2010	2009	2010	2009	2010	2009	2010
T_1	290	350	37.5	36.5	37.5	36.9	4.07	3.95
T_2	345	311	40.1	37.4	27.2	25.5	3.76	3.46
T_3	363	318	35.6	36.9	29.3	28.6	3.79	3.54
T_4	360	321	39.0	37.0	28.7	28.2	4.02	4.09
T_5	358	356	37.0	37.4	30.8	31.1	4.06	4.12
T_6	342	342	40.2	37.3	29.8	32.1	4.09	4.34
T_7	358	353	37.5	35.0	30.7	33.0	4.11	4.36
T_8	298	328	38.2	36.4	31.4	31.8	3.56	3.68
T_9	350	338	37.9	36.2	30.6	30.9	4.05	4.17
T_{10}	315	355	38.3	37.7	34.8	35.1	4.17	4.29
T_{11}	323	342	36.9	35.7	32.5	32.4	3.86	3.77
T_{12}	340	319	36.3	33.3	27.4	26.7	3.36	3.14
T_{13}	268	279	36.4	38.5	29.5	29.8	2.88	2.94
T_{14}	330	357	38.7	36.2	32.8	33.5	4.18	4.38
T_{15}	332	366	38.7	36.3	32.6	33.9	4.19	4.37
LSD (P=0.05)	29.9	29	3.4	1.9	1.7	1.8	0.14	0.29

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Distribution of weed flora of greengram and blackgram in Haryana

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ABSTRACT

To study the floristic composition of weeds in greengram, 50 fields were surveyed in Hisar, Sirsa, Bhiwani, Mahender Garh and Fatehbad districts of Haryana state during July-August, 2011 and 23 fields were surveyed for blackgram in Shiwalik foot hills region of Panchkula, Ambala and Yamuna Nagar districts of the state during August-September, 2012. Weed flora in greengram was more diverse as compared to blackgram. Twenty-two weed species (5 grassy, 3 sedges and 14 broad-leaved) belonging to12 families were found dominant in greengram, where as in blackgram only 11 weeds of 7 families were found to be very aggressive. Broad-leaved weed *Digera arvensis* (L.) of family *Amarthanceae* was the most dominant and aggressive weed of both crops with a relative density and frequency of 511% and 86% in green gram whereas in blackgram it was 38% and 96%, respectively. *Dactyloctenium aegyptium* (L.) was the most dominant grassy weed with IVI values of 24.5 and 22.6 in greengram and blackgram, respectively. Important broad-leaved weeds found in greengram were: *Trianthema portulacastrum, Mollugo distachya*, *Cleome viscosa*, *Cucumis callosus*, *Corchorus tridens*, *Corchorus aestuans* and *Tribulus terristeris*, whereas in blackgram *Commelina benghalensis, Physalis minima, Solanum nigrum* and *Chorchorus olitorious*.

Key words: Blackgram, Distribution, Greengram, IVI, Relative density, Weed flora

Due to limited irrigation facilities, greengram is the important *Kharif* season crop of south-western part of Haryana, and blackgram in Shiwalik foot hills region of Panchkula, Ambala and Yamuna Nagar districts. Weeds have been reported to offer serious competition to crop and full season competition with the weeds cause yield reduction to the extent of 25-100% in these crops. Weed emergence in greengram and blackgram begins almost with the crop emergence leading to crop-weed competition from initial stages. Critical period of crop-weed competition in green gram and blackgram is 20-40 days after sowing (Saraswat and Mishra 1993). Horse purslane (*T. portulacastrum*), an annual broad-leaved weed germinates at the same time as greengram crop and completes its life cycle with in 30 days (Balyan 1985). Grassy weeds *D. aegyptium* and *E. colona* germinate immediately after onset of rains. The magnitude of loss as a result of crop-weed competition depends upon type of weed species, associated with crop, their densities and duration of competition with crops. Crop type and soil properties have greatest influence on the occurrence of weed species. The type of irrigation, cropping pattern, weed control measures and environmental factors had a significant influence on the intensity and infestation of weeds. So, knowledge of weed species associated with crops in a region is therefore pivotal and necessary to plan and execute a sound and economical weed management schedule depending upon various factors affecting weed distribution in different areas. The present survey was the first attempt to document weed composition of blackgram and greengram crops in Haryana and to suggest their control measures.

MATERIALS AND METHODS

To study the floristic composition of weeds in greengram, in all 50 fields in south-western region of the state situated at 28.26-29.95^{0}N latitude and 74.66-76.15^0 E longitude characterized by loamy sand soil texture, with rain fall of 300-500 mm were surveyed in Hisar, Sirsa, Bhiwani, Mahender Garh and Fatehbad districts of during July-August, 2011. Greengram cultivation in this part is totally dependent upon rainfall. Another pulse crop, black gram gown in Shiwalik foot hills region of Panchkula, Ambala and Yamuna Nagar districts of state situated at 30.83-30.15^{0}N latitude and 76.78-77.30^0 E longitude is characterized by sandy loam to silty soils, with rain fall of 900-1200 mm. Total 23 blackgram fields were surveyed in this region for recording weed distribution pattern during August-September, 2012. This period depicted most appropriate representation of majority of weed species as the weeds have cumulative effects of all agronomic practices, soil type, fertilizer and irrigation application and weed control measures adopted during initial crop growing pe-

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riod. The road map of Haryana state was followed and routes were planned to establish sampling localities as equidistantly as possible (about 10 km) avoiding inhabited areas. Four observations on density of individual weeds were recorded per field at one spot by using quadrate of (0.5 x 0.5 m), 100 m deep inside the fields. Pooled average values of observations of relative density, relative frequency and IVI of individual weeds were thus calculated as per method suggested by Raju (1977).

RESULTS AND DISCUSSION

Twenty two weed species (5 grassy, 3 sedges and 14 broad-leaf) of 12 families were found to be dominant weed species in the phyto-sociological survey of weeds in greengram crop in Hisar, Sirsa, Bhiwani, Mahender Garh and Fatehbad districts of the state (Table 1). Broad-leaf weed *Digera arvensis* L. of family *Amarnthacea* with a relative density of 50.7% and IVI value of 63.8 was the most dominant weed occurring at 86% of sites surveyed in all districts. Among grassy weeds *Dactyloctenium aegyptium* was most dominant grassy weed with relative density of 10.7% and IVI value of 24.46. Perennial sedges *Cyperus rotundus* L., *Cyperus compressus* and *Bulbostyllis barbata* also showed infestation in greengram crop with IVI values of 15.8, 3.0 and 2.9, respectively. *Trianthema portulacastrum* with RD of 6.3 plants/m^2 occurring at 24% sites with IVI value of 10.8 was the 4th most important weed of greengram accorded to be given preference for adopting control measures. Other important weeds of light textured soils found in low rainfall areas, *viz. Cenchrus echinatus*, *Mollugo distachya*, *Cucumis callosus*, *Corchorus tridens*, *Corchorus aestuans* and *Tribulus terristeris* were found to provide competition to greengram. Yellow coloured flowering creeper *C. callosus* L. of family *Cucurbitacae* which has a depressive influence on crop growth under rainfed conditions by way of releasing toxins although with low density (0.96 plants/m^2) also occurred at 34% locations surveyed in greengram. Similar weed flora of *Kharif* pulses has been documented in extensive surveys made under AICRP on Weed Control during 1978-1991 (AICRP-WC, 1978-84)

Eleven weed species (5 grassy, 1 sedge and 5 broad-leaved) belonging to 7 families were found to be dominant weed species in blackgram crop in Ambala. Panchkula and Yamuna Nagar districts of the state (Table 2). *Digera arvensis* with a relative density of 38.2% and IVI value of 86.7 was the most dominant weed occurring at 46% of

Table 1. Weed flora of greengram in Haryana

Weed species	Family	Density (no./m^2)	RD (%)	Frequency (%)	R F (%)	IVI
Grassy						
Dactyloctenium aegyptium L. Beauv.	Gramineae poaceae	10.1	10.7	78	14.4	24.5
Digitaria sanguinalis L. Scop.	Gramineae poaceae	0.2	0.3	20	3.7	3.9
Echinochloa colona L.	Gramineae poaceae	0.2	0.2	6	1.1	1.3
Brachiaria reptans L. Lamk.	Gramineae poaceae	0.9	0.9	8	1.5	2.4
Cenchrus echinatus L.	Gramineae poaceae	0.7	0.7	8	1.5	2.0
Sedges						
Cyperus rotundus L.	Cyperaceae	7.8	8.1	60	8.0	15.8
Bulbostyllis barbata L.	Cyperaceae	0.8	0.8	12	2.2	3.0
Cyperus compressus L.	Cyperaceae	0.8	0.8	12	2.2	3.0
Broad-leaved						
Digera arvensis L.	Amaranthaceae	47.9	50.7	86	15.9	63.8
T. portulacastrum L.	Aizoaceae	6.3	6.7	24	4.4	10.8
Molluga distachya L.	Mollugonaceae	4.9	5.1	26	4.8	9.7
Giesekia phernecoides L.	Gisekiaceae	3.4	3.6	32	5.9	9.3
Cleome viscose L.	Capparidaceae	2.2	2.4	26	4.8	7.1
Cucumis callosus L. Roxb.	Cucurbitaceae	1.0	1.0	34	6.3	7.3
Tribulus terrestris L.	Zygophylaceae	0.7	0.8	32	5.9	6.7
Corchrus aestuans L.	Tiliaceae	1.7	1.8	24	4.4	6.1
Corchrus tridens L.	Tiliaceae	0.7	0.7	18	3.3	4.0
Crotolaria medicaginea L. Lamk.	Papilionaceae	2.9	3.0	12	2.2	5.1
Corchrus olitorius L.	Tiliaceae	0.2	0.2	6	1.1	1.3
Amaranthus spinosus L.	Amaranthaceae	0.8	0.9	6	1.1	2.0
Convolvulus arvensis L.	Convolvulaceae	0.3	0.4	4	0.7	1.1
Commelina kurzi L.	Commelinaceae	0.2	0.2	6	1.1	1.3

Table 2. Weed flora of blackgram in Haryana (11 weeds)

Weed species	Family	Density (no./m^2)	RD (%)	Frequency (%)	RF (%)	IV
Grassy						
Dactyloctenium aegyptium L. Beauv	Poaceae	2.56	11.68	74	10.78	22.
Digitaria sanguinalis L. Scop	Poaceae	1.21	5.54	52	5.58	11.
Echinochloa colona L.	Poaceae	0.95	4.36	48	5.11	9.
Eleusine indica L.	Poaceae	1.39	6.33	48	5.51	11.
Eragrotis tenella L.	Poaceae	2.04	9.30	52	5.11	14.
Sedges						
Cyperus rotundus L.	Cyperaceae	0.30	1.38	52	5.11	6.
Broadleaf						
Digera arvensis L.	Amaranthaceae	8.39	38.20	96	46.51	84.
Physalis minima L.	Solanaceae	1.56	7.12	43	4.65	11.
Corchrus olitorius L.	Tiliaceae	0.34	1.58	80	0.93	2.
Solanum nigrum L.	Solanaceae	1.52	6.93	52	4.65	11.
Commelina benghalensis L.	Commelinaceae	1.65	7.52	52	5.11	12.

sites surveyed in all districts. *D. aegyptium* L. was most dominant grassy weed with 11.7% RD and IVI value of 22.63 followed by *Eragrotis tenella* and *Eleusine indica.* Perennial sedge *Cyperus rotundus,* with relative density of 1.38%, also showed infestation at 52% locations surveyed in blackgram crop with IVI value of 22.6. Other broad-leaf weeds found to compete with this crop were *Commelina benghalensis, Physallis minima* and *Solanum nigrum*. Similar composition of weeds was reported in blackgram fields in Haryana (Hooda *et al.* 1993) and in Tarai region of Uttaranchal (Mishra and Singh 1993). Nandan *et al*. (2011) also reported presence of *C. benghalensis* L. in blackgram fields of Shiwalik region of Jammu.

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Weed management by sowing methods and herbicides in soybean

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ABSTRACT

A field experiment was conducted at Jabalpur to evaluate the different sowing methods and weed control practices for higher grain yield of soybean. The dominated weed species among monocot weeds were *Cyperus iria, Ehinochloa colona* and *Cynodon dactylon*, however among dictot weed species *Eclipta alba*, *Commelina diffusa*, *Alternenthera sessilis* and *Phylanthus niruri* were observed during the growing season.The results revealed that the weed density of monocot (25.1/m^2) and dicot (18.7/m^2) weed was lowest in broad bed furrow (BBF) sowing method and application of pendimethalin (0.75 kg/ha) *fb* imazethapyr (0.75 g/ha. Maximum weed control efficiency (80.0%) was observed with the application of pendimethalin (0.75 kg/ha) *fb* imazethapyr (0.75 kg/ha). BBF sowing method also recorded highest yield attributes and grain and straw yield (1.47 and 1.51 t/ha). The BBF sowing method of soybean gave maximum net monetary returns and B:C ratio (` 16,584 /ha and 1.87, respectively).

Key words: Herbicides, Soybean, Sowing methods

Soybean is one of the important oil seed crops among all the seed crops. It has been termed as miracle bean because of higher protein (40%) and oil (20%) content (Chouhan and Joshi 2005). In India it is cultivated in 106.95 lakh ha with the annual production of 126.7 lakh t. Madhya Pradesh contributes 58.1 lakh ha with production of 66.8 lakh MT with 1.15 t/ha of productivity (Anonymous 2012). Weed infestation is considered as a complex constraint in soybean production. Several herbicides, *viz.* pendimethalin, alachlor, chlorimuon, imazethapyr *etc.* are presently being used for controlling the weeds in soybean but these herbicides were not found much effective to control many broad-leaved weeds in soybean. The broad bed furrow was also found to reduce seed rate and provides favorable environment for the growth and development of the soybean crop under rainfed condition (Ram and Kler 2007). Hence, the present investigation was done to evaluate the suitable sowing method and post-emergence herbicides for controlling the broad spectrum weeds for higher growth and yield of soybean.

MATERIALS AND METHODS

The experiment was conducted at research farm of JNKVV, Jabalpur during 2012 and 2013. The soil of the experimental field was clay loam having 7.7 pH, OC and available N, P, K (258, 14.2, 375 kg/ha), respectively. The treatment was laid out in split plot design with sowing method as main plot and weed control method as sub plot treatments. Three sowing methods (flat bed [FB], broad bed furrow [BBF] and ridge furrow [RF]) and three weed control practices (pendimethalin 1 kg/ha, imazethapyt 1 kg/ha and pendimethalin (0.75 kg/ha) *fb* imazethapyr (0.75 g/ha) were evaluated in three replications. Soybean variety '*JS 97-52'* was sown on 24 June, 2012 and 18 June, 2013 with tractor drawn seed drill machine as per sowing method using 70 kg of seeds/ha . Recommended dose of N (20 kg/ha), P (60 kg/ha) and K (20 kg/ha) were applied through DAP (diammonium phosphate), muriate of potash, respectively. The herbicides were applied with their respective doses as per treatments. Spraying was done with flat fen nozzle with knapsack sprayer 500 liter of water/ha. Weed population and weed dry weight was taken using 0.25 x 0.25 m sized quadrate at 60 DAS. Weed data were subjected to square root transformation before statistical analysis. Grain, straw yield and economics were also recorded.

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RESULTS AND DISCUSSION

Effects on weeds

The experimental field was infested various weed species consisting of different species of monocot and dicot weeds. The dominated weed species among monocot weeds were *Cyperus iria, Ehinochloa colona* and *Cynodon dactylon*. However, among dictot weed species, *Eclipta alba, Commelina diffusa, Alternenthera sessilis* and *Phylanthus niruri* were observed during the growing season. The weed density and weed dry weight was significantly differ with the sowing methods and also with the weed control practices (Table 1). Among the different sowing methods, the higher density of monocot (43.2/m^2) and dicot (34.4/m^2) weeds were recorded under flat bed method of sowing and lowest weed density of monocot and dicot (25.1 and 18.7/m^2) weed under BBF method of sowing. However, among different weed control practices, application of pendimethain (1 kg/ha) *fb* imazethapyr (100g/ha) recorded lowest density of monocot and dicot weeds (23.1 and 16.1/m^2). The density of monocot (74.4/m^2) and dicot (98.4/m^2) weeds in control plot was higher. Habimana *et al*. (2013a) reported similar observation that pendimethalin (0.75 kg/ha) at 3 DAS *fb* imazethapyr (100 g/ha) at 20 DAS recorded minimum weed density and weed dry weight as compare to alone application of pendimethalin. The weed dry weight of the monocot and dicot weeds was highest in flat bed sowing method (21.2 and 32.2 g/m^2) and control plot (54.1 and 86.1 g/m^2) among different treatment because of higher infestation of different weed species. However, weed dry weight of monocot and dicot was lowest in case of BBF sowing methods (15.0 and 17.5 g/m^2).

Weed control efficiency

Maximum weed control efficiency (80.1%) was observed with the application of pendimethalin (0.75 kg/ha) *fb* imazethapyr (0.75 kg/ha). The higher weed control efficiency with pendimethalin *fb* imazethapyr may be contributed to the lowest weed competition and resulted higher grain yield. However, among different method of sowing BBF method also contributed the higher weed control efficiency 76.9%, followed by ridge furrow method (71.9%). Habimana *et al*. (2013a) also reported that pendimethalin at 0.75 kg/ha at 3 DAS *fb*. imazethapyr at 0.75 g/ha at 20 DAS recorded 81.9% weed control efficiency in soybean crop.

Table 1. Weed density and weed dry weight as influenced by sowing methods and herbicides (mean of 2-011 and 2012)

Treatment	Density of monocot weeds (no./m^2)	Density of dicot weeds (no./m^2)	Dry weight of monocot weeds (g/m^2)	Dry weight of dicot weeds (g/m^2)
Sowing method				
Flat bed	6.6 (43.2)	5.9 (34.4)	4.6 (21.2)	5.7 (32.2)
Broad bed furrow	5.0 (25.1)	4.3 (18.6)	3.9 (15.0)	4.2 (17.5)
Ridge and furrow	6.2 (38.7)	5.1 (25.5)	4.1 (16.4)	4.8 (23.2)
LSD (P=0.05)	0.36	0.66	0.24	0.54
Herbicide				
Pendimethalin (1.0 kg/ha)	7.1 (50.1)	6.6 (43.3)	5.5 (30.4)	6.2 (38.3)
Imazethapyr (1.0 kg/ha)	6.3 (39.3)	5.0 (25.1)	4.9 (23.9)	5.9 (35.2)
Pendimethalin (0.75 kg/ha) *fb* Imazethapyr (0.75 g/ha)	4.8 (23.1)	4.0 (16.0)	3.6 (12.6)	4.0 (15.7)
Control	8.6 (74.4)	9.9 (98.3)	7.3 (54.1)	9.3 (86.1)
LSD (P=0.05)	1.32	0.99	0.45	0.20

Table 2. Weed control efficiency and economics of soybean as influenced by sowing methods and herbicides

Treatment	Weed control efficiency (%)		Mean	Net monetary returns (x10^3/ha)		Mean	B:C ratio		Mean
	2012	2013		2012	2013		2012	2013	
Sowing method									
Flat-bed	60.6	63.4	62.0	6.47	7.98	7.23	1.36	1.44	1.40
Broad-bed furrow	74.7	79.1	76.9	15.93	17.23	16.58	1.84	1.91	1.87
Ridge furrow	69.0	74.8	71.9	13.78	14.81	14.30	1.75	1.80	1.77
Herbicide									
Pendimethalin (1.00 kg/ha)	48.5	53.9	51.2	10.51	11.41	10.96	1.55	1.60	1.58
Imazethapyr (1.00 kg/ha)	54.8	61.2	58.0	11.27	12.33	11.80	1.59	1.65	1.62
Pendimethalin (0.75 kg/ha) *fb* Imazethapyr (0.75 g/ha)	75.9	84.1	80.0	13.29	14.09	13.69	1.66	1.70	1.68
Control	0.0	0.0	0.0	2.56	3.52	3.04	1.14	1.20	1.17

Table 3. Yield attributes and yield of soybean crop as influenced by sowing methods and herbicides

Treatment	Plant height (cm)	Branches/ plant	Pods/ plant	Seed index (g)	Grain yield (t/ha)		Mean	Straw yield (t/ha)		Mean
					2012	2013		2012	2013	
Sowing method										
Flat-bed	65.6	3.45	60.3	9.76	1.01	1.07	1.04	1.21	1.28	1.24
Broad-bed furrow	84.1	5.73	90.4	10.40	1.44	1.49	1.47	1.48	1.54	1.51
Ridge furrow	77.1	5.12	83.4	10.10	1.33	1.37	1.35	1.45	1.45	1.45
LSD (P=0.05)	5.42	0.46	5.83	0.25	0.05	0.06	0.05	0.02	0.03	0.33
Herbicide										
Pendimethalin (1.00 kg/ha)	68.8	4.57	71.0	10.10	1.22	1.25	1.24	1.26	1.30	1.28
Imazethapyr (1.00 kg/ha)	70.0	4.77	76.8	10.12	1.25	1.29	1.27	1.31	1.37	1.34
Pendimethalin (0.75 kg/ha) *fb* imazethapyr (0.75 g/ha)	78.1	5.34	87.1	10.34	1.37	1.41	1.39	1.37	1.46	1.41
Control	58.8	3.81	55.1	9.57	0.84	0.88	0.86	1.16	1.24	1.20
LSD (P=0.05)	1.37	0.18	4.32	0.17	0.08	0.03	0.04	0.04	0.44	0.05

Yield attributes and yield

Soybean grown in BBF recorded higher plant height (84.12 cm), number of branches (5.7), number of pods (90.4) and seed index (10.40 g) *fb* ridge and furrow sowing method. The plant of flat bed sowing recorded lowest plant height (65.6 cm), number of branches (3.4) number of pods (60.3) and seed index (9.76 g). The grain (1.47 t/ha) and straw (1.51 t/ha) yields of soybean crop was also highest in BBF sowing method and lowest in flat bed sowing method (1.04 and 1.24 t/ha). Similar findings also reported by Kang *et al.* (2012). Among different weed control practices, application of pendimethalin *fb* imazethapyr recorded highest plant height (78.1 cm), number of branches (5.34), number of pods (87.1) and seed index (10.34 g). The grain and straw yield was also higher with the application of pendimethalin *fb* imazethapyr (1.39 and 1.41 t/ha), whereas control plot recorded lowest yield attributes, grain (0.86 t/ha) and straw yield (1.20 t/ha) of soybean due to higher weed density. Habimana *et al.* (2013a) similarly reported that pendimethalin *fb* imazethapyr recorded highest grain and straw yields in soybean.

Economics

Net monetary returns and B:C ratio were higher with the BBF sowing method (` 16,584/ha and 1.87, respectively) than other sowing method of soybean. Ram *et al.* (2011) also reported that NMR and B:C ratio were highest in raised bed sowing (2.12) method which were significantly higher than ridge furrow (1.99) and flat-bed method of sowing (2.00). Application of pendimethalin *fb* imazethapyr recorded higher NMR (` 13,696/ha) and B:C ratio (1.68) among the weed control practices (Habimana *et al.* 2013b). The control plot recorded lowest NMR (` 3,045/ha) and B:C (1.17) ratio among all the treatments because of lowest yield of soybean crop.

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Determination of critical period of crop-weed competition in sesame

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ABSTRACT

A field experiment was conducted during summer season of 2006 and 2007 under irrigated condition in a sandy loam soil at Sriniketan, West Bengal to determine the critical period of crop-weed competition in sesame. Results revealed that weed-free condition between 15 and 45 days after sowing (DAS) significantly increased the yield of sesame, whereas the lower yield of was recorded when weeds were allowed to grow during this period. The maximum competition between crop and weed was between 15 and 45 DAS, which can be considered as critical period of crop-weed competition. However, the extrapolated critical period was determined from 19-42 DAS. To avoid the yield loss, weed management should be done in such a time so that minimum weed infestation is achieved in summer sesame.

Key words: Critical period, Precision Sesame, Weed competition, Weed management

Sesame ranks third in terms of total oilseed area and fourth in terms of total oilseed production in India. The average yield of sesame is very low (274 kg/ha) (Anonymous 2012a). It is one of the important oilseed crops in West Bengal mainly grown on marginal lands with minimum care. Sesame is cultivated in summer, *Kharif* and post- *Kharif* season on an area of about 0.18 m ha (Anonymous 2012b). The area, production and productivity of sesame are higher in summer season than other seasons. Out of several factors, weed competition is considered to be the most important responsible for low productivity of the crop. Prevalence of high temperature with high relative humidity and frequent rainfall during the crop season coupled with slow early growth favour luxuriant weed growth since seedling emergence, resulting in about 50-75% reduction in seed yield (Bhadauria *et al.* 2012). Determination of exact critical period of weed competition in sesame is essential for timely and effective weed management and higher productivity and profitability. The present investigation was carried out to determine the critical period of weed competition in summer sesame of West Bengal.

MATERIALS AND METHODS

An experiment was conducted at agricultural farm of the Institute of Agriculture, Visva-Bharati University, Sriniketan, West Bengal in summer season of 2006 and 2007. The soil of the experimental field was sandy-loam in texture, poor in organic C, medium in fertility status and acidic in nature. Ten treatments, *viz*. weedy for initial 15, 30, 45 and 60 DAS and then weed-free, and weed-free for initial 15, 30, 45 and 60 DAS and then weedy, weed-free and weedy up to harvest were assigned in a randomized block design with three replications. The sesame variety '*Rama*' ('*Improved Selection-5*') was sown with seed rate of 4.5 kg/ha in rows 30 cm apart. The crop was fertilized with 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha in the form of urea, single superphosphate and muriate of potash, respectively. Half of the N and full dose of P and K were broadcast at the time of sowing, while the remaining N was applied at 30 DAS. The net plot size was 5.0 × 3.0 m. Complete weed removal was practiced through hand weeding in weed-free plots right from the germination. However, later weeds were hand pulled as and when emerged. In weedy plots no weed control measures had been employed. In all other weedy treatments, *viz.* weedy up to 15, 30, 45 and 60 DAS, the weeds were allowed to grow up to the respective days, thereafter, complete weed removal was practiced. In other treatments having certain weed-free periods *viz.* weed-free up to 15, 30, 45 and 60 DAS, the weeds were completely removed from the plot up to the respective days and after that the weeds were allowed to grow freely. Seed yield of each treatment was recorded and worked out as per cent of weed-free check.

RESULTS AND DISCUSSION

Weed flora

The total number of weed species present in the experimental field was eight under four families and two categories – four broad-leaved and four grasses. The species under grass category were: *Digitaria sanguinalis*, *Echinochloa colona*, *Eleusine indica* and *Dactyloctenium aegyptium* and those under broad-leaved were *Spilanthes*

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acmella, Trianthema portulacastrum, Tephrosia purpurea and *Ageratum conyzoides*. Species-wise data of weed composition revealed that *Digitaria sanguinalis* among the grassy weeds and *Spilanthes acmella* among the broadleaved weeds were the most dominant at 60 DAS. The grassy weed *Digitaria sanguinalis* was the most predominant (66.7%) among the total weed species present followed by *Spilanthes* (15.5%). The experimental field was mostly dominated by grassy weed, which comprised of about 80% of the total weed population.

Effect on weeds

Weedy check recorded significantly higher number as well as dry matter of grassy weeds at 60 DAS than that of rest of the treatments during both the years, followed by that of weedy up to 60 DAS then weed-free, and weed-free 15 DAS then weedy treatments, which were statistically at par. The other treatments *i.e.* weed -free, weedy up to 15 DAS and then weed-free, weedy up to 30 DAS and then weed-free, weedy up to 45 DAS and then weed-free and weed-free 60 DAS then weedy remained comparable with each other (Table 1). The treatment weed-free up to 30 DAS recorded significantly lower number of grassy weed than that of weed-free for first 15 DAS. However, the number of grassy weed was significantly lower in weed-free up to 45 DAS then weedy over that of weed-free 30 DAS then weedy.

Similar trend was observed in case of broadleaved weeds as well as total number of weeds where weedy check recorded significantly higher number and dry matter of broadleaved weeds and total numbers of weeds at 60 DAS and was at par with those of weedy up to 60 DAS and then weed-free, and weed-free 15 DAS and then weedy treatment. The remaining treatments including weed-free, weedy up to 15 DAS then weed-free, weedy up to 30 DAS then weed-free, weedy up to 45 DAS then weed-free and weed-free 60 DAS then weedy were at par with each other.

The highest number and dry weight of grassy, broadleaved and total weeds was recorded in the treatment where weeds were allowed to grow up to maturity, and it was equivalent with that of weedy up to 60 DAS and then weed-free, and weed-free 15 DAS and then weedy treatments when observations were taken at 60 DAS. Thus, any attempt to make weed-free condition at very initial stage of crop growth had no impact on reducing the number as well as dry weight of grassy, broadleaved and total weeds. However, when the weed-free conditions were extended from 15 DAS onwards, the number as well as dry weight of weeds progressively reduced significantly. Similar observations were reported by Das and Yaduraju (1996) and Wanjari *et al.* (2000).

Table 1. Effect of weed competition treatments on density and biomass of weed in summer sesame at 60 DAS

Treatment	Weed density (no./m^2)						Weed biomass (g/m^2)					
	2006			2007			2006			2007		
	Grasses	BLW	Total	Grasses	BLW	Total	Grasses	BLW	Total	Grasses	BLW	Total
Weedy up to 15 DAS and then weed-free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
Weedy up to 30 DAS and then weed-free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
Weedy up to 45 DAS and then weed-free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
Weedy up to 60 DAS and then weed-free	13.92 (193.3)	8.09 (78.7)	16.50 (272.0)	14.97 (223.6)	8.89 (78.5)	17.39 (302.1)	12.20 (148.3)	2.75 (7.1)	12.48 (155.4)	11.88 (140.6)	3.03 (8.7)	12.64 (159.3)
Weed-free 15 DAS and then weedy	13.72 (187.7)	7.74 (59.4)	15.73 (247.1)	14.19 (200.9)	8.77 (76.4)	16.66 (277.3)	11.56 (133.1)	2.65 (6.5)	11.85 (139.7)	11.76 (137.7)	2.84 (7.6)	12.07 (145.3)
Weed-free 30 DAS and then weedy	10.01 (100.0)	5.52 (29.9)	11.42 (129.9)	10.49 (109.5)	6.12 (36.9)	12.1 (146.6)	0.71 (0.0)	2.12 (3.9)	9.19 (83.9)	9.24 (84.9)	2.05 (3.7)	9.44 (88.6)
Weed-free 45 DAS and then weedy	6.96 (47.9)	4.15 (16.7)	8.07 (64.7)	6.64 (43.6)	4.72 (21.8)	8.12 (65.4)	5.39 (28.6)	1.67 (2.3)	5.59 (30.8)	5.76 (32.0)	1.07 (0.6)	5.76 (32.6)
Weed-free 60 DAS and then weedy	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
Weed-free	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
Weedy	14.84 (219.7)	8.27 (67.9)	16.97 (287.6)	15.02 (225.1)	9.30 (85.9)	17.64 (310.7)	12.26 (149.0)	2.92 (8.0)	12.59 (157.7)	12.43 (154.0)	3.04 (8.7)	12.77 (162.7)
LSD (P=0.05)	1.132	0.567	1.250	0.839	0.595	1.028	0.831	0.285	0.757	0.822	0.274	0.807

Table 2. Effect of weed competition treatments on yield components and yield of sesame at harvest

Treatment	No. of capsules/plant		No. of seeds/ capsule		1000-seed weight (g)		Seed yield (t/ha)		Seed yield (% of weed-free check)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Weedy up to 15 DAS and then weed-free	54.5	49.8	44.0	38.0	2.5	2.6	1.24	0.99	93.5	90.0
Weedy up to 30 DAS and then weed-free	39.4	35.4	33.0	31.0	2.5	2.5	0.71	0.60	53.8	54.9
Weedy up to 45 DAS and then weed-free	35.5	31.1	34.0	30.0	2.4	2.5	0.58	0.47	43.9	42.6
Weedy up to 60 DAS and then weed-free	32.1	30.8	33.0	30.0	2.4	2.4	0.51	0.41	38.4	37.7
Weed-free 15 DAS and then weedy	36.9	31.7	35.0	32.0	2.4	2.5	0.62	0.50	46.9	45.3
Weed-free 30 DAS and then weedy	46.0	46.4	40.0	36.0	2.5	2.5	1.02	0.84	77.2	76.2
Weed-free 45 DAS and then weedy	54.1	50.0	44.0	38.0	2.5	2.6	1.19	0.99	90.2	90.2
Weed-free 60 DAS and then weedy	54.3	51.1	45.0	40.0	2.6	2.6	1.27	1.06	96.2	96.9
Weed-free	58.6	51.6	46.0	40.0	2.6	2.6	1.32	1.10	100	100
Weedy	31.9	30.2	33.0	30.0	2.4	2.4	0.51	0.41	38.4	37.4
LSD (P=0.05)	6.4	3.5	6.1	4.3	NS	NS	0.15	0.11	-	-

Yield components and yield

The highest number of capsules/plant and seeds/capsule was produced in weed-free throughout the period. The treatments weed-free, weedy up to 15 DAS and then weed-free, weed-free 45 DAS and then weedy, and weed-free 60 DAS and then weedy were statistically at par with respect to production of capsules/plant and weed-free for first 30 DAS and then weedy. The lowest number of capsules/plant and seeds/capsule was observed under weedy check, which was comparable with that of weedy up to 45 DAS and then weed-free, weedy up to 60 DAS and then weed-free, and weed-free 15 DAS and then weedy treatment weed-free(Table 2). However, test weight of sesame did not vary significantly. Seed yield of sesame was significantly higher in weed-free situation maintained throughout the growing period than that of weedy check treatments, and it was at par with that of weedy up to 15 DAS and then weed-free, weed-free 45 DAS and then weedy, and weed-free 60 DAS then weedy treatments. The lowest seed yield was recorded in weedy check treatment and it was comparable with that of weedy up to 45 DAS and then weed-free, weedy up to 60 DAS and then weed-free, and weed-free 15 DAS then weedy treatments. The maintenance of weed-free condition for first 30 DAS registered significantly higher seed yield than that of the situation where weeds were allowed to grow for first 30 days and then weed-free. The weed- free conditions between 15 and 45 DAS significant increased the yield of sesame whereas the minimum yield was recorded when weeds were allowed to grow during this period (Table 2, Fig. 1 and 2). The maximum competition between crop and weeds was between 15 and 45 DAS, which can be considered as critical period of crop weed competition in case of summer sesame. The results were in conformity with Singh *et al.* (1993) and Venkatakrishnan and Gnanamurthy (1998).

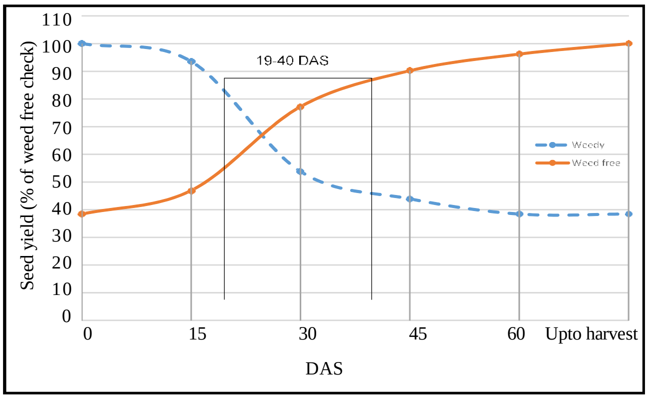

Fig. 1. Critical period of weed competition in sesame (2006)

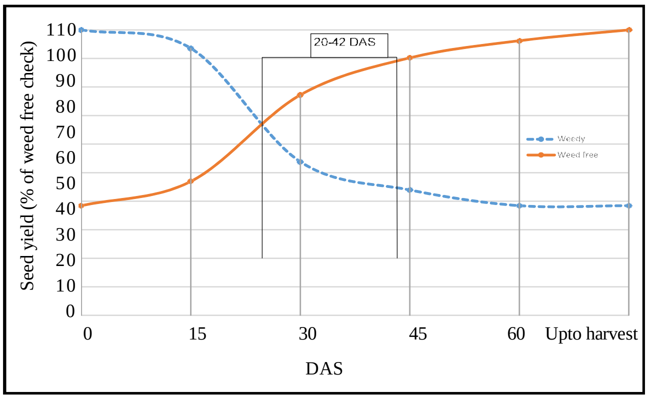

Fig. 2. Critical period of weed competition in sesame (2007)

Seed yield of sesame (% of weed-free check)

To determine the critical period of weed competition, the sesame seed yield was expressed in terms of per cent yield over weed-free check and presented in Table 2. The highest seed yield on the basis of percentage of weed-free check was recorded in the plot weed-free up to 60 DAS and then weedy, followed by that of weed-free up to 45 DAS and then weedy treatments. The lowest value was recorded in weedy check, followed by that in weedy up to 60 DAS and then weed-free, weedy up to 45 DAS and then weed-free, weed-free up to 15 DAS and then weedy, and weedy up to 30 DAS and then weed-free treatments. Maximum yield loss due to weed competition was to the tune of 61.6 and 62.6% in 2006 and 2007, respectively. Weedy for first 45 days resulted in 56.1-57.4%.

Critical period of weed competition

Weed-free condition between 15 and 45 DAS resulted in significant increase in the yield of sesame whereas the minimum yield was recorded when weeds were allowed to grow during this period. Thus, it was observed that the critical period of weed competition in sesame was between 15-45. However for determining the exact critical period of weed competition, the data on seed yield was first converted into per cent considering weed-free as 100%. Then two curves were drawn by selecting two items i. e. first some days weed-free then weedy and weed infestation for first few days and then weed-free treatments in the same graph. After analyzing the data, the LSD (P=0.05) for seed yield was determined. The value of the LSD was converted into per cent of weed-free check (8.8 and 10.0% in 2006 and 2007, respectively). By using the LSD per cent value, it was seen up to which weedy period the seed yield was statistically at par with weed-free check. From the graph (Fig. 1 and 2), an extrapolated critical period of weed competition was worked out in summer sesame under irrigated condition. It was between 19-40 and 20-42 DAS in 2006 and 2007, respectively.

To avoid the yield loss of sesame, the weed control measures should be taken in such a time so that minimum weed pressure will be there during 19-2 DAS or the effect of any weed management practices should be long enough to cover this critical period of competition in the lateritic soil of West Bengal.

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Integrated weed management studies in sugarcane ratoon

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ABSTRACT

A field experiment was conducted at GB Pant University of Agriculture & Technology, Pantnagar (Uttarakhand) to study the effect of different weed management practices on sugarcane ratoon. The soil of the experimental field was clay loam in texture, medium in organic carbon (0.64 %), available phosphorus (26.5 kg P/ha) and potassium (240.3 kg K/ha) with P^H 7.3. Experiment consisted of eight treatments was laid out in randomized block design with three replications. In the experimental field, *Digitaria sanguinalis, Echinochloa* spp., *Ipomoea* spp.,*Cyperus rotundu* and *Parthenium hysterophorus* were major weeds in both the years. Other weeds were *Brachiaria mutica, Euphorbia hirta, Cleome viscosa, Phyllanthus niruri, Cannabis sativa, Lippia graveolens, Trichosanthes cucumerina* and *Physalis minima.* Lowest density as well as dry weight of total weeds were recorded with hand weeding thrice at 30, 60 and 90 days after ratoon (DAR) of main crop which was at par with metribuzin 0.88 kg/ha at 3 DAR followed by (*fb*) one hoeing at 45 DAR followed by (*fb)* 2,4-D (Na Salt) 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds *fb* pre-emergence application of atrazine 1.5 kg/ha at 3 days after ratooning (DAR) *fb* 2,4-D (Na salt) 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds. The highest cane yield was recorded with the execution of three hand weedings at 30, 60 and 90 DAR treatment which was closely *fb* metribuzin at 0.88 kg/ha at 3 DAR *fb* one hoeing at 45 DAR *fb* 2,4-D (Na salt) 0.75kg / ha at 2-4 leaf stage of weeds.

Key wards: Density, Hand weedings, Herbicide, Integrated weed management, Sugarcane ratoon

Sugarcane is a long duration crop which takes longer time for germination due to which crop faces tough competition with weeds between 60 to 120 days of its planting which causes heavy reduction in cane yield ranging from 40-67% (Chauhan and Srivastava 2002). Sugarcane ratoon occupies about 50% of total sugarcane area, though its productivity is quite low (45 t/ha) against 80 t/ha, productivity of main planted crop. This low productivity is mainly due to heavy weed infestation (Srivastava *et al.* 2002). Widely spaced crop of sugarcane allows wide range of weed flora to grow profusely in the interspaces between the rows. Frequent irrigations and fertilizer application during early growth phases increase the weeds menace by many folds in the crop (Singh *el al.* 2008). It is well known that cultural method of weed management is most effective to control weeds but timely availability of labours is a problem besides increase in wages. Therefore, herbicidal control of weeds has been considered to be economical in sugarcane (Chauhan*el al.* 1994). Several herbicides have, been tried in sugarcane ratoon with varying degree of success but the information on combined use of chemical and cultural practices are scarce. The present investigation was undertaken to study the integrated weed management practices in the sugarcane ratoon crop.

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MATERIALS AND METHODS

A field experiment was conducted during 2011 and 2012 at Norman E. Borlaug, Crop Research Centre, G.B. Pant University of Agriculture & Technology, Pantnagar (Uttarakhand). The soil of experimental field was clay loam in texture, medium in organic carbon (0.64%), available P (26.5 kg P /ha) and K (240.3kg K/ha) with p^H 7.3. Experiment consisted of eight treatments *viz.* pre-emergence application of atrazine 1.5 kg/ha at 3 days after ratooning (DAR), 2, 4-D (Na salt) 0.75kg/ha at 2-4 leaf stage of broad-leaved weeds, atrazine 1.5 kg/ha at 3 DAR *fb* 2, 4-D (Na salt) 0.75kg/ha at 2-4 leaf stage of broad-leaved weeds, metribuzin 0.88 kg/ha at 3 DAR *fb* one hoeing at 45 DAR *fb* 2,4-D (Na salt) 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds, ethoxysulfuron 37.5 g/ha at 2-4 leaf stage of weeds, chlorimuron-ethyl 10% + metsulfuron-methyl 10% 8 g/ha at 2-4 leaf stage of broad-leaved weeds, hand weeding at 30, 60 and 90 days after ratooning with weedy check (Table 1) were laid out in randomized block design with three replications. Three budded setts of sugarcane variety '*Co. Pant 90223*' ware planted on 16 February, 2010 and March 13, 2011, respectively. Herbicides as per treatments were applied as spray using 600 literes of water per hectare. The crop was harvested on 15 February, 2011 during first year and 12 March, 2012 during second year. Data pertaining to density and dry matter accumulation by weeds were subjected to log transformation by adding 1.0 to original values prior to statistical analysis.

RESULTS AND DISCUSSION

In the experimental field, *Digitaria sanguinalis, Ehinochloa* spp., *Ipomoea* spp.,*Cyperus rotundus, Solanum nigrum* and *Parthenium hysterophorus* were major weeds in both the years. Other weeds were *Euphorbia hirta, Cleome viscosa, Phyllanthus niruri, Cannabis sativa, Luffa graveolans, Trichosanthus cucumerina* and *Physalis minima.*

All the weed control measures led to significant reduction in density and dry matter accumulation by total weeds during both the years (Table 1). Lowest density (Table 1) as well as dry weight (Table 2) of total weeds were recorded under the treatment of three hand weeding at 30, 60 an 90 DAR which was at par with pre-emergence application of metribuzin at 0.88 kg/ha at 3 DAR *fb* one hand weeding at 45 DAR *fb* 2,4-D Na salt 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds but recorded significant superiority over rest of the treatments. Among the herbicidal treatments, metribuzin at 0.88 kg/ha at 3 DAR *fb* one hand hoeing at 45 DAR *fb* 2,4-D 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds recorded lowest density and dry weight of total weeds which was at par with application of atrazine 1.5 kg/ha at 3 DAR *fb* 2,4-D (Na salt) 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds and chlorimuron-ethyl 10% + metsulfuron-methyl 10% 08 g/ha at 2-4 leaf stage of broad-leaved weeds in respect to total weeds density where as application of metribuzin at 0.88 kg/ha at 3 DAR *fb* one hand hoeing at 45 DAR *fb* 2,4-D 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds being at par with atrazine 1.5 kg/ha at 3 DAR *fb* 2,4-D 0.75 kg/ha at 2-4 leaf stage of broad-leaved weeds recorded significantly lower total weed dry weight as compared to rest of the herbicidal treatments.

On an average, presence of total weeds throughout the crop period caused 56.70% reduction in the ratoon cane yield when compared with the execution of three

Table 1. Effect of weed management treatments on density of weeds at 120 days after ratooning (DAR).

Treatment	Weed density (no./m^2)												Total weeds	
	C. rotundus		*Digitaria sanguinalis*		*Echinochloa* spp.		*P. hysterophorus*		*Ipomoea* spp.		Other weeds			
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Atrazine 1.5 kg/ha , PE at 3 DAR (days after ratooning)	3.62 (37)	3.65 (41)	1.92 (7)	2.01 (8)	2.94 (19)	2.94 (19)	2.69 (15)	2.32 (9)	2.34 (11)	2.44 (11)	2.32 (9)	2.90 (17)	4.67 (107)	4.75 (116)
2,4-D (na-salt) 0.75 kg/ha at 2- 4 leaf stage of broad-leaved weeds(BLW)	3.08 (21)	3.35 (29)	2.73 (15)	3.09 (23)	3.79 (44)	3.65 (39)	1.07 (3)	1.07 (3)	1.07 (3)	0.54 (1)	2.00 (7)	2.21 (9)	4.59 (114)	4.73 (112)
Atrazine 1.5 kg/ha at 3 DAR *fb* 2, 4-D 0.75 kg/ha at 2-4 leaf stage of BLW	3.14 (23)	3.27 (27)	2.32 (9)	2.32 (9)	3.09 (21)	3.08 (21)	0.53 (1)	0.54 (1)	0.54 (1)	0.0 (0)	1.81 (5)	2.01 (8)	4.19 (68)	4.28 (73)
Metribuzin 0.88 kg/ha at 3DAR *fb* one hoeing at 45 DAR *fb* 2,4-D 0.75 kg/ha at 2-4 leaf stage of BLW	2.69 (15)	2.91 (20)	2.00 (7)	1.81 (5)	2.72 (15)	2.41 (11)	0.53 (1)	0.0 (0)	0.54 (1)	0.0 (0)	1.07 (3)	1.27 (4)	3.86 (47)	3.79 (44)
Ethoxysulfuron 37.5 g/ha at 2-4 leaf stage of weeds	1.27 (4)	1.07 (3)	2.69 (15)	3.18 (24)	3.72 (41)	3.55 (35)	3.14 (23)	0.54 (1)	1.07 (3)	1.27 (4)	2.00 (7)	1.81 (5)	4.59 (93)	4.33 (76)
Chlorimuron -ethyl 10% +metsulfuron-methyl 10% 8 g/ha at 2-4 leaf stage of BLW	2.44 (11)	2.60 (13)	2.87 (17)	2.97 (21)	3.77 (43)	3.72 (41)	0.0 (0)	0.0 (0)	0.54 (1)	0.0 (0)	2.12 (8)	1.81 (5)	4.42 (97)	4.42 (83)
Hand weeding at 30, 60 and 90 DAR	2.41 (11)	2.34 (12)	1.07 (3)	1.07 (3)	3.80 (5)	1.27 (4)	0.0 (0)	0.0 (0)	1.07 (3)	1.27 (4)	0.53 (1)	1.07 (3)	3.16 (27)	3.22 (26)
Weedy check	3.56 (35)	3.79 (45)	2.88 (17)	3.14 (23)	3.56 (35)	3.59 (37)	2.94 (19)	2.92 (19)	2.69 (15)	2.87 (17)	2.87 (17)	3.22 (25)	5.02 (163)	5.21 (182)
LSD (P=0.05)	0.90	1.04	0.86	0.90	0.47	0.68	1.07	1.05	1.57	1.25	1.03	1.15	0.72	0.61

Data in parentheses indicate actual values and transformed to loge (x+1)

Table 2. Effect of treatments on total weed dry weight, yield attributing characters and cane yield of sugarcane ratoon

Treatment	Weed dry weight (g/m^2) at 120 DAP		WCE (%)		Cane length (cm)		Millable cane (x10$^{3`}$/ ha)		Cane yield (t/ha)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Atrazine 1.5 kg/ha, PE at 3 DAR (days after ratooning)	4.97 (142.9)	5.05 (155.6)	53.2	54.7	162.9	152.9	175.8	165.1	67.9	60.9
2, 4-D (Na-salt) 0.75 kg/ha at 2- 4 leaf stage of broad-leaved weeds (BLW)	5.13 (169.1)	(5.21 182.3)	44.6	46.9	156.5	146.0	144.8	141.8	57.9	52.5
Atrazine 1.5 kg/ha at 3 DAR fb 2, 4-D (Na-salt) 0.75 kg/ha at 2-4 leaf stage of BLW	4.50 (88.4)	4.56 (95.7)	71.0	72.1	166.1	157.4	188.7	178.7	78.3	72.0
Metribuzin 0.88 kg/ha at 3DAR *fb* one hoeing at 45 DAR *fb* 2, 4-D 0.75 kg/ha at 2-4 leaf stage of BLW	3.77 (42.4)	3.66 (38.3)	86.1	88.8	169.5	161.7	197.7	188.5	82.4	76.0
Ethoxysulfuron 37.5 g/ha at 2-4 leaf stage of weeds	5.01 (150.0)	5.11 (167.0)	50.9	51.3	159.7	149.5	150.9	145.8	60.5	54.1
Chlorimuron-ethyl 10% + metsulfuron-methyl 10% 8 g/ha at 2-4 leaf stage of BLW	5.05 (155.9)	5.09 (162.4)	49.0	52.7	158.0	147.9	149.5	147.5	59.4	54.1
Hand weeding at 30, 60 and 90 DAR	2.98 (18.7)	2.84 (16.5)	93.9	95.2	170.7	163.7	202.3	193.8	84.9	78.8
Weedy check	5.72 (305.5)	5.84 (343.2)	-	-	152.5	141.2	94.7	86.6	37.5	32.8
LSD (P=0.05)	0.82	0.90	-	-	5.0	6.48	11.7	0.45	3.6	3.7

Data in parentheses indicate actual values and transformed to loge (x+1)

hand weeding at 30, 60 and 90 days after ratooning (Table 2). The highest ratoon yield was obtained with the execution of three hand weeding at 30, 60 and 90 DAR which was closely followed by pre-emergence application of metribuzin 0.88 kg/ha at 3 DAR followed by one hand weeding at 45 DAR followed by 2,4-D at 0.75 kg/ha. The higher cane yield under these treatments was due to higher value of cane girth, cane length and millable cane per hectare.

It was concluded that application of metribuzin at 0.88 kg/ha at 3 DAR followed by one hand weeding at 45 DAR followed by 2,4-D at 0.75 kg/ha at 2-4 leaf stage of broad- leaved weeds of ratoon crop was found most effective for controlling the weeds of sugarcane ratoon crop.

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Effect of weed management on weeds, growth and yield of toria

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ABSTRACT

A field experiment was carried out at Ludhiana, Punjab during 2009 and 2010 to study the effect of different weed control treatments on growth and yield of rapeseed. Eight herbicide treatments, *viz*. trifluralin at 0.48 kg and 0.60 kg/ha (pre-plant and pre-emergence), pendimethalin at 0.56 kg and 0.75 kg/ha (pre-emergence), pendimethalin at 0.75 kg/ha (pre-plant) and oxyfluorfen at 0.25 kg/ha (pre-emergence), two hand weeding (25 and 45 days after sowing) and unweeded control were kept. Two hand weedings, pre-plant application of trifluralin at 0.60 kg/ha, and pre-plant and pre-emergence application of pendimethalin at 0.70 kg/ha significantly decreased dry weight of associated weeds as compared to unweeded control. Weed control efficiency recorded similar trend as of dry matter of weeds. Accordingly, the increased with application of these weed control treatments.

Key words: Pendimethalin, Oxyflourfen, Trifluralin, Toria, Yield

Among the various oilseeds grown in India, rapeseed and mustard group is the second most important crop after groundnut, contributing nearly 18% of the total oilseed production in the country. These crops are grown on an area of 5.59 million ha with a production of about 6.61 million tonnes, out of which Punjab occupies 30,000 ha and produces 39,000 tonnes, respectively (Anonymous, 2011). The agro-climatic conditions in Punjab are congenial for the production of oilseed crops. Rapeseed (toria) is an important oilseed crop. Adoption of high-yielding varieties with the judicious use of inputs and irrigation plays an important role in boosting its production. As it is exclusively grown under irrigated conditions, problem of weeds poses a serious threat to its potential production. The crop is infested with both grasses and broad-leaved weeds, which pose a serious competition during early period of crop growth, and reduce seed yield by 15-20% (Brar *et al*. 1991). Weeds cause enormous damage to the mustard and the magnitude of losses ranges from 30-50%, depending upon the growth and persistence of weed population (Gill *et al.* 1984). Weed competition not only decreases the mustard crop yield but also reduced its quality and market value. In the present study, new herbicides were tried at different levels and compared with recommended treatments to find out the most effective and safe method of weed control in this crop.

MATERIALS AND METHODS

The field investigation was carried out for two years at Punjab Agricultural University, Ludhiana during 2009 and 2010. The soil of the experimental field was loamy sand in texture, low in organic C, low in available N (230 kg/ha), medium in available P (18.6 kg/ha), available K (150 kg/ha), and neutral in reaction. The trial was laid out in randomized block design with four replications. Among the herbicidal treatments, trifluralin at 0.48 kg and 0.60 kg/ha, pendimethalin at 0.56 kg and 0.75 kg/ha as pre-emergance, pendimethalin 0.75 kg/ha as pre-plant and oxyfluorfen at 0.25 kg/ha were applied pre-emergence. In addition, two hand weedings (25 and 45 days after sowing) and unweeded control were also kept for comparison.

The sowing of rapeseed (toria*)* variety '*TL 15*' was done during mid-September, using a seed rate of 3.75 kg/ha at a distance of 30 cm in rows. Plant to plant distance of 10 cm was maintained by thinning after 20 days of sowing. All the nutrients, *i.e.* 62 kg N and 20 kg P_2O_5/ha were applied at the time of sowing. Herbicides were sprayed after dissolving in water as per the treatment with knapsack sprayer fitted with flat fan nozzle using a spray volume of 375 litres/ha. The data on dry matter production by weeds was recorded at 45 days after sowing with the help of quadrat (30 × 30 cm) placed randomly at two spots in each plot. Observations on plant height, branches/plant and siliqua/plant were recorded at harvest from randomly selected five plants from each treated plot. Crop was raised using recommended agronomic practices and protected against insects and diseases. The data on weeds were subjected to square root transformation to normalize their distribution. Weed control efficiency was calculated by using standard formula

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RESULTS AND DISCUSSION

All the weed control treatments reduced the dry matter of weeds significantly as compared with unweeded control (Table 1). Two hand hoeings and pre-plant application of trifluralin at 0.60 kg/ha resulted in minimum dry matter of weeds, which was significantly lower as compared to unweeded control. Hand weeding was at par with most of the herbicidal treatments, *viz*. trifluralin 0.48 kg and 0.60 kg as pre-plant and pre-emergence pendimethalin 0.75 kg/ha as pre-plant, and pendimethalin 0.56 kg and 0.75 kg/ha as pre-emergence in terms of dry matter of weeds. Oxyfluorfen 0.25 kg/ha resulted in significantly higher dry matter of weeds as compared to all other herbicidal treatments. Weed control efficiency recorded a similar trend as of dry matter of weeds. The maximum weed control efficiency (92.0%) was recorded with pre-plant application of trifluralin at 0.60 kg/ha and two hand hoeings. Minimum weed control efficiency (37.7%) was recorded with oxyfluorfen 0.25 kg/ha. Singh *et al.* (2001) reported that while the weed management methods significantly reduced the dry matter of weeds, two manual weeding at 25 and 45 days after sowing were found the most effective in reducing dry matter accumulation of weeds over the other methods of the weed control. Also, Rajput *et al.* (1993) concluded that application of hand hoeing twice at 30 and 45 days after sowing resulted in a decrease in dry weight of weeds associated with Indian mustard plants. Doshora *et al.* (1990) reported that pendimethalin at 0.75 kg/ha was found to be more effective than other treatments.

All the herbicidal treatments registered higher plant height as compared with unweeded control, except oxyfluorfen at 0.25 kg/ha (Table 2). The maximum plant height was recorded under two hand weedings, which

Table 1. Effect of different weed control treatments on dry matter of weeds

Treatment	Dose (kg/ha)	Time of application	Dry matter of weeds (t/ha)			Weed control efficiency (%)		
			2009	2010	Mean	2009	2010	Mean
Trifluralin	0.48	Pre-plant	0.54 (3.47)	0.57 4.00)	0.56 (3.74)	59.1	51.8	55.5
Trifluralin	0.60	Pre-plant	0.100 (0.00)	0.10 (0.00)	0.10 (0.00)	92.4	91.6	92.0
Pendimethalin	0.75	Pre-plant	0.26 (13.9)	0.10 (0.00)	0.18 (0.71)	80.1	91.6	85.9
Trifluralin	0.48	Pre-emergence	0.37 (3.33)	025 (2.25)	0.31 (2.79)	72.3	71.1	71.7
Trifluralin	0.60	Pre-emergence	0.34 (2.78)	0.20 (0.63)	0.27 (1.71)	74.2	82.9	78.6
Pendimethalin	0.56	Pre-emergence	0.31 (2.22)	0.25 (2.25)	0.28 (2.24)	76.4	78.7	77.6
Pendimethalin	0.75	Pre-emergence	0.25 (1.25)	0.10 (0.00)	0.18 (0.63)	80.8	91.6	86.2
Oxyfluorfen	0.25	Pre-emergence	0.81(8.60)	0.76 (5.63)	0.78 (7.12)	38.9	36.5	37.7
Two hand weedings (25 and 45 DAS)	-	-	0.10 (0.00)	0.10 0.00)	0.10 (0.00)	92.4	91.6	92.0
Unweeded Control	-	-	1.32 (17.34)	1.19 (14.88)	1.26 (16.11)	-	-	-
LSD (P=0.05)	-	-	0.46	0.29	-	-	-	-

Data are subjected to square root transformation; values in the parentheses are original values

Table 2. Plant height, number of branches, siliqua/plant and seed yield of toria as influenced by different herbicidal treatments

Treatment	Dose kg/ha	Time of application	Plant height (cm)		No. of branches/plant		No. of siliqua/plant		Seed yield (t/ha)	
			2009	2010	2009	2010	2009	2010	2009	2010
Trifluralin	0.48	Pre-plant	139.2	124.9	8.4	6.6	233.8	238.5	1.81	1.80
Trifluralin	0.60	Pre-plant	136.1	130.7	8.7	6.9	235.0	241.8	1.83	2.01
Pendimethalin	0.75	Pre-plant	137.3	131.4	8.5	7.0	235.9	243.0	1.84	1.97
Trifluralin	0.48	Pre-emergence	135.5	124.2	8.4	6.7	231.9	238.0	1.63	1.77
Trifluralin	0.60	Pre-emergence	133.1	128.2	8.4	6.9	240.3	241.8	1.79	1.89
Pendimethalin	0.56	Pre-emergence	134.9	124.3	8.0	6.8	235.2	239.3	1.67	1.71
Pendimethalin	0.75	Pre-emergence	137.4	133.5	8.4	7.0	234.8	240.8	1.88	2.18
Oxyfluorfen	0.25	Pre-emergence	119.8	116.6	7.2	6.2	199.1	214.3	1.13	1.47
Two hand weedings (25 and 45 DAS)	-	-	138.8	134.0	8.6	7.6	242.0	244.8	1.96	2.20
Unweeded control	-	-	115.4	107.8	8.5	5.9	192.7	229.8	0.99	1.29
LSD (P=0.05)	-	-	15.4	11.5	NS	NS	28.1	7.38	0.32	0.40

was at par with all the herbicidal treatments except oxyfluorfen at 0.25 kg/ha. Oxyflourfen showed phytotoxic effect on the crop. The differences in the number of branches/plant were non-significant. The maximum number of siliqua/plant (242.0) were recorded in two hand weedings, which was closely followed by trifluralin at 0.60 kg/ha. All the herbicidal treatments registered higher number of siliqua/plant as compared with unweeded control, except oxyfluorfen at 0.25 kg/ha. All the weed control methods significantly increased seed yield over unweeded control. Maximum seed yield of 1.96 and 2.20 t/ha was obtained with two hand weedings, which was at par with all other herbicidal treatments and significantly higher than oxyfluorfen at 0.25 kg/ha. The second best treatment was pendimethalin 0.75 applied as pre-emergence. These results are in line with Saudy (2004), Sharma and Jain, (2002). Sidhu *et al*. (1998) reported that pre-emergence application of pendimethalin 0.5 kg/ha was quite safe to crop along with good weed control. Jat and Giri (2000) concluded that the maximum increase in seed yields was recorded with pendimethalin.

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Parthenium invasion in Rawalpindi, Pakistan

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ABSTRACT

Parthenium hysterophorus, is an annual herb that aggressively colonizes disturbed sites. In Pakistan, this weed is spreading very fast especially in north eastern parts of the province, Punjab. Due to lack of information on its spread, a survey was carried out in the district Rawalpindi where 8 sites were selected for sampling. The survey revealed very high density of *P. hysterophorus* at all sites and a total of 33 plant species were associated with *P. hysterophorus*. The relative density of weed in different sites of the district ranged from 8.2-64.5% while the relative frequency ranged from 14.2-29.6%. The extent of infestation was highest in denuded and fallow lands, especially in areas where soil has been disturbed. It was concluded that *Parthenium* is an extremely aggressive and prolific invasive weed in distract Rawalpindi and coordinated efforts are needed to manage this weed to stop its further spread.

Key words: Distribution, Invasive alien species, *Parthenium,* Spread

Parthenium hysterophorus is highly invasive species of global significance. This plant is native to southern United States and Mexico, Central and South America and it has been accidentally introduced into several countries, and has become a serious agricultural and rangeland weed in parts of Australia, Asia and Africa and Pacific Islands (Adkins *et al*. 2010). It grows on any type of soil and in a wide range of habitats. It affects the production of crops, animals, human and animal health, and biodiversity. (Nath 1981, McFadyen 1995, Shabbir and Bajwa 2006). In Pakistan, the first documented report of *P. hysterophorus* date back in 1980 from the Gujarat district of Punjab Province (Razaq *et al*. 1994). It is thought that since then the weed has rapidly spread throughout the province of the Punjab, the Islamabad Capital Territory (ICT) and parts of the Khyber Pukhtunkhwa (KPK) province (Shabbir *et al*. 2012). *Parthenium* is found mostly in naturally disturbed areas and in areas that have poor ground cover such as wastelands, cleared lands, and grazed pastures (Shabbir and Adkins 2008). Other common habitats for this weed include many types of crops, orchards, plant nurseries, public lawns and open spaces in towns, sides of roads, rivers, canals and railway tracks, on construction sites and in forests (Shabbir *et al*. 2012). The core infestations of this weed are in the central and northern districts of the Punjab, including the district of Rawalpindi. As yet little information is available on its spread in this region and its impacts on the local vegetation. The present study is therefore, designed to document the spread of *P. hysterophorus* and its impacts on local plant communities.

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MATERIAL AND METHODS

Rawalpindi is a heavily populated district of the Punjab province, located in the Pothohar region of Pakistan. It is very close to the national capital city of Islamabad, and that's why both cities are well known as twin cities. The climate of the district is a humid subtropical with long and very hot summers, and mild winters, the average annual rainfall is 1100 mm most which fall in summer monsoon. The mean maximum temperature in summer is over 38°C, while mean minimum temperature is 4°C winters. Rainfed agriculture and livestock production is the main economy of the district. Most of the selected filed sites in Rawalpindi were wastelands and situated at 33 °35′ - 33° 45′N and 73° - 73° 5.7′E (Table 1).

Floristic data were collected from 40 randomly selected plots (1 × 1 m) from 8 field sites selected in the district Rawalpindi. Most of the selected sites were wastelands except Ayub National Park and Morgah (a rainfed pasture, Table 1) and there were five plots at each location. The data was collected in the summer (July – September). All plant species growing in these plots were counted and identified by referring work of Stewart (1972) and Nasir *et al.* (1987). The collections of National Herbarium, NARC and Natural History Museum, Islamabad were also consulted for identification of plants.

RESULTS AND DISCUSSION

The survey revealed a total of 33 plant species belonging to more than 16 angiospermic plant families accompanied with *P. hysterophorus*. Most of the sites in district Rawalpindi were heavily infested with *P.*

Table 1. Locations and characteristics in district Rawalpindi

Sites	Latitudes (Decimal deg.)	Longitudes (decimal deg.)	Site characteristics
Dhoke khaba	33.608 N	73.081 E	Wasteland
Satellite town	33.635 N	73.072 E	Wasteland
Pirwadhai	33.616 N	73.022 E	Wasteland
Chaklala	33.632 N	73.039 E	Wasteland
Ayub National Park	33.582 N	73.092 E	National park
Tench bhata	33.571 N	73.083 E	Wasteland
Westridge	33.588 N	73.035 E	Wasteland
Morgah	33.531 N	73.084 E	Pasture

hysterophorus. In general, plants associated with *P. hysterophorus* in different sites showed independent associations, which over all reflect the herbaceous flora of these habitats in the district Rawalpindi.

At the Westridge site, *P. hysterophorus* was found to be dominated weed species which was accompanied by twelve other plant species. *Lantana camara* and *Cynodon dactylon* were co-dominant with *Parthenium* at this site. *Amaranthus viridus* was observed to be a common weed of wastelands and roadsides, having third highest relative density (10.2%) after *Parthenium* (17.9%) and *C. dactylon* (15.3% (Table 2). *Convolvulus arvensis, Alternanthera pungens, Achyrenthes aspera, Sacchrum spontanum* and *Cassia occidentalis* had overlapping values of relative frequency of occurrence i.e. 5.1%. The Westridge site is among one of the highly populated suburban areas of the district Rawalpindi and *P. hysterophorus* was generally found in disturbed and unmanaged lands.

The herbaceous vegetation of wastelands of Pirwadhai site recorded a total of 16 weed species in association with *P. hysterophorus*. *Parthenium hysterophorus* was again the most dominant weed species of wastelands with the highest relative density (39 %) followed by *C. dactylon* (21 %) and *A. pungens* (7 % (Table 2). *Elucine indica, A. aspera, Datura innoxia, C. occidentalis, Atylosia mollis, Boerhaavia procumbens, Euphorbia prostrata, Sida cordata*, *Desmostachya bipinnata*, were found in limited associations. The relative frequency of occurrence of plant species other than dominants ranged from 2.7-5.5%. This site is adjacent to Islamabad Capital Territory and a general bus stand is also situated in this area. The high density of *P. hysterophorus* at this site could be due to seed spared by vehicles as this weed has been reported to be spread mainly by vehicles and farm machinery (Parsons and Cuthbertson 1992).

At the satellite town, the most dominant plant species was *A. pungens* with highest relative density (29%) followed by *C. dactylon* (28%) and *D. bipinnata* (19%). *Parthenium hysterophorus* in this sector had frequent to occasional level of occurrence that was significantly lower than the other dominants (Table 2). *Alternathera pungens* is another alien plant species spreading very fast in this region and is very common along the roadsides and in horticultural parks.

The floristic composition of the Chaklala site indicated that *P. hysterophorus* was the most dominant species accompanied by twenty other plant species (Table 2). As most of the long distance dispersal of this weed is by vehicles and farm machinery, huge infestations were recorded along the roadsides and eroded sites, particularly the G.T. road and Airport link road, Islamabad (Chaklala).

The Ayub National Park is situated at southeast corner of the Rawalpindi at a distance of 4.5 km from the city. *Acacia modesta, Prosopis juliflora* and *Olea cuspidata* were common woody species of this national park. The survey of this site revealed a heavy infestation of *P. hysterophorus* especially as a part of vegetation under the forest cover. Twenty three herb species were recorded from the park. *P. hysterophorus* exhibited highest relative frequency value (13.7%) followed by *M. corromendelianum* (8.2%) and *C. occidentalis* (6.8%). Around the world *P. hysterophorus* has become a major threat to many protected areas, forest reserves and national parks including the Kruger National Park, South Africa (Strathie *et al*. 2011), Chitwan National Park, Nepal (Bharat person. comm.), Van Vihar and Corbet National Park, India (Sushilkumar 2010, 2013), and the Masai Mara/Serengeti ecosystem, in Kenya and Tanzania (Anonymous, 2011).

At the Dhoke Khaba site, *P. hysterophorus* was most frequent species accompanied with fifteen other plant species. *Cannabis sativa* exhibited a good sociability with *P. hysterophorus* especially in the shady places. *Cannabis sativa* has third highest relative density value (6.1%) after *P. hysterophorus* and *Malvastrum coromendelianum* (Table

Table 2. Datasheet showing the relative frequency and relative density of wasteland plants in selected sites of Rawalpindi

Wasteland plant species	Relative density (%)								Relative frequency (%)							
	1	2	3	4	5	6	7	8.	1	2	3	4	5	6	7	8
Abutilon indicum	1.1	-	-	-	-	-	-	-	1.3	-	-	-	-	-	-	-
Agropyron repens	0.9	-	-	-	-	0.4	-	-	2.7	-	-	-	-	3.2	-	-
Alternanthera pungens	4.7	-	3.5	-	-	2.8	-	7.0	5.4	-	5.1	-	-	3.2	-	11.1
Atylosia mollis	3.1	-	0.7	-	-	2.2	22.9	2.0	5.4	-	2.5	-	-	4.8	17.8	5.5
Boerhaavia procumbens	0.6	0.8	0.7	-	-	-	-	1.4	1.3	2.5	2.5	-	-	-		5.5
Cassia occidentalis	7.9	1.6	2.5	-	-	6.5	1.3	3.5	6.8	5	5.1	-	-	11.2	3.5	2.7
Conyza canadensis	1.1	-	-	-	-	0.2	-	1.4	2.7	-	-	-	-	1.6	-	5.5
Cynodon dactylon	6.7	2.7	17.6	28.2	46.6	-	22.5	21.2	4.1	5	15.3	25.9	16.6	-	14.2	11.1
Cyperus rotundus	1.3	-	-	-	-	2.0	-	0.8	2.7	-	-	-	-	4.8	-	2.7
Datura innoxia	0.9	0.5	-	1.9	-	0.4	0.4	0.2	4.1	2.5	-	11.1	-	3.2	3.5	2.8
Desmostachya bipinnata	8.0	4.7	-	2.7	11.7	3.6	19.3	1.4	5.4	5	-	3.7	4.2	6.4	14.2	2.7
Elusine indica	3.1	-	-	-	-	2.8	-	1.4	5.4	-	-	-	-	6.4	-	2.8
Erigeron conyzanthus	0.6	1.1	-	-	-	-	-	-	1.3	2.5	-	-	-	-	-	-
Euphorbia hirta	2.9	-	-	-	-	1.4	-	-	5.4	-	-	-	-	3.2	-	-
Euphorbia indica	2.0	-	-	-	-	-	-	-	2.7	-	-	3.7	-	-	-	-
Euphorbia prostrata	1.1	-	-	2.3	-	1.6	-	0.8	2.7	-	-	-	-	4.8	-	2.7
Lantana camara	3.6	-	-	11.5	-	0.8	-	-	4.1	-	15.3	-	-	3.2	-	-
Lespediza juncea	0.9	1.6	1.0	-	-	5.5	-	-	2.7	5	2.5	-	-	6.4	-	-
Malvastrum coromendelianum	8.8	9.1	-	-	13.3	-	15.7	1.7	8.2	15	-	-	4.7	-	17.8	2.7
Parthenium hysterophorus	30.9	64.1	35.9	53.7	8.2	60.6	13.0	38.9	13.7	25	17.9	29.6	2.9	16.1	14.2	22.2
Rhynchonsia minima	2.4	-	-	-	3.5	2.0	1.3	1.7	2.7	-	-	-	1.2	3.2	3.5	2.7
Sida cordata	2.7	-	-	-	-	1.4	-	3.5	2.7	-	-	-	-	1.6	-	5.5
Solanum nigrum	3.1	-	-	2.7	-	2.4	-	-	5.4	-	5.1	11.1	-	4.8	-	-
Convolvulus arvensis	-	1.1	1.7	-	-	0.6	-	-	-	5	7.6	-	-	1.6	-	-
Setaria glauca	-	1.6	3.2	-	-	2.2	1.3	-	-	5	-	3.7	-	6.4	7.1	-
Cannabis sativa	-	6.1	-	1.9	16.4	-	1.8	-	-	10	-	7.4	-	-	3.5	
Heteropogan contortus	-	-	-	5.1	-	-	-	-	-	-	5.1	3.7	5.8	-	-	5.5
Saccharum spontanem	-	-	1.7	0.7	-	-	-	1.4	-	-	-	-	-	-	-	-
Achyranthes aspera	-	-	3.2	-	-	-	-	-	-	-	5.1	-	-	-	-	5.5
Amaranthus viridus	-	-	11.1	-	-	-	-	1.7	-	-	10.2	-	-	-	-	-
Ipomoea cornea	0.5	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-
Tribulis terristris	-	1.9	-	-	-	-	-	-	-	5	-	-	-	-	-	-
Trichodesma indicum	-	1.3	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-
Barleria cristata	-	0.5	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-

2). An earlier study conducted in the neighboring city of Islamabad, Shabbir and Bajwa (2006) revealed that a transition phase of competition was underway between *P. hysterophorus* and *C. sativa*, both species very invasive in the capital city, Islamabad.

Data collected from Morgah site revealed that the weed *P. hysterophorus* was associated with very few other plant species. The most dominant species of the site was *C. dactylon* with highest relative frequency of 46% followed by *Cannabis Sativa* (16.4%) and *M. coromendelianum* (13%). The remaining plant species at this site had appreciably low level of relative frequency of occurrence ranging from 1.2 to 4.2 % (Table 2). Once become a dominant species, *Parthenium* weed has known to form monoculture stands and very little or no vegetation is found in such stands (Navie *et al*. 2006). Similarly, at the Tench bhata site, *P. hysterophorus* was again the most dominant weed species and very little vegetation was seen associated with the weed.

Despite the fact that *Parthenium hysterophorus* is spreading at an alarming rate in most parts of the country, it has not yet attracted the attention of any city district government. There is little action taken to stop its further spread and no weed management plan developed, as a result the weed is continued to expand its range, both in the northern and southern parts of the country. Furthermore, there is lack of coordination among various research organizations and agriculture extension departments. A national management plan against this is needed otherwise the problem of *Parthenium* weed may become out control.

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Distribution of some obnoxious weeds in north-western Ghats of India

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ABSTRACT

Flora and fauna of Western Ghats, a biodiversity hot spot are under major threat due to various factors. Invasion of exotic species has been considered as one of the major threat in the area. In the present study, potential distribution of three obnoxious weeds, *viz. Chromolaena odorata*, *Lantana camara* and *Parthenium hysterophorus* was modeled using 32 environmental variables and MAXENT modeller. These three species showed distinct potential distribution patterns with only slight overlap between *C. odorata* and *L. camara,* and between *L. camara* and *P. hysterophorus.* Overlap of the former pair was seen mostly along the wet western slopes of Western Ghats, and latter along the eastern, rain shade dry areas. The environmental variables that contributed to the model showed that it was basically precipitation and temperature seasonality that defined their distribution. It was interpreted that the weeds might have adapted to different sets of environmental conditions throughout their distributional range; and hence, the variables operating in the study area contributing to the model may not be useful in predicting their presence elsewhere. It is concluded that to understand the full adaptability of these weeds, environmental variables can be studied at local levels and the results compiled for larger areas to get the full spectrum.

Key words: *Chromolaena odorata,* Ecology amplitude, *Lantana camara, Parthenium hysterophorus*

Invasive species are considered among the greatest threats to native biological diversity and functioning of natural ecosystems. Bioinvasion is homogenizing the worlds flora and fauna (McKinney and Lockwood 1999, Baiser and Lockwood 2011), altering the biogeochemical cycles (Strayer *et al.* 2006) and is recognized as a primary cause of global biodiversity loss (Czech and Krausman 1997, Wilcove *et al.* 1998) and species extinction (di Castri 1989). Millenium Ecosystem Assessment (2003) considered climate change along with invasive species as the most pervasive forms of ecosystem disturbance. Foxcroft *et al.* (2009) gained insight into broad patterns of invasion in Southern Kruger National Park and found that at that scale invasion was over-estimated, though it was useful for determining current and potential species distribution over a wider land scale. As the understanding of geographic range is considered as an ecological challenge, important tools such as bioclimatic models, ecological niche models and species distribution models have been used in the study of their geographic range (Jeschke and Strayer 2008).

Usefulness of bioclimatic models has been well established in inferring the full geographic range when distributional information available is scanty (Walther *et al.* 2005, Pearson *et al.* 2007). In spite of proven values of applying models for the distribution of weeds, only a small percentage have used models as predictive tool (Freckleton and Stephens 2009). Wang and Wang (2006) applied ecological niche models to predict potential invasion areas of *Ageratina adenophora* in China by indicating favourable and less favourable areas. Mandle *et al.* (2010) developed ecological niche models for both the native and introduced ranges using MAXENT and used them to explore the question of expansion in greater detail. In the present study, an attempt has been made to understand the potential distribution of three obnoxious weeds, *viz. Chromolaena odorata*, *Lantana camara* and *Parthenium hysterophorus* using BIOCLIM data and MAXENT model.

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MATERIALS AND METHODS

Western Ghats is a hill range that runs north to south for about 1600 km parallel to the west coast of India. Along with Sri Lanka, it forms one of the 34 biodiversity hotspots. It is divided into northern, central and southern Western Ghats. The study area is north-western Ghats but is restricted to the state of Goa and north-western Karnataka and south-western Maharashtra. The area extends from Deccan plateau in the east to the west coast through the mountains of Western Ghats. The sampling area was between 73.7°-74.9° E and 14.9°-16.7° N (Fig. 1).

Field trips were carried out from June 2007 to May 2011 to record the distribution of populations of three weeds, *viz. C. odorata*, *L. camara* and *P. hysterophorus* using GARMIN GPS 12. Total 104 occurrences were recorded for *C. odorata*, 48 for *L. camara* and 20 for *P. hysterophorus*. Additional distributional data points for *L. camara* (4 points) and *P. hysterophorus* (6 points) were collected from outside the study area and incorporated for analysis to test the effectiveness of local versus additional data in prediction of potential distribution of weeds.

MAXENT software (version 3.3.3e) was used for modeling environmental variables at 30 arc-seconds resolution (~1 km) were downloaded from WorldClim (http://www.worldclim.org). One altitude layer, 12 monthly precipitation layers and the following 19 bioclim variables were used in the study: BIO1 [annual mean temperature], BIO2 [mean diurnal range (mean of monthly (max temp - min temp)], BIO3 [isothermality (BIO2/BIO7) (*100)], BIO4 [temperature seasonality (standard deviation *100)], BIO5 [max temperature of warmest month], BIO6 [min temperature of coldest month], BIO7 [temperature annual range (BIO5-BIO6)], BIO8 [mean temperature of wettest quarter], BIO9 [mean temperature of driest quarter], BIO10 [mean temperature of warmest quarter], BIO11 [mean temperature of coldest quarter], BIO12 [annual precipitation], BIO13 [precipitation of wettest month], BIO14 [precipitation of driest month], BIO15 [precipitation seasonality (coefficient of variation)], BIO16 [precipitation of wettest quarter], BIO17 [precipitation of driest quarter], BIO18 [precipitation of warmest quarter], BIO19 [precipitation of coldest quarter]. MAXENT model was run using random seed with random test percentage of 30. Five replicates with replicated run type as Bootstrap and 500 as maximum iterations were used for the model. Output format was set as cumulative and output file type saved as asc. Coordinates collected from the field using GPS for the presence of weeds was used as sample file. Per cent contribution and permutation importance of each variable and map generated for minimum prediction (to avoid over estimation) were considered for interpretation. Potential areas predicted by the model were checked for their presence to validate the prediction. The potential distribution of invasive species has been modeled based on several modelling software (Chejara *et al.* 2010).

RESULTS AND DISCUSSION

In the present study, we predicted the potential distribution of three invasive weeds, *viz*. *C. odorata*, *L. camara* and *P. hysterophorus* based on actual presence data of populations in the field and building models using MAXENT.

Chromolaena odorata

Potential distribution of *C. odorata* on large scale has been attempted by McFadyen and Skarratt (1996) and Kriticos *et al.* (2005) using CLIMEX. Based on earlier data and compilation the distribution of *C. odorata* has been shown all along the Western Ghats (McFadyen 2003, Kriticos *et al.* 2005, Muniappan *et al.* 2005). In the present study distribution data has been collected from a small segment of Western Ghats and using BIOCLIM layers and MAXENT potential distribution has been modelled. The results showed that its potential distribution starts from coastal areas and extends up to the hilly regions of Western Ghats in Goa and in border areas of Karnataka and Maharashtra states; the potential distribution is predicted only to the hilly areas towards north and south (Fig. 2). As its presence has been well documented throughout the Western Ghats, the model was not able to predict its presence for a larger area based on local data. Even the maximum distribution (not shown here) as predicted by the model increased its potential distribution only marginally.

The skewed distribution towards the coast in Goa can be attributed to the hilly undulating terrain that extends almost to the coast of Goa with good rainfall and vegetation. As *C. odorata* is known to have preferences for humid and wet conditions that is provided by monsoon with longer days (Zachariades *et al.* 2009), thus explaining its distribution towards the western side of Western Ghats. This is reflected in the model as nearly 90% of the prediction is contributed by three parameters, *viz*. precipitation in the month of January, May and July (Table 1). In January, the precipitation is only through dew, and July is the heaviest rainfall month in the region. In addition, permutation importance of various layers showed that BIO4 is 61.1% followed by precipitation in January and driest months (22.3 and 9.3%), respectively. However, the rainfall requirement seemed to be different in different geographical regions (Zachariades *et al.* 2009), which suggested that the model used here may not be fitting elsewhere.

Lantana camara

This is considered as a weed of international significance due to its impact on agriculture, forestry and biodiversity (Sharma *et al*. 2005). The potential distribution of *L. camara* in study area is predicted along the hilly areas (Fig. 3). The environmental variables that contributed to the model are basically precipitation in the months of January, May and July as in the case of *C. odorata*. Apart from precipitation of various months, altitude seems to be contributing substantially. The permutation importance is basically provided by three layers of data, *viz*. BIO14 (precipitation of driest month), followed by precipitation in January and BIO4 (Table 1). These variables

Table 1. WorldClim environment variables that define the potential distribution of three obnoxious weeds in Western Ghats

Variable	Percent contribution	Permutation importance
Chromolaena odorata		
Prec1	41.3	22.3
Prec7	27.7	1.7
Prec5	21.6	0.3
Bio19	2.5	0.1
Prec12	2.2	0.6
Bio4	1.3	61.1
Bio14	0.4	9.3
Lantana camara		
Prec1	39	18.8
Prec7	21	0.4
Prec5	14	0.5
Prec11	8	0.5
Prec2	6.6	0
Alt	2.5	0
Bio19	2.4	0.1
Prec12	1.5	0.6
Bio14	1.3	54.1
Bio17	1.2	3.2
Prec4	1.2	0.1
Bio4	0.1	18.3
Lantana camara (with additional distribution data incorporated from outside study area)		
Prec1	30.5	2.2
Prec7	27.1	1.4
Prec11	10.5	0
Bio14	8.8	56.4
Alt	7.6	0
Prec2	5.1	0.1
Prec4	3.2	0
Bio19	2.5	0
Prec12	1.9	1
Bio4	0.3	34.4
Parthenium hysterophorus		
Bio4	27.8	29
Prec1	26.9	17.2
Prec3	8.2	0.4
Bio2	7.4	0
Prec9	6.5	0
Prec6	6.1	1.3
Prec5	4.3	0
Prec7	2.1	0.5
Bio14	2.1	29.6
Bio19	1.3	0.7
Prec12	1.2	0.6
Bio17	1.1	12.2
Parthenium hysterophorus (with additional distribution data incorporated from outside study area)		
Bio4	42.2	36.7
Prec1	19.1	23.4
Bio14	7.1	12.5
Bio2	5	1
Prec3	4.3	1.3
Prec2	2.9	3.6
Bio8	2.4	0
Prec7	2.2	0
Bio1	2	0
Prec6	1.8	1.2
Bio13	1.6	0.4
Bio16	1.6	0
Bio6	1.4	1.2
Prec12	1.4	1.2
Bio19	1.3	0
Bio12	0.3	6.5

were generally in agreement with some of those used by Li (2011) while predicting potential distribution of *L. camara* in China.

Additional four data points collected from outside the study area did not alter the potential distribution significantly (Fig. 4). However, precipitation in the month of May (Prec 5) has not contributed to the model as compared to the data from study area alone. Permutation importance has changed substantially in favour of BIO4 while reducing that of Prec1 (Table 1). The model could not predict its distribution in larger area, as in the case of *C. odorata*. It is adapted to grow in wide climatic conditions (Day *et al.* 2003), hence it was not the same climatic factors that were contributing to its distribution in different areas, thus rendering the model only locally applicable.

Parthenium hysterophorus

The resulting image showed that its distribution along the coastal area was almost nil and most of its potential distribution was shown on the eastern side of Western Ghats (Fig. 5). Twelve environmental variables contributed 1% or more to the model of which BIO4 and precipitation in January contributed 54.7% to the model. Permutation importance to the model was provided by BIO14 in addition to BIO4, Prec1 and BIO17 (Table 1).

The prediction extends the potential distribution towards east into drier areas and substantially into north and south with the addition of six data points from outside the study area (Fig. 6). Dhileepan and Senaratne (2009) earlier documented 495 recorded sites for this species in India and used CLIMEX to develop a model in which heat stress and temperature have rendered high value to the model. High Eco-climatic Index (EI) values have been predicted for the Deccan plateau and east coast. McConnachie *et al.* (2011) in their study concluded that modeled distribution in South Asia was in agreement with the available distribution data. Comparison of environmental variables that contributed to them showed that BIO4 was the major factor followed by precipitation in January and of driest month. The same factors, especially the former one in the form of heat stress and temperature have been identified by Dhileepan and Senaratne (2009).

Within the study area, slight overlapping in distribution was predicted between *C. odorata* and *L. camara* at one side and *L. camara* and *P. hysterophorus* on the other side, but not between *C. odorata* and *P. hysterophorus.* In the cases of *L. camara* and *P. hysterophorus*, the distribution was not predicted along the western coastal regions.

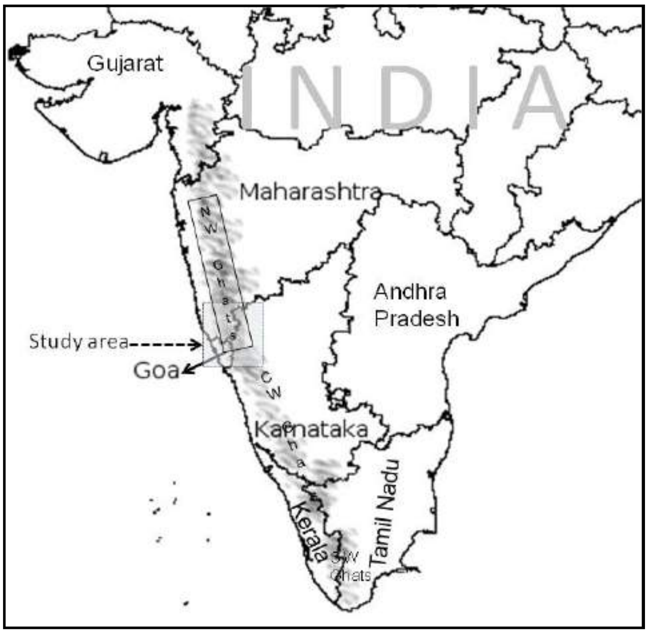

Fig. 1. Map of peninsular India showing the study area

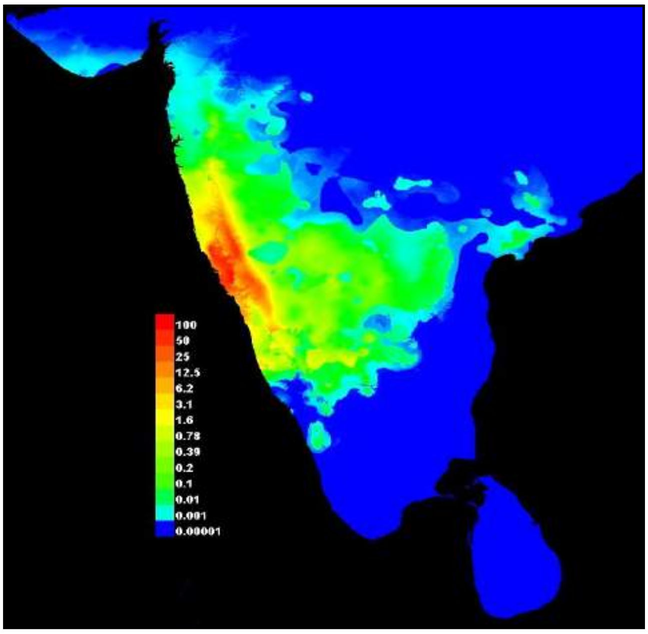

Fig. 2. Potential distribution of *Chromolaena odorata* predicted using MAXENT and distributional data from study area

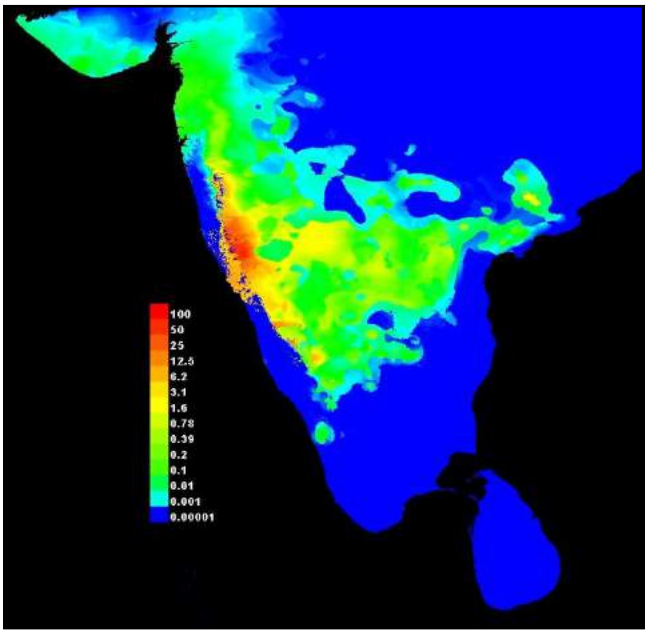

Fig. 3. Potential distribution of *Lantana camara* predicted using MAXENT and distributional data from study area

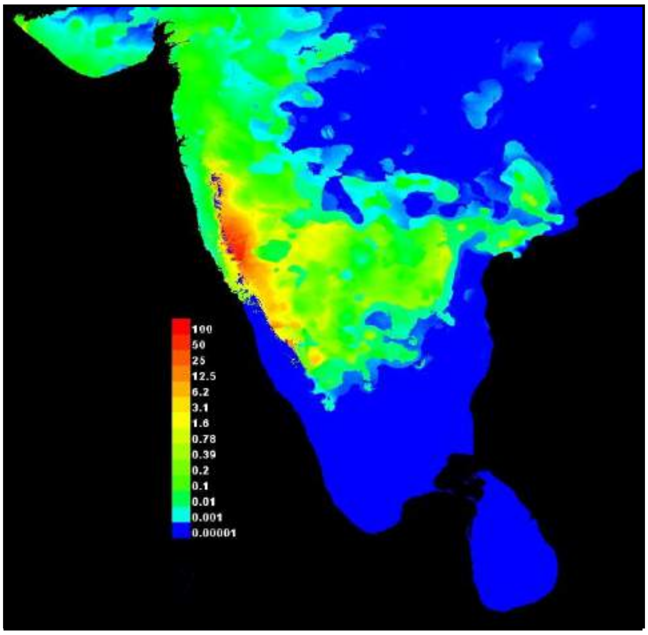

Fig. 4. Potential distribution of *Lantana camara* predicted using MAXENT and distributional data from study area as well as from outside study area

In all the above three cases, distribution was not predicted for south-western Ghats or the areas east of it wherein their distribution is documented. This proved that local data may not be useful to predict the weeds even in the same phyto-geographical zone as these weeds are well adapted to different environmental conditions. Hence, it was safe to work for smaller geographical areas and compile the data to understand the environmental variables that contribute to their presence in different areas.

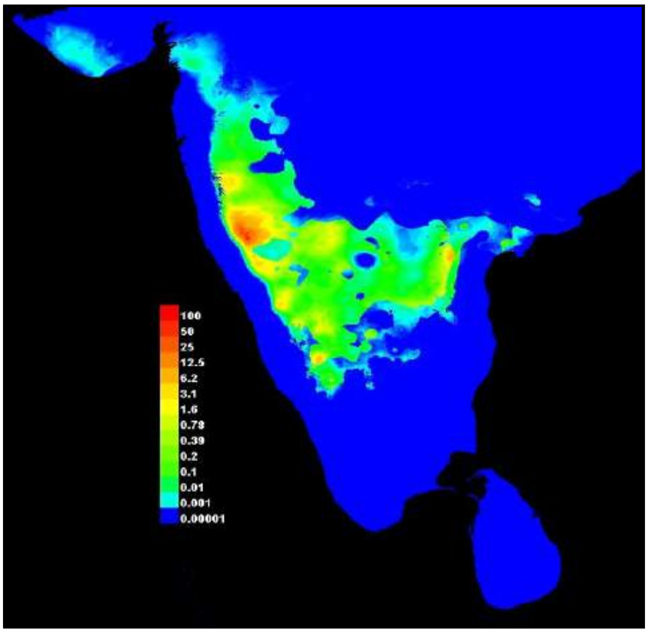

Fig. 5. Potential distribution of *Parthenium hysterophorus* predicted using MAXENT and distributional data from study area

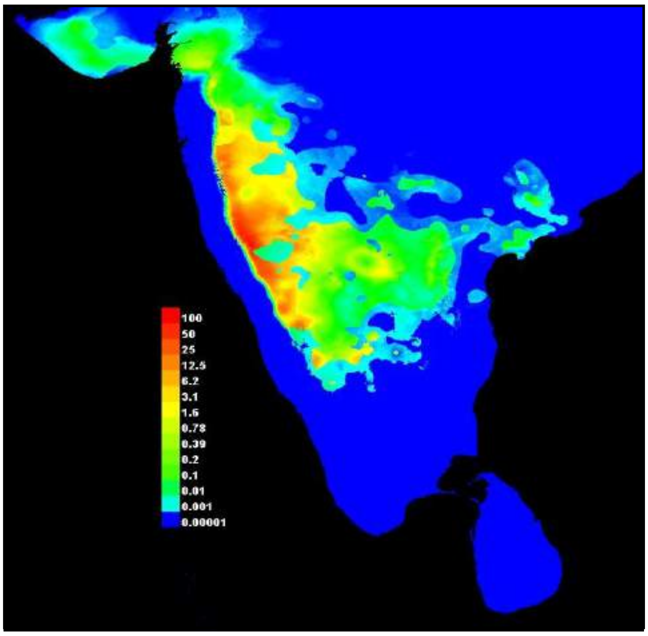

Fig. 6. Potential distribution of *Parthenium hysterophorus* predicted using MAXENT and distributional data from study area as well as from outside study area

In the present study, potential distribution has been predicted for these weeds. It was concluded that a) the ecological requirement was distinct for each of these weeds and hence distribution overlap was seen only to lesser extent, and b) the weeds probably have adapted to different environmental variables even within the same phytogeographical region and hence local distributional data cannot predict their potential distribution far beyond the local area. To understand adaptations of any weed to different environmental conditions, studying large areas by dividing them into smaller units will help.

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Adsorption–desorption of atrazine on vertisols and alfisols

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ABSTRACT

Adsorption–desorption of atrazine was measured in four soils of Hyderabad using batch equilibrium method at 27±1ºC. The Freundlich equation was used to describe batch results. Both adsorption and desorption isotherms were well described by the Freundlich model. Fitted K_f value for desorption isotherms were consistently higher than those associated with adsorption. The opposite trend was observed for the exponential parameter *n*. The results revealed that the desorption data deviated significantly from adsorption data. The deviation, which is commonly referred to as hysteresis, was more prominent with higher adsorbed concentration of atrazine and incubation time. Desorption was significantly higher at the lowest adsorbed level of atrazine. The Freundlich K_f and *n* values were higher than that for adsorption and increased with increase in initially adsorbed concentration of atrazine.

Key words: Adsorption, Alfisols, Atrazine, Desorption, Vertisols

Adsorption–desorption processes are necessary in understanding herbicide retention behaviour and its potential mobility within the soil. Atrazine can be released from soil adsorption sites when its concentration in the solution phase decreased due to dilution, volatilization or translocation. This process is called desorption and can be initiated by diluting or replacing the soil solution with atrazine free solutions (Clay and Koskinen 1990a, Ma *et al*. 1993). Batch equilibration has been extensively used in several investigations. The Freundlich model is a commonly used approach describing atrazine distribution between soil and solution for both sorption processes. However, the fitted N is consistently lower and K_f is higher than that obtained from adsorption isotherms (Clay and Koskinen 1990a, b, Ma *et al*. 1993, Stechouwer *et al*. 1993, Laird *et al*. 1994). Therefore, less herbicide is desorbed from soils than predicted by the adsorption isotherm, which is often referred to as hysteresis.

Several factors such as organic matter content, soil pH, extracting solvent, temperature and incubation time. influenced the amount of atrazine adsorbed and desorbed in soil, Hysteresis is more obvious under low soil pH, long reaction time, high organic matter content, frequent drying and wetting and high degradation rates (Clay and Koskinen 1990a, Pignatello and Huang 1991). Laird *et al*. (1994) reported that extensive hysteresis resulted from atrazine adsorption on organic components, while little or no hysteresis was observed for clay minerals. Adsorption–desorption properties of atrazine can be directly related to their mobility in soil and thus, predict their movement to ground water. There is increasing evidence that some fraction of most pesticides is irreversibly bound on adsorption sites in soils (Khan 1982). Hence, a detailed study of atrazine adsorption–desorption phenomenon on two soils was conducted.

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MATERIALS AND METHODS

One sample each from vertisol and alfisol of ANGRAU campus, Rajendranagar and other two samples from vertisol and alfisol of ICRISAT, Hyderabad were selected for the study. The samples were analyzed for physico-chemical properties using standard procedures (Table 1). Technical grade atrazine (>95% purity) obtained from M/S Rallis India Ltd. was used. Atrazine (2-chloro-4 ethyl amino-6-isopropyl amino-1-3, 5 traizine) is a soil and foliar applied pre- and post- emergence herbicide used for the control of broad-leaved weeds in sorghum, maize, sugarcane and other cereals.

Adsorption was studied by equilibrating 5 g of 0.25 mm sieved soil with 20 mL of aqueous solutions containing 0 to 50 mg/mL atrazine in 0.01 M $CaCl_2$ for 24 hr at 27±1ºC and centrifuging at 4,000 rpm for 15 minutes. Identical soil blanks without atrazine were maintained as control. The equilibrium concentration of atrazine was determined spectrophotometrically at 221 nm with respect to standard curve, after correcting for soil blanks.

Desorption was studied using batch equilibration followed by replacing the supernatant with 0.01 M $CaCl_2$. Five grams of 0.25 mm sieved soil samples were taken and treated with atrazine solution containing 0 to 50 mg/mL and 0.01 M $CaCl_2$. After incubating for 2 hr at 27 ± 2^{o}C, the slurry was centrifuged at 2000 rpm for five minutes and 5 mL of the supernatant was taken out and its absorbance was measured at 221 nm. The volume of the remaining slurry was made up again to 20 mL by adding 5 mL of 0.01 M $CaCl_2$ solution, equilibrated against for five consecutive days. The same operations were carried out simultaneously with soil blanks and corrections were applied at every stage. The amount of atrazine desorbed and the amount remaining adsorbed on the successive days were calculated and isotherms were drawn. The amount desorbed was calculated using

$$C_o^{n} = C_e^{\,n-1} \text{ x } \frac{15}{20}$$

where C_o^n is initial concentration of atrazine on nth day, C_e^{n-1} is equilibrium concentration on (n-1)th day. Amount desorbed on nth day is given by (C_e^n – C_o^n) x 20.

RESULTS AND DISCUSSION

-Adsorption–desorption isotherms for selected soils are given (Fig. 1-4). The adsorption isotherms were found to be mainly parabolic in nature with S-shaped curvature mainly confined to initial stages of adsorption. The tendency for S-shaped character indicated a stronger initial competition of water molecules to the adsorbent as compared to the herbicide, till a certain level of adsorbed herbicide is built up. This is a common feature for the adsorption of organic chemicals on the soils of low organic matter or on clay (Raman and Rao 1987). The adsorption data was described by Freundlich equation and the constants K_f and n are given in Table 2.

K_f value was high for soil V2, which was due to high organic carbon content. The resistive effect of organic matter on adsorption of pesticide is well established (Graham and Khan 1992, Ma *et al.* 1993, Raman and Reddy 1993, Rocha and Walker 1995).

Desorption isotherms for every level of initial concentration of added atrazine in both the soils did not coincide with adsorption isotherms (Fig. 1-4). The slope of

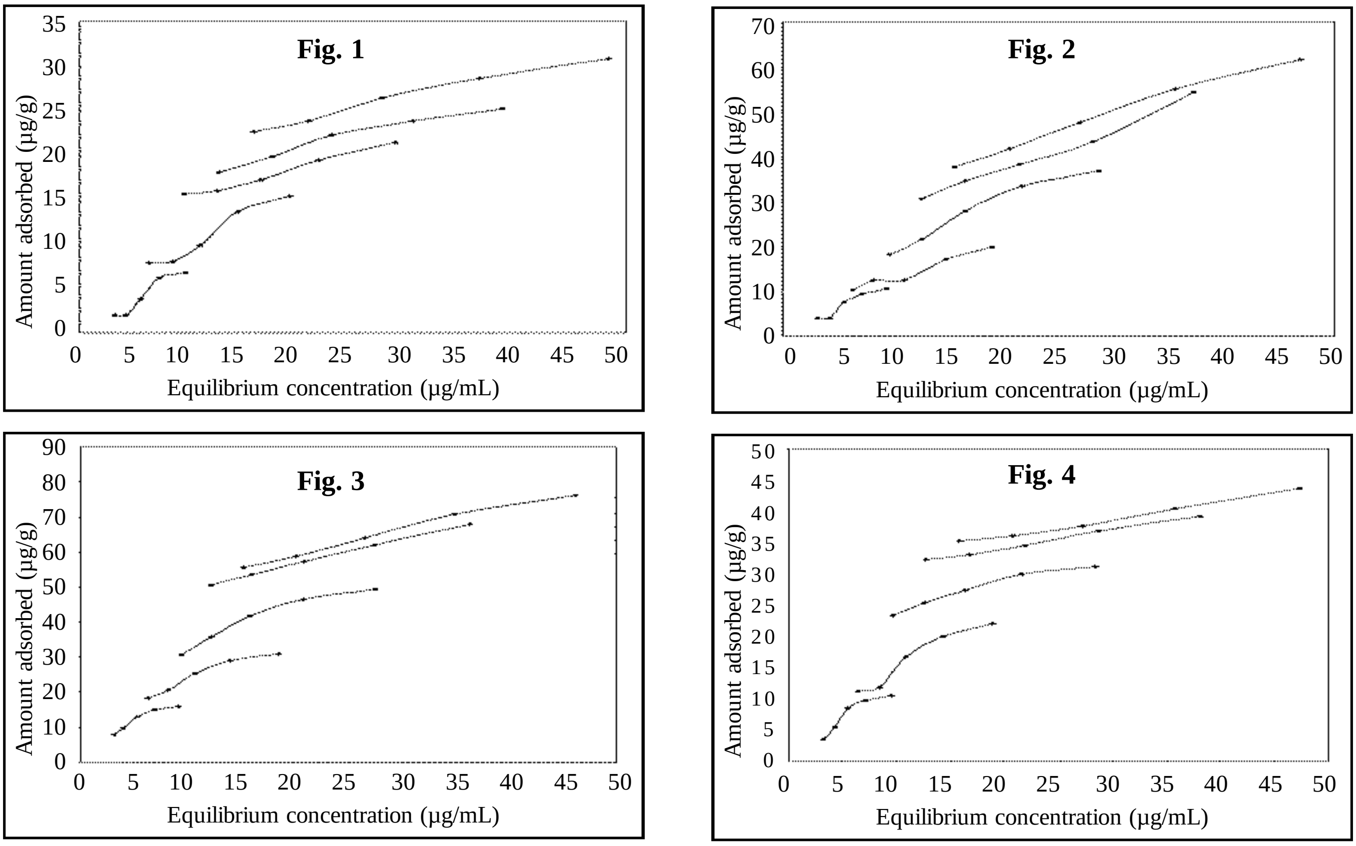

Fig. 1-4. Adsorption-desorption isotherms of atrazine on vertisols and alfisols

Table 1. Physico-chemical properties of selected soils

Soils	pH	EC (dS/m)	Organic C (g/kg)	Mechanical composition (%)			Texture
				Sand	Silt	Clay	
V_1 (College farm ANGRAU, Hyderabad)	7.32	0.61	0.53	30.0	41.8	28.2	Silty clay loam
V_2 (ICRISAT, Hyderabad)	6.99	1.44	1.17	18.8	46.2	35.0	Silty clay loam
A_1 (College farm ANGRAU, Hyderabad)	7.03	0.19	0.09	69.4	18.6	12.3	Loamy sand
A_2 (ICRISAT, Hyderabad)	6.67	0.53	0.37	75.6	6.2	18.2	Loamy sand

Table 2. Freundlich constants for adsorption of atrazine on vertisols and alfisols

Soil	V_1	V_2	A_1	A_2
Organic carbon (g/kg)	0.53	1.17	0.09	0.37
K_f	2.66	4.08	1.81	2.41
N	1.13	1.02	0.83	1.08

K_f and n are Freundlich constants

isotherms for desorption was obtained by desorbing the herbicide adsorbed at the initial concentrations. The slope of desorption isotherm was much less than the slope for adsorption isotherm and less amount of herbicide was present in equilibrium solution than during adsorption. The results indicated that desorption isotherm deviated significantly from the adsorption isotherms. Such a deviation between adsorption and desorption isotherm is referred to as hysteresis. Hysteresis is often observed in pesticide adsorption–desorption studies with soil (Koskinen and Harper 1990, Ma *et al.* 1993, Reddy *et al.* 1995, Mersie and Seybold 1996, Jenks *et al.* 1998).

The hysteresis was more pronounced when desorption was carried out from higher levels of adsorbed atrazine. Thus, when desorption was carried out from soils where less amount of atrazine was present, the desorption isotherms were very close to the adsorption isotherms. This showed that the degree of irreversity increased with increase in sorbed atrazine.

Ppercent desorption in both the soils decreased with increase in the amount initially adsorbed (Table 3). The desorption from the lower levels of concentration was significantly higher in both the soils, from the other levels of concentration. The percent desorption was more in alfisols than vertisols in the order of $A_2 > A_1 > V_1 > V_2$, which was in the order of decreasing organic carbon of the soils. The significant variation in cumulative desorption between all the soils at different levels of initial concentration of atrazine could be due to the fact that soil is a heterogenous entity with sorptive sites that vary widely in the type and energy of binding.

In the present study, it was found that the desorption isotherms were also of Freundlich in nature and similar to those obtained by Seybold and Mersie (1996), Graham and Khan (1992), Moreau and Mouvet (1997) and Benoit *et al.* (1999). The constants K_f and n for desorption were calculated and are given in Table 4.

Table 3. Cumulative desorption of atrazine in five consecutive days in vertisols and alfisols

Initial concentration (µg/mL)	Per cent desorbed in five days			
	V_1	V_2	A_1	A_2
10	62.82	50.30	70.59	67.31
20	58.58	41.09	68.83	63.01
30	50.00	38.06	63.55	57.87
40	43.75	29.50	60.32	51.10
50	38.96	27.03	53.90	48.17

The Freundlich K_f values for the desorption isotherms were found to increase with increasing initial concentrations of atrazine in both the soils. Similar results were reported by Ma *et al.* (1993), Pignatello (1989) and Gan *et al.* (1996). Larger K_f values for adsorption than desorption indicate stronger binding of atrazine to soils (Reddy *et al.* 1995).

The extent of hysteresis was more pronounced as the incubation time increased and indicated that atrazine recovery decreased with incubation (Ma *et al.* 1993) for atrazine desorption. It is generally accepted that the rate of desorption is slower than rate of adsorption (Calvet 1989).

The higher clay content, organic C content and CEC of clay loam soils (V1 and V2) compared to loamy sand (A1 and A2) may be the factors that are responsible for increased amounts of non-desorbable atrazine on clay loam. These results are in conformity with the results reported earlier by Ma *et al.* (1993), Seybold *et al.* (1994), Gan *et al.* (1996) and Reddy *et al.* (1997). The values of K_f and n however, may not have the same physical significance as in adsorption isotherms because a part of the soil applied pesticide has often been shown to become bound and unextractable by water or even by organic solvents (Khan 1980, 1982). Ideally, K_f and n for desorption isotherms should be similar to those for adsorption isotherms, if the non desorbable portion at each step is known and is compensated for. This is unfortunately not possible. The

Table 4. Freundlich K_f and n values for desorption of atrazine from selected vertisols and slfisols

Soils	10 µg/mL		20 µg/mL		30 µg/mL		40 µg/mL		50 µg/mL	
	K_f	n	K_f	n	K_f	N	K_f	n	K_f	n
V_1	1.06	0.86	2.34	1.25	6.83	1.33	9.44	1.37	10.19	1.38
V_2	2.28	1.36	4.89	1.21	10.42	1.27	11.16	1.31	13.17	1.32
A_1	0.42	1.05	1.77	0.90	3.18	1.11	5.81	1.28	7.18	1.26
A_2	0.66	1.11	2.01	1.08	5.16	0.98	6.33	1.09	9.07	1.11

increasing K_f values with increasing adsorbed concentration is indicative of increasingly difficult desorption.

The main cause of hysteresis, during desorption was the presence of a number of heterogenous adsorbing sites of varying energy levels on soils. In addition to this, are the modifications that take place in the soil it self during adsorption–desorption process (Calvet 1980). Desorption of atrazine from both vertisols and alfisols was hysteric. The adsorption of herbicides and their consequent desorption is not a single valued relationship, hence, a portion of adsorbed herbicide is resistant to desorption. Degradation of parent compound may have occurred during equilibrium and also by physical adsorption/or chemical properties of soil solution system (Cheng 1990). As the herbicide degrades, a new equilibrium is established with more parent compound being removed from solution and bound to soil. Changes in solution composition during desorption might have occurred. Soluble soil organic carbon decreased when 0.01 M $CaCl_2$ was used for desorption replacement solution. Also, the herbicide may be bound to replicated soil sites and not have been readily released into solution (Clay and Koskinen 1990a). Repeated centrifugation of the slurry in batch equilibration has been reported to be partly responsible for hysteresis observed in some pesticides (Bowman and Sans 1985).

Ma *et al.* (1993) suggested two possible mechanisms responsible for reversible or irreversible atrazine adsorption in soils. One was due to the formation of atrazine soil complexes that are not easily desorbable into soil solution. In fact, atrazine can strongly bound to soil organic matter by either chemical or physical means other mechanisms include chemical and microbial degradation of atrazine. Further with increasing amount of adsorbed pesticide not only the surface sites are occupied but the pesticides may find its way into soil micropores caused by clay and structurally complex polymer net work. Thus, rediffusion of herbicide into soil solution becomes hindered due to tortuosity of the pores followed by the unfavorable energetics (Pignatello 1989, Raman and Patnaik 1993).

In the present investigation, extent of hysteresis during adsorption–desorption of atrazine on both vertisols and alfisols was quantified. A portion of observed hysteresis with atrazine on vertisols and alfisols could be a result of soil bound desirable parent herbicide or degradation products. The amount of non-desorbable atrazine and the amount of hysteresis accounted for in this study were dependent on soil type, solvent used for extraction, repeated centrifugation of slurry and irreversible conjugation of atrazine with soil organic compounds and observed hysteresis may be due to change in soil structure–ionic strength and dissolved organic carbon content of the solution phase during desorption process (Barriuso *et al.* 1992, Wang *et al.* 1992). However, the amount of non-desorbable herbicide may explain a portion of observed hysteresis during laboratory batch desorption experiments.

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Expert system for identification of weed seedlings

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ABSTRACT

Weeds can be controlled effectively only when the management practices are employed at and early growth stage. Therefore, identifying weeds at seedlings stage is very essential for designing an efficient strategy for their management. However, it is a difficult task unless one has enough knowledge and experience. To help identifying weeds at seedling stage, an expert system has been developed at the Directorate. The expert system uses scientific name-based classification and a mix of the text description and images. The system is supported by a database containing information on 138 weed species with colour images of weed seedling at five growth stages. The expert system was evaluated following the conventional expert system evaluation methodologies. Results indicated that non-expert users were able to make weed seedling identification using the expert system more efficiently.

Key words: Agriculture, Identification, Information, Knowledge, Expert system, Weed seedling

Weeds can be managed efficiently when they are small and in their early vegetative stage. Therefore identifying weeds at seedling stage is very much important for planning right management strategy. Also identification of weed seedlings is technically important because it would be helpful to identify the seed bank of the expected competitor weeds so that management can be planned in advance. Identifying weeds at the seedling stage is important because they are most susceptible to chemical or mechanical control at this stage. Also, accurate identification of these seedling weeds often is necessary to select the best herbicide or other method of weed control. Weed seedling identification is important for timely implement action the appropriate weed control practice. Controlling the weeds in the early stages of growth not only increase the effectiveness of the control measures, but also reduces the crop losses.

Identifying a weed at seedling stage is very difficult compared to identifying a grown-up weed. Assistance in the form of a manual or software is very much needed for effective identification of weed seedlings. In order to overcome this type of problem, expert systems have been developed. The primary goal of expert systems is to enable decision makers and technicians to do the job more efficiently. The expert system technology is a new approach for weed identification.

An expert system is a computer program that contains formally encoded knowledge of experts in a given problem area or domain, and is able to use this knowledge to provide help to a non-specialist in problem solving in that domain (Donald 2004, Patterson 2004). In agriculture, expert systems were developed in various disciplines (Gonazalez *et al.* 1990, Lonchamp *et al.* 1991, Olmo and Recasens 1995, Schulthess *et al.* 1996, Chakrabarti and Chakraborty 2007, Ravisankar *et al.* 2009, 2010, Ahmed Rafea 2010) that combine the experimental knowledge and experience with intuitive reasoning skills of specialists to aid in making the best decisions.

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The information system on weed seedlings allows their identification by performing the search with scientific name or with cotyledon shapes. Images of each shape with its name are displayed for performing the search easily. Under each shape, list of scientific names gets displayed. With the selection of scientific name, its description and seedling stages of the plant get displayed. With each choice you make, the list of possible plants shrinks. It is easy to confirm the identity of weed seedlings by comparing the sample specimen to the many coloured photos. This application is as useful to the amateur enthusiast as it is for professionals in the field of weed science. An attempt has been made to develop an expert system for identifying seedlings of 138 commonly found weed species of cropped and non-cropped areas in the country.

MATERIALS AND METHODS

An expert system on weed seedling identification was developed with the combined efforts of specialists from the concerned subject, software professionals and other technical experts. The first step in building an expert system requires knowledge acquisition (Spangler *et al.* 2003).

For this expert system, the domain expert is the "Agricultural Scientists in the field of Weed Science". The knowledge engineer codes the information in the form of rules or some other representation scheme. System editor (Software expert) serves as intermediary between the domain expert and the computer that will emulate their expertise. The software expert acquires the information about the weeds in the form of facts and rules through consultation and document analysis and then prepares a knowledge base for the system. The process is repeated until a sufficient body of knowledge has been collected to build the expert system.

A study was carried at the Directorate of Weed Science Research, Jabalpur (M.P) during the period from 2002 to 2012. Category-wise listing of weed seedlings, their characteristics and other related information was generated through pot culture studies and also gathered partly from literature. Weed seeds were sown in pots and after germination the images were captured at five different stages in the early vegetative growth. The information about scientific names, morphological features of cotyledons, true leaves, petioles, along with weed seedling images at five stages was documented and catalogued.

The expert system was developed using Visual Basic .NET (Gaddis *et al.* 2003, Balena 2005) as front-end application and MS Access (Teresa *et al.* 2010) as back-end application with user-friendly menus. A prototype of the expert system was built and validated. All the images were stored in digitized form. The knowledge base contained information about 138 weeds consisting of 5 parameters which were stored as rules of inference for use during the reasoning process. These rules were of 'if…then…else' nature or any other valid form. Reports were designed using 'Crystal reports' by providing flexibility to the user to view selected parameters and take the hard copy. Interface was provided to the back-end to access the database from 'MS Access' and to store the new information into it.

To use the system easily, the user-friendly interface was developed with GUI which allows the user to communicate with the system in a more natural way by permitting the use of simple selection drop down option menus or the use of a restricted language which is close to a natural language. Through user-interface, the user is allowed to view and search query for the weed seedling information, view the complete data for a particular seedling by selecting the scientific name which is considered as a primary key. One powerful tool included in this system is that by using search query, the users can shortlist the weed seedlings based on Cotyledon shape and can get the identity of a particular weed seedling by selecting the scientific name within that shape.

RESULTS AND DISCUSSION

The main menu of this software consists of 4 modules, *viz.* Weed Seedling Information, Search Query, (Fig. 1), About software and Exit. The scientific names of plants are considered as primary key for identifying the characteristics of weed seedling.

Weed seedling information: It is a simple search mechanism which allows the user to search for a particular weed seedling by its scientific name. For easy searching, all the names are arranged alphabetically, *viz.* A ….. Z (Fig. 2). For example if the user is searching for a particular weed seedling and its name starts with 'M' like '*Mimosa pudica* L.', the user has to select 'M', then a list of scientific names gets displayed. By selecting '*Mimosa pudica* L.' from the list, the information, *viz.* seedling description, image of the weed (grown-up) and images of weed seedling at 5 different stages get displayed. The user can also view the full image of the plant by selecting the option 'Full View'.

Fig. 1. Main menu

Search /query: It is a powerful tool through which the user can make a query for a particular weed seedling by selecting cotyledon shapes. nineteen cotyledon shapes are defined and designed in such a way, with its image followed by the name and all the plants scientific names,

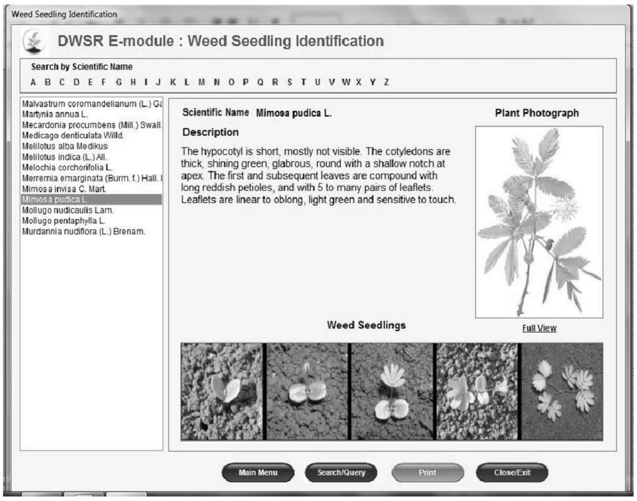

Fig. 2. Weed seedling information menu

are classified into these nineteen shapes. Once any one of the above shape is selected, a list of scientific names of weed seedlings that have the opted characteristics gets displayed and selecting one among the list displays the information of a particular weed seedling having the characteristics opted. For example, if the user selects the 'oblong' in cotyledon shape option, a list of scientific names of weed seedlings having oblong cotyledons gets displayed (Fig. 3). The user can select one of the scientific names from that list to display the characteristics of that particular weed seedling, *viz.* description, plant photo and five different stages of weed seedlings (Fig. 4). Hard

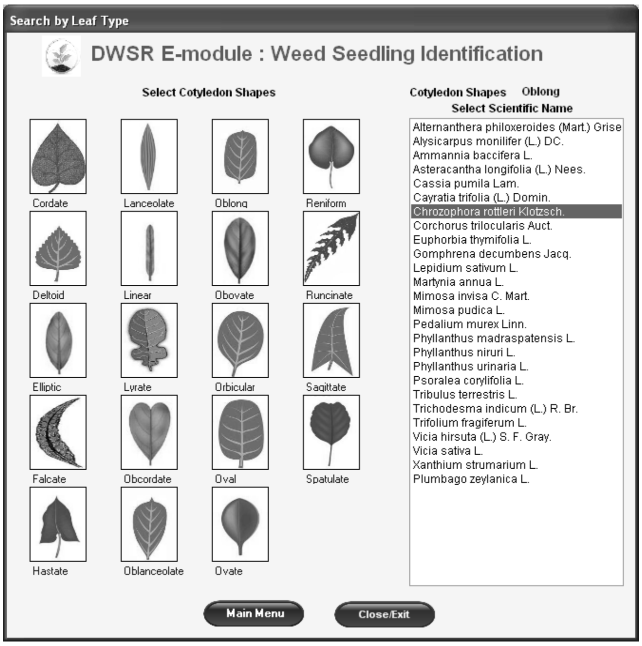

Fig. 3. Search by leaf type

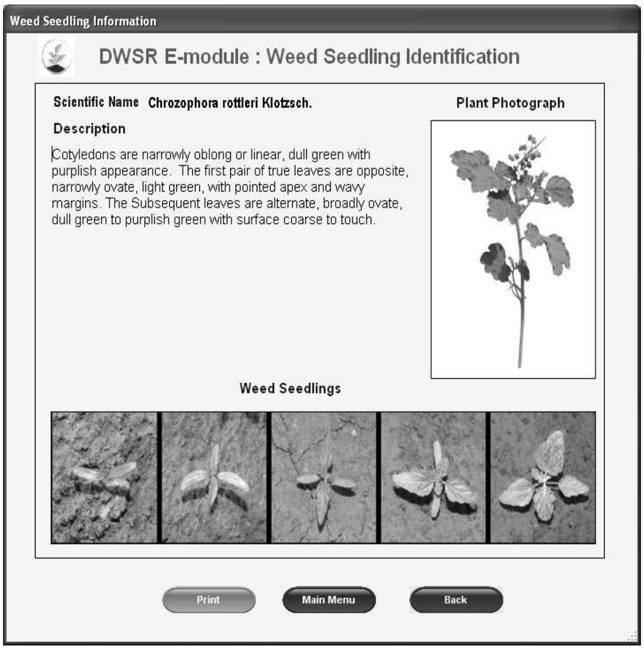

Fig. 4. Weed seedling identification

copy of the report can be taken by selecting the 'Print' option. Navigating tools allow the user to move back and forth between the screens easily.

About Software: This is portable software, which makes possible to execute this software in any system. For this, a 'SETUP' program is created (executable file) including all the files and data. Any user can install this software by running this 'SETUP' program and the execution of the software is self-explanatory.

The idea of an expert system is shifting the focus of the research community to knowledge dissemination in contrast to knowledge accumulation. The expert system in combination with powerful personal computers and devices like CD-ROM has the potential to open whole warehouses of accumulated knowledge for agricultural development. The main purpose of the expert system is to serve as delivery systems for extension information and management for decision makers. It also plays an important instrument in agricultural education. It helps in dissemination of up-to-date scientific information in a readily accessible and easily understood form to agricultural researchers, advisers and farmers.

With the help of the expert system for weed seedling identification, one can arrive at accurate identification of the weeds at their seedling stage. The correct identification of weeds at early stages will help in planning appropriate management practices at right time. Further modification and additions to current system will be a continuous process based on the information and impressions received from various stakeholders.

Results of validation indicated that identification of weeds at seedling stage was an easy task with the use of this expert system even for an ill-skilled person. Those who tried this expert system opined that the system had educational and management importance. Use of images of five different stages of weed seedlings would be helpful to narrow down the identity correctly. This expert system available on the website of the Directorate. The suggestions for refinement, if any, will be considered to make the system accessible to every one.

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Short communication

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Bioefficacy of new herbicides in transplanted rice

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In India, rice is the staple food for millions of people and is next to wheat. It plays a pivotal role in the economy of India. Feeding the 9 billion people expected to inhabit our planet by 2050 will be an unprecedented challenge for the mankind. Modern sustainable rice cultivation worldwide involves extensive use of agrochemicals such as insecticides, fungicides and herbicides. The goal of herbicide use is to kill or stunt weed infestation allowing the rice to grow and gain a competitive advantage. Weeds are the most important biological constraint to increasing yield. It has been estimated that without weed control, the yield loss can be as high as 90% (Ferrero and Tinarelli 2007). Various methods like cultural, mechanical, biological and chemicals are used for weed control. The chemical weed control method is becoming popular among the farmers because it is the most efficient means of reducing weeds competition with minimum labor cost. The yield of rice in India is much lower than that of other countries. Therefore, proper weed management is essential for satisfactory rice production. The present study was undertaken to evaluate bioefficacy of new herbicides on yield and weed control efficiency in transplanted rice.

A field experiment was conducted during *Kharif* season of 2009 and 2010 at the Agriculture Research Station, Kota, Rajasthan. The soil was clayey in texture, slightly alkaline in reaction (pH 7.5), low in organic C (0.56%) and medium in available N (278 kg/ha) and available P (14.3 kg/ha) and high in available K (305 kg/ha). The experiment was laid out in randomized block design with 7 treatments comprising of butachlor 1.5 kg/ha at 5-7 days after transplanting (DAT), bispyribac-sodium 25 g/ha at 15-20 DAT, bispyribac-sodium 35 g/ha at 15-20 DAT, bispyribac-sodium 50 g/ha at 15-20 DAT, weed-free until harvest, two hand weedings at 20 and 40 DAT and unweeded control, replicated four times. Fertilizers were applied uniformly @ 120-60-40 kg/ha of N-P_2O_5-K_2O in the form of from urea, single superphosphate, muriate of potash, respectively. The whole amount of P and K was applied as basal dose while N was top-dressed in three equal installments at 20, 40 and 55 DAT. The variety '*Jaya*' was used as the test crop. Thirty-day old rice seedlings were transplanted at 20 x 10 cm spacing in the end of July. Data on weed infestation were collected from each unit plot at 30, 60, 90 DAT and at harvest. The weeds inside each quadrate were uprooted, cleaned and separated species-wise. After drying, weight and weed control efficiency was calculated.

Major weeds in the experimental plots were: *Echinochloa colonum*, *Echinochloa crusgalli* among grasses; *Cyperus rotundus, Cyperus difformis, Cyperus iria* among sedges; and *Eclipta alba* and *Ammenia baccifera* among broad-leaved weeds.

Results revealed that all the treatments gave significant control of weed population (Table 1). The highest weed control was achieved with manual hand weeding (64-82%). However, the hand weeding is laborious, tedious, expensive and time-consuming, hence it cannot be practicable on a large scale. Among the weedicides, bispyribac-sodium 50 g/ha at 15-20 DAT gave the highest weed control (58-75%). Bispyribac-sodium at 25 and 35 g/ha at 15-20 DAT reduced the weed density. The weed control efficiency with bispyribac-sodium 50 g/ha at 15-20 DAT ranged between 58 and 75% The weed control efficiency with butachlor 1.5 kg/ha at 5-7 DAT ranged between 28 and 47%, which was comparatively lower than other treatments. Lower weed persistence index were observed in all the weedicide treated plots. Among the herbicides, bispyribac-sodium gave lower weed persistence index (0.02). The highest herbicidal efficiency index (3.39-4.02) was found with bispyribac-sodium 50 g/ha, followed by bispyribac-sodium 35 g/ha (2.60-2.96). This was due to the fact that bispyribac-sodium inhibited the plant enzyme acetolactate synthase (ALS), which was involved in biosynthesis of the branched-chain amino acids. Without these amino acids, protein synthesis and growth are inhibited, ultimately causing plant death (WSSA 2007).

All herbicide treatments showed significantly higher number of panicles and panicle weight over the unweeded check due to less competition for moisture, light and nutrient uptake by the crop plants. Significantly higher number of panicle/m^2 and weight/panicle were observed in plots treated with bispyribac-sodium 35 g/ha at 15-20 DAT,

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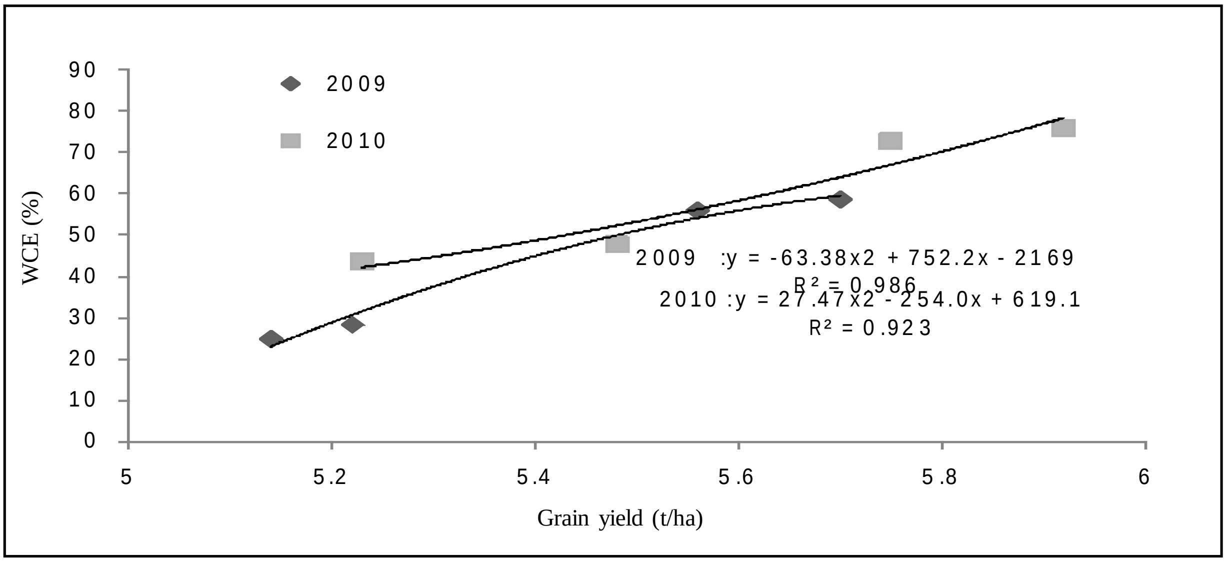

Fig. 1. Regression between gain yield and weed control effeciency

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

Treatment	Weed density (no./m^2)		Dry weight of weeds (g/m^2)		Weed persistence index		Weed competition index (%)		Weed control efficiency (%)		Herbicidal efficiency index	
	2009	2010	2010	2010	2009	2010	2009	2010	2009	2010	2009	2010
Butachlor 1.5 kg/ha at 5-7 DAT	24	22	32.7	35.8	0.18	0.14	13.6	16.4	28.2	47.7	0.80	0.97
Bispyribac-sodium 25 g/ha at 15-20 DAT	27	25	35.2	39.2	0.22	0.18	15.0	20.2	24.8	43.8	0.70	0.74
Bispyribac-sodium 35 g/ha at 15-20 DAT	9	10	12.6	13.6	0.03	0.03	8.1	12.3	55.8	72.8	2.60	2.96
Bispyribac-sodium 50 g/ha at 15-20 DAT	7	8	10.4	11.0	0.02	0.02	5.7	11.5	58.7	75.7	3.39	4.02
Weed-free	-	-	-	-			-	-	-	-		
Two hand weedings (20 and 40 DAT)	4	4	6.3	4.8	0.01	0.00	2.2	4.8	64.3	82.8		
Unweeded control	59	62	73.0	88.2	1.00	1.00	36.5	4.0				
LSD (P=0.05)	2.13	2.10	2.13	3.14								

which was at par with next higher dose of bispyribac-sodium. These results are in close conformity with those of Kumar and Sharma (2005) and Singh *et al.* (2005)

All the weed control treatments significantly reduced the weed growth as compared to weedy check, and thus recorded higher grain yield of rice. The crop yield and weed control efficiency were positively correlated (Fig. 1). It was revealed that all the herbicides showed significant effects on grain yield. The highest rice yield was recorded from weed-free plot, followed by two hand weedings treatment. Among the herbicides, bispyribac-sodium 50 g/ha at 15-20 DAT resulted in the highest yield, which was at par with bispyribac-sodium 35 g/ha. These results are in close conformity with Hussain *et al.* (2008). The grain yield with butachlor 1.5 kg/ha at 5-7 DAT was also higher than untreated check.

It was concluded that application of bispyribac-sodium 35 g/ha at 15-20 DAT may be recommended in transplanted rice for controlling predominant weeds in the sub-humid south east plain zone of Rajasthan.

SUMMARY

An experiment was conducted in randomized block design with 7 treatments comprising butachlor 1.5 kg/ha at 5-7 DAT, bispyribac-sodium 25 g ha at 15-20 DAT, bispyribac-sodium 35 g/ha at 15-20 DAT, bispyribac-sodium 50 g/ha at 15-20 DAT, weed-free, until harvest, two hand weedings at 20 and 40 days after transplanting and unweeded control. Results revealed that application of bispyribac-sodium 50 g/ha at 15-20 DAT resulted in significantly higher grain yield (5.70 t/ha), which was at par with bispyribac-sodium 35 g/ha at 15-20 DAT. Number and dry weight of weeds was also minimum in these treatments.

Table 2. Yield performance of transplanted rice as influenced by different treatments

Treatment	No. of panicles /m^2		Panicle weight (g)		Grain yield (t/ha)		Straw yield (t/ha)		Harvest index (%)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Butachlor 1.5 kg /ha at 5-7 DAT	323	320	3.56	3.40	5.22	5.48	7.45	7.47	41.2	42.3
Bispyribac-sodium 25 g/ha at 15-20 DAT	316	314	3.68	3.46	5.14	5.23	7.24	7.05	41.5	42.6
Bispyribac-sodium 35 g/ha at 15-20 DAT	345	347	3.95	3.90	5.56	5.75	7.68	7.87	42.0	42.2
Bispyribac-sodium 50 g/ha at 15-20 DAT	356	351	4.06	4.01	5.70	5.92	8.13	8.45	41.2	41.2
Weed-free	382	385	4.41	4.32	6.05	6.55	8.28	8.75	42.2	42.8
Two hand weedings (20 and 40 DAT)	371	374	4.30	4.25	5.91	6.23	8.30	8.75	41.6	41.6
Unweeded control	268	270	3.12	3.10	3.84	3.94	5.76	5.41	40.0	42.1
LSD (P=0.05)	15.0	13.5	0.18	0.21	0.20	0.23	3.60	3.90	2.3	2.3

However, the highest grain yield (6.05 and 6.55 t/ha) was obtained from weed-free treatment. Significantly lower weed density (9-10/m^2), weed dry weight (12.5-13.7 g/m^2), weed persistence index (0.03) and weed competition index (8.05-12.55) were recorded in the plots where bispyribac-sodium 35 g/ha at 15-20 DAT was applied. Significantly higher weed control efficiency and herbicidal efficiency index were recorded with bispyribac-sodium 35 g/ha at 15-20 DAT .

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Short communication

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Performance of low dose high efficacy herbicides in drum seeded rice

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In recent years, rice (*Oryza sativa* L.) production systems are undergoing several changes and one of such changes is shifting from transplanted rice to direct sown rice due to increased cost of labour and non availability of labour during peak periods of agricultural operations. Sowing of sprouted rice seeds in wet puddled soils offers an attractive alternative and labour saving technique for stand establishment to the traditional transplanting. Wet seeded rice is gaining momentum in India and it have the advantages of quick and easier planting, reduces labour requirement and increased water use efficiency. However, direct seeded rice is associated with several constraints like heavy weed infestation, water management immediately after sowing and lack of perfect levelling *etc*. Among them, heavy infestation of heterogenous weed flora becomes the biggest biological constraint as rice and weed seeds germinate simultaneously. The yield loss due to unchecked weed growth was reported upto 30-48% in direct seeded rice (Subramanian *et al*. 2004). The failure and success of the drum seeded rice depends on weed and water management practices. Therefore, the present study was carried out to evaluate the relative efficacy of low dose high efficacy, pre- and post-emergence herbicides along with mechanical weeding with two row power weeder for the broad spectrum control of weeds in drum seeded rice.

A field investigation was conducted during *Kharif*, 2012 at of S.V. Agricultural College farm, Acharya N.G. Ranga Agricultural University, Tirupathi, Andhra Pradesh in order to know the response of drum seeded rice to different pre-and post-emergence herbicides. The soils of the experiment field was sandy loam in texture, neutral in reaction (pH 6.9), low in OC (0.43%), avalible N (215 kg/ha) and phosphorus (23.5 kg/ha) and medium in P (250 kg/ha). Sowing of sprouted seeds of rice variety, '*Somasila*' (NLR–33358) was done through eight row drum seeder with a row to row spacing of 20 cm. The experiment was laid out in randomized block design with three replications. The treatments consisted of ten weed management practices, *i.e* pre-emergence application of pretilachlor 500 g/ha, oxadiargyl 75 g/ha, pretilachlor 500 g/ha followed by *(fb)* mechanical weeding with power weeder at 40 DAS, pre-emergence application of oxadiargyl 75 g/ha *fb* mechanical weeding with power weeder at 40 DAS, pre-emergence application of pretilachlor 500 g/ha *fb* azimsulfuron 30 g/ha at 40 DAS, pre-emergence application of oxadiargyl 75 g/ha *fb* azimsulfuron 30 g/ha at 40 DAS, pre-emergence application of pretilachlor 500 g/ha *fb* bispyribac-sodium 30 g/ha at 40 DAS and pre-emergence application of oxadiargyl 75 g/ha *fb* bispyribac-sodium 30 g/ha at 40 DA besides two hand weeding at 20 and 40 DAS and unweeded check. The required quantities of pre-emergence (pretilachlor and oxadiargyl) herbicides were mixed with fine sand 50 kg/ha and then broadcasted at 7 DAS. Post-emergence herbicides (bispyribac-sodium and azimsulfuron) were applied uniformly at 40 DAS by using spray fluid 500 l/ha with the help of knapsack sprayer. Mechanical weeding with two row power weeder was carried out at 40 DAS as per the treatments. The crop was fertilized with 120 kg N, 60 kg P and 60 kg K/ha. One third dose of nitrogen and entire phosphorus and potassium were applied as basal and remaining dose of nitrogen was top dressed in two equal splits at active tillering and panicle initiation stage. Category wise weed density and dry weights were recorded at 60 DAS and at harvest and these data was subjected to square root ($\sqrt{x + 0.5}$) transformation before statistical analysis to normalize their distribution.

The dominant weed flora associated with drum seeded rice were sedges; *Cyperus difformis* (40.0%), *Cyperus iria* (21.40%) and *Cyperus rotundus* (12.22%), grasses; and *Echinochloa colonum* (10.1%) and *Eclipta alba* among broad-leaved weeds, Hassk (6.5%) and *Ammania baccifera* (4%). All the weed management practices at 60 DAS and at harvest were significantly reduced the density and dry weight of weeds. Hand weeding twice at 20 and 40 DAS showed the superiority in suppressing the density and dry weight of all the categories of weeds,

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which was significantly lesser than with the rest of the weed management practices (Table 1). Pre-emergence application of oxadiargyl 75 g/ha or pretilachlor 500 g/ha *fb* by post-emergence application of bispyribac-sodium 30 g/ha were very effective in suppressing the density and dry weight of grasses and broad-leaved weeds and these two weed management practices were at par with each other. Post-emergence application of bispyribac-sodium 30 g/ha was very effective in suppressing the density and dry weight of grasses and broad-leaved weeds. Pre-emergence application of oxadiargyl 75 g/ha *fb* by post-emergence application of bispyribac-sodium 30 g/ ha reduced the dry weight of grasses and broad-leaved weeds by 90.8 and 88% respectively compared to unweeded check at harvest. Yadav *et al*. (2011) reported that post-emergence application of bispyribac-sodium 25 g/ha significantly reduced the density and dry weight of weeds in wet direct seeded rice. This clearly indicated that post-emergence application of azimsulfuron 30 g/ha was found superior in suppressing the annual sedges, *viz. Cyperus iria* and *Cyperus difformis* more effectively than bispyribac-sodium 30 g/ha by inhibiting the acetolactate synthase enzyme in target plants due to reduced production of branched chain amino acids, *viz*. leucine, isoleucine and valine leading to death of weeds (Ferrero *et al*. 2002).

The lowest density and dry weight of total weeds with higher weed control efficiency (94%) was resgistered with two hand weedings at 20 and 40 DAS in drum seeded rice. The next best treatment was with the pre-emergence application of oxadiargyl 75 g/ha *fb* post-emergence application of azimsulfuron 30 g/ha, which was at par with bispyribac-sodium 30 g/ha in reducing the total density and dry weight. Pre-emergence application of pretilachlor 500 g/ha or oxadiargyl 75 g/ha supplemented with mechanical weeding with two row power weeder was not effective in controlling weeds as the weed density was very high in between the plants. Among the herbicidal treatments, pre-emergence application of pretilachlor 500 g/ha or oxadiargyl 75 g/ha alone recorded the highest density and dry weight of weeds coupled with lower weed control efficiency of 75 and 76%, respectively in drum seeded rice.

Table 1. Effect of pre- and post-emergence low dose high efficiency herbicides against weeds in drum seeded rice

Treatment	Dose (g/ha)	Time of application (DAS)	Weed density (no./m^2)						Weed dry weight (g/m^2)					
			60 DAS			At harvest			60 DAS			At harvest		
			G	S	BLWs	G	S	BLWs	G	S	BLWs	G	S	BLWS
Pretilachlor	500	7	3.53	6.74	3.02	3.80	7.44	3.18	3.11	6.03	2.72	3.44	6.04	3.04
			(12.0)	(45.0)	(8.7)	(14.0)	(55.0)	(9.7)	(9.2)	(36.0)	(6.9)	(11.4)	(36.0)	(8.79)
Oxadiargyl	75	7	3.38	6.65	2.85	3.67	7.29	3.13	3.05	5.97	2.60	3.36	5.92	3.01
			(11.0)	(44.0)	(7.7)	(13.0)	(52.7)	(9.3)	(8.8)	(35.2)	(6.3)	(10.8)	(34.6)	(8.59)
Pretilachlor *fb* power weeder	500	7+40	2.67	3.53	2.54	3.02	4.52	2.79	2.41	3.24	2.30	3.06	3.93	2.80
			(6.7)	(12.0)	(6.0)	(8.7)	(20.0)	(7.3)	(5.3)	(10.0)	(4.8)	(8.1)	(15.0)	(7.40)
Oxadiargyl *fb* power weeder	75	7+40	2.54	3.48	2.48	2.91	4.41	2.73	2.30	3.13	2.2	3.00	3.88	2.77
			(6.0)	(11.7)	(5.7)	(8.0)	(19.3)	(7.0)	(4.8)	(9.3)	(4.5)	(7.8)	(14.6)	(7.20)
Pretilachlor *fb* azimsulfuron	500+30	7+40	2.12	2.48	1.95	2.41	2.97	2.33	1.92	2.38	1.89	2.64	2.95	2.54
			(4.0)	(5.7)	(3.3)	(5.3)	(8.3)	(5.0)	(3.2)	(5.2)	(3.1)	(6.5)	(8.2)	(6.00)
Oxadiargyl *fb* azimsulfuron	75+30	7+40	2.03	2.40	1.95	2.33	2.79	2.11	1.84	2.27	1.77	2.54	2.77	2.46
			(3.7)	(5.3)	(3.3)	(5.0)	(7.3)	(4.0)	(2.9)	(4.7)	(2.7)	(6.0)	(7.2)	(5.60)
Pretilachlor *fb* bispyribac-sodium	500+30	7+40	1.55	3.23	1.60	1.85	3.76	1.67	1.44	2.91	1.61	2.34	3.42	2.28
			(2.0)	(10.0)	(2.3)	(3.0)	(13.7)	(2.3)	(1.6)	(8.0)	(2.1)	(5.0)	(11.2)	(4.70)
Oxadiargyl *fb* bispyribac-sodium	75+30	7+40	1.46	3.07	1.55	1.77	3.53	1.55	1.34	2.77	1.51	2.25	3.27	2.19
			(1.7)	(9.0)	(2.0)	(2.7)	(12.0)	(2.0)	(1.3)	(7.2)	(1.8)	(4.6)	(10.2)	(4.30)
HW twice	-	20+40	1.07	2.03	1.07	1.35	2.34	1.22	1.00	2.05	1.34	1.87	2.54	1.87
			(0.7)	(3.7)	(1.7)	(1.3)	(5.0)	(1.0)	(1.0)	(3.7)	(1.3)	(3.0)	(6.0)	(3.00)
Unweeded check			6.81	13.35	5.58	6.95	13.79	6.09	6.09	11.95	4.99	7.10	12.26	5.04
			(46.0)	(178)	(30.3)	(48.0)	(190)	(5.8)	(36.)	(142)	(24.5)	(50)	(25.0)	(25.00)
LSD (P=0.05)			0.32	0.24	0.17	0.30	0.33	0.27	0.11	0.20	0.13	0.19	0.21	0.14

Figures in parentheses are original values. Data transformed to ($\sqrt{X+0.5}$). *fb:* followed by. G: Grasses, S: Sedges, BLWs: Broad leaved weeds

Table 2. Effect of pre- and post-emergence low dose high efficiency herbicides on weed parameters, yield components and yield of drum seeded rice

Treatment	Dose (g/ha)	Time of application (DAS)	Weed density (no./m²)	WCE (%)	Panicles (no./m²)	No. of filled grains/ panicle	1000-grain weight	Grain yield (t/ha)	Net returns (x10³ ₹ /ha)	B:C Ratio
Pretilachlor	500	7	8.88 (78.66)	75.02	275	80.2	18.00	3.81	39.97	2.50
Oxadiargyl	75	7	8.68 (75.0)	76.00	280	82.4	18.06	3.93	41.80	2.53
Pretilachlor *fb* power weeder	500	7+40	6.03 (36.0)	86.44	289	89.3	18.33	4.59	50.83	2.92
Oxadiargyl *fb* power weeder	75	7+40	5.90 (34.3)	86.84	290	89.8	18.35	4.60	52.27	2.91
Pretilachlor *fb* azimsulfuron	500+30	7+40	4.37 (18.6)	90.79	303	97.5	18.54	5.18	59.41	3.00
Oxadiargyl *fb* azimsulfuron	75+30	7+40	4.09 (16.33)	91.73	318	105.8	18.75	5.75	68.76	3.30
Pretilachlor *fb* bispyribac-sodium	500+30	7+40	4.41 (19.0)	90.71	300	96.3	18.50	5.10	58.93	3.01
Oxadiargyl *fb* bispyribac-sodium	75+30	7+40	4.14 (16.6)	91.59	305	98.6	18.63	5.20	60.41	3.08
HW twice	-	20+40	2.79 (7.3)	94.66	314	105	18.70	5.71	65.91	3.06
Unweeded check	-	-	16.46 (271)	-	230	74.1	17.50	2.82	23.69	1.91
LSD (P=0.05)			0.200	0.700	8	3.6	NS	0.139	2.90	0.04

Among the weed management practices, pre-emergence application of oxadairgyl 75 g/ha *fb* post-emergence application of azimsulfuron 30 g/ha recorded significantly higher yield attributes, *viz.* panicles/m², filled grains/panicle, number of grains/panicle and thousand grain weight and grain yield of drum seeded rice (Table 2) and it was comparable with hand weeding twice at 20 and 40 DAS with respect to all the above yield attributes and yield. The former weed management practice increased the no. of panicles/m² and filled grains/panicle by 39.1 and 42.8%, respectively over unweeded check.

This might be due to effective control of all the categories of weeds during critical period of crop weed competition, which lead to increased growth resources and better translocation of photosynthates from source to sink (Dharminder *et al.* 2012). The next best weed management practice to obtain broad spectrum weed control with increased yield attributes and yield with the pre-emergence application of oxadiargyl 75 g/ha or pretilachlor 500 g/ha *fb* post-emergence application of bispyribac-sodium 30 g/ha. The lowest grain yield attributes and yield were recorded with unweeded check followed by pre-emergence application of oxadiargyl 75 g/ha or pretilachlor 500 g/ha alone. The reduction in grain yield in unweeded check was 51% competed to the best weed management practice *i.e.* pre-emergence application of pretilachlor 500 g/ha *fb* azimsulfuron 30 g/ha. These results are in conformity with those of Tiwari *et al.* (2006).

The highest net returns (₹ 68,766/ha) were realized with pre-emergence application of oxadiargyl 75 g/ha *fb* azimsulfuron 30 g/ha, which were comparable with two hand weedings at 20 and 40 DAS and both of them were significantly higher than with rest of the weed management practices (Table-2). However, the highest benefit-cost ratio of 3.30 was registered with the pre-emergence application of oxadiargyl 75 g/ha *fb* azimsulfuron 30 g/ha, which was significantly higher than with rest of the weed management practices tried In conclusion, pre-emergence application of oxadiargyl 75 g/ha followed by post emergence application of azimsulfuron 30 g/ha applied at 40 DAS resulted in the highest grain yield and economic returns as well as broad spectrum weed control in drum seeded rice.

SUMMARY

A field experiment was conducted at S.V. Agricultural College Farm, Tirupati to identify the effective and economic weed management practices for the control of weeds in drum seeded rice. The major weed flora in experiment field were *Cyperus difformis* (40.0%), *Cyperus iria* (21.40%), *Cyperus rotundus* (12.22 %), *Echinochloa colonum* (10.1%), *Eclipta alba* (6.5%) and *Ammania baccifera* (4%). Among the weed management practices, pre-emergence application of oxadiargyl 75 g/ha *fb* azimsulfuron 30 g/ha was found to be the most effective weed management practice in reducing the density and dry weight of weeds with higher weed control efficiency,

higher yield attributes and yield (5.75 t/ha) including benfit : cost ratio (3.30) but it was being at par with two hand weedings. The reduction in grain yield due to heavy weed infestation in unweeded check was 51% compared to best weed management practice. Post-emergence application of azimsulfuron 30 g/ha was found effective in controlling sedges and bispyribac-sodium 30 g/ha was very effective in suppressing the grasses and broad-leaved weeds in drum seeded rice.

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Short communication

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Sensitivity and yield performance of wheat varieties as influenced by sulfosulfuron + metsulfuron application

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Key words: Chemical control, Sensitivity, sulfosulfuron + metsulfuron, Variety, Wheat

Wheat is an important cereal *Rabi* crop of Haryana. The crop is severely infested by both grass and broad-leaf weeds. A new herbicide, ready mixture of sulfosulfuron + metsulfuron, provides excellent control of resistant population of *Phalaris minor* and broad-leaved weeds (Malik *et al.* 2007, Punia *et al.* 2008, Chhokar *et al.* 2011). Some wheat varieties have been found to be sensitive to 2,4-D and isoproturon (Balyan 1999, Yadav and Malik 2005). Keeping it in view, the present experiment was planned to study the sensitivity of popular wheat varieties to this new herbicide.

A study was done to find the sensitivity of 9 wheat varieties to sulfosulfuron + metsulfuron (R.M.) at CCS HAU, Hisar during *Rabi* season of 2005-06 and 2006-07. Nine wheat varieties, viz. *'WH 1022, HD-2687, C-306, UP-2338, PBW-343, WH-542, WH-711, WH-283'* and *'WH-147'* were kept as main plots treatments, and two doses of herbicide, *viz.* sulfosulfuron + metsulfuron at 32 g/ha (x), double to recommended 64 g/ha (2x) and weedy check were kept as subplot treatments, with four replications in a plot size of 5.0 x1.6 m. All agronomic practices except herbicide doses were same in all treatments. Observations on visual phytotoxicity to crop such as yellowing and stunting were recorded at 15 and 30 days after treatment on 0-10 scale. Crop was harvested on 11.4.2006 and data on grain yield was recorded.

Results showed that with recommended dose of herbicide 32 g/ha, leaves of all wheat varieties except *'C-306'* showed slight yellowing of leaves at 15 days after treatment (DAT), which disappeared with passage of time as at 30 DAT no yellowing was visible on leaves (Table 1). At double to recommended dose (64 g/ha), even slight yellowing on leaves was also observed. Wheat plants of any variety did not show stunted growth at both application rates**.** Yadav *et al.* (2009) also reported that no phytotoxicity on wheat crop was observed with application of sulfosulfuron + metsulfuron (ready-mix) 32 g/ha and sulfosulfuron 25 g/ha *fb* metsulfuron 4 g/ha in wheat.

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Grain yield of wheat did not differ significantly in x and 2x doses, and weed-free check but the yield was significantly higher than weedy check (Table 1). The yield also varied significantly among different varieties at both the herbicide doses. During 2005-06, maximum grain yield (4.52 t/ha) was recorded in 'WH-1022' but in 2006-07, the maximum grain yield (6.95 t/ha) was in 'WH-542' and minimum (2.96 and 4.25 t/ha) in 'C-306'. It may be due to inherent low yield potential of '*C-306'* which is tall growing with good grain quality. Grain yield of all wheat varieties did not vary significantly among herbicide rates. During 2006-07, the grain yield of *'PBW-343', 'UP-2338', 'WH-283'* and *'PBW-502'* was numerically higher in double dose herbicide than weed-free. Malik *et al.* (2007) reported that sulfosulfuron + metsulfuron (15 + 4 g/ha) proved effective against all weeds and reduced the total weed dry weight to the extent of 87-96%. Sulfosulfuron + metsulfuron produced effective tillers and grain yield of wheat statistically at par with weed-free check , which was 40–42% higher than weedy check. Yadav *et al.* (2009) also observed that sulfosulfuron + metsulfuron and sulfosulfuron *fb* metsulfuron reduced the density and dry weight of *P. minor* and it was as good as weed-free check in respect of effective tillers and grain yield of wheat.

No phytotoxicity of sulfosulfuron + metsulfuron was observed on any wheat variety with x and 2x doses, and the grain yield did not vary significantly among varying herbicide rates.

SUMMARY

An investigation to study the sensitivity of nine wheat varieties, *viz. 'WH 1022', 'HD-2687', 'C-306', 'UP-2338', 'PBW-343', 'WH-542', 'WH-711', 'WH-283'* and 'WH-147' to most popular used herbicide combination, *i.e.* sulfosulfuron + metsulfuron (R.M.) was undertaken at Hisar during *Rabi* seasons of 2005-06 and 2006-07. At 15 DAT with recommended dose of herbicide 32 g/ha, the leaves of all wheat varieties except '*C-306*' showed slight yellowing of leaves which disappeared with passage of time as at 30 days after treatment no yellowing was vis-

Table 1. Grain yield (t/ha) of different wheat varieties as affected by different doses of sulfosulfuron+metsulfuron

Varieties	Herbicide doses (2005-06)				Herbicide doses (2006-07)			
	Recommended dose (x)	Double to recommended dose (2x)	Weed-free	Mean	Recommended dose (x)	Double to recommended dose (2x)	Weed-free	Mean
'WH 1022'	5.69	5.67	5.68	5.68	5.83	5.86	5.88	5.86
'HD-2687'	5.58	5.73	5.75	5.69	6.34	6.37	6.38	6.36
'C-306'	3.75	3.88	3.80	3.81	4.28	4.27	4.18	4.25
'UP-2338'	4.67	4.82	4.80	4.76	5.63	5.73	6.00	5.65
'PBW-343'	5.58	5.53	5.58	5.56	6.76	6.83	6.64	6.74
'WH-542'	5.62	6.00	5.60	5.61	6.98	6.92	6.96	6.95
'WH-711'	5.13	5.19	5.20	5.17	6.98	6.86	6.92	6.92
'WH-283'	5.16	5.23	5.23	5.20	6.02	5.79	5.79	5.87
'WH-147'	4.95	5.01	5.10	5.02	6.09	5.80	5.87	5.92
'WH 502'					6.61	6.49	6.35	6.48
Mean	5.12	5.18	5.17		6.15	6.09	6.06	
LSD (P=0.05) for variety		0.45				0.26		
LSD (P=0.05) for dose		NS				NS		
LSD (P=0.05) for V x H		NS				NS		

ible on leaves even at double to recommended dose (64 g/ha). In all wheat varieties, the grain yield with x and 2x doses was at par with weed-free check but higher than weedy check, indicating no detrimental effect of the herbicide on any variety tested.

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Short communication

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Effect of new herbicides on growth and yield of wheat

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Key words : Herbicides, Weed control, Yield, Wheat

Wheat (*Triticum aestivum*) is the world's most widely cultivated food crop and in India it is second important staple food, rice being the first. A formidable factor that limits its productivity is severe weed competition, which competes with crop plants for water, nutrients, space and solar radiation resulting in reduction of yield by 29% (Pandey *et al. 2006*). Wheat field is generally infested from both monocot and dicot weeds. The most common weeds in wheat which cause reduction in grain yield of wheat are *Chenopodium album*, *Convolvulus arvensis*, *Cynodon dactylon* etc. in crop-weed ecosystem (Singh and Singh, 2004), controlling these weeds at initial stage, results in greater benefit. There are many good pre-emergence herbicides used for weed control in India and they were found effective in controlling weeds in wheat. This trial was done to assess efficacy of post-emergence herbicides for weed control in wheat, its effect on growth and yield of wheat and economics of different herbicidal treatments.

A field investigation was conducted during *Rabi* season 2009-10 at the Experimental Farm, Department of Agronomy, Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra. The experimental field was leveled and well drained, clayey in texture with pH 7.8, organic carbon 0.52%, medium in available N, P and high in available K. The maximum and minimum temperature recorded during the experimental period was 40.2^{0}C and 6.6^{0}C, respectively. The experiment was laid out in randomized block design with ten treatments. Each experiment unit of 5.4 x 6.0 m gross plot size and having 3.6 x 4.2 m of net plot size was repeated three times. In weed free treatment, the plot was kept weed free by weeding at 20 days interval for three times where as in two hand weeding, weeding were carried out at 20 and 35 days after sowing. Variety *'NIAW-301'(Trimbak*) was sown manually on 2nd December, 2009 at a row spacing of 22.5 cm using 125 kg seeds/ha. The basal dose consisting of NPK 50 : 50 : 50 kg/ha in the form of Urea, SSP and MOP was applied before sowing. The remaining half dose of 50 kg N was applied on 23rd December, 2009, 22 days after sowing. Pre-emergence application of pendimethalin 750 g/ha was done on 4th December 2009. The remaining PoE herbicides were applied on 4th of January, 2010 (32 days after sowing) Various ancillary observations on crop growth were periodically recorded along with post harvest studies to evaluate treatment effects. Necessary observations on weeds were also recorded during the conduct of experiment.

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The dominant dicot weeds were: *Acalypha indica*, *Parthenium hysterophorus*, *Phyllanthus medraspatensis*, *Convolvulus arvensis*, *Euphorbia geniculata*. In monocot weeds *Cynodon dactylon*, *Cyprus rotundus* and *Brachiaria eruciformis* were dominant.

Throughout the crop growth period, lower weed intensity was observed in weed free and it was followed by metsulfuron-methyl 4 g/ha. In weedy check, dicot weeds were higher than monocot at 60 DAS (Table 1). These results were in conformity with Pandey *et al.* 2001 and Singh and Ali 2004). The treatment of weed-free did not record any dominant weeds at 60 DAS except *Cynodon dactylon* and *Cyprus rotundus*, whereas metsulfuron-methyl 4 g/ha. controlled dicot weeds than monocot weeds. Similar reports were given by Pandey *et al.* (2001), Singh and Ali (2004). Lowest monocot weed weight was observed with weed free treatment followed by metsulfuron-methyl 4 g/ha whereas, highest monocot weeds dry weight was recorded with treatment weedy check. At 60 days after sowing, lowest dicot weed weight was recorded with treatment weed free followed by metribuzin 300 g/ha. The treatment weedy check showed highest dicot weed dry weight followed by 2,4-D Na salt 750 g/ha. The highest weed control efficiency was observed in weed free condition followed by metsulfuron-methyl 4 g/ha at 30 DAS and at 60 DAS. The results of the present quest are in line with the findings of Pandey *et al.* (2001) and Verma *et al.* (2007).

The highest dry matter accumulation was recorded with weed free treatment followed by metsulfuron-methyl 4 g/ha over weedy check (Table 2). This might be due to effective control of weeds, so it resulted in mini-

Table 1. Effect of herbicides on weed population, dry weed weight and weed control efficiency (60 days after sowing)

Treatment	Dose (g/ha)	Weed population (no./m^2)		Dry weed weight (g/m^2)	
		Monocot	Dicot	Monocot	Dicot
Pendimethalin	750	17.6	22.6	141.5	177.0
Carfentrazone	25	21.6	40.6	141.7	251.6
Fenoxaprop	120	23.3	30.6	194.9	262.7
2,4-D	750	17.6	48.0	123.8	352.4
Metsulfuron-methyl	4	14.3	53.6	42.6	161.4
Metribuzin	300	18.6	25.6	90.1	125.1
Fenoxaprop + metribuzin	90+140	21.3	30.6	158.5	237.0
Weed free	-	6.6	8.6	10.5	12.1
2 HWs	-	24.3	33.6	102.7	130.7
Weedy check	-	51.3	91.3	464.9	729.3
LSD (P=0.05)	-	21.7	38.5	47.0	71.2

Table 2. Effect of herbicides on growth, yield attributes and yield of wheat

Treatment	Dose (g/ha)	Plant height at harvest (cm)	No. of tillers per plant at harvest	Ear length (cm)	Number of grains/ ear	1000-grain weight (g)	Grain yield (t/ha)	Gross monetary returns (x10^3 `/ ha)	Net monetary returns (x10^3`/ ha
Pendimethalin	750	88.4	4.40	8.10	50.3	39.0	2.93	40.34	26.91
Carfentrazone	25	88.7	4.26	7.90	47.8	37.5	2.67	36.69	24.24
Fenoxaprop	120	88.4	4.33	7.80	47.5	37.1	2.60	35.74	23.34
2,4-D	750	87.8	4.40	7.93	48.6	37.9	2.69	37.16	24.75
Metsulfuron-methyl	4	90.1	4.73	8.33	50.8	40.0	3.16	43.66	31.35
Metribuzin	300	89.4	4.46	8.30	50.7	39.4	3.15	43.43	30.90
Fenoxaprop + metribuzir	90+140	87.8	4.33	8.06	48.6	38.4	2.81	40.68	26.23
Weed free	-	90.2	5.00	8.36	51.9	41.2	3.36	46.26	30.84
2 H Ws	-	88.7	4.26	8.23	50.6	39.1	3.01	41.35	29.13
Weedy check	-	85.6	4.13	7.63	46.1	36.6	2.54	34.61	22.78
LSD (P=0.05)	-	2.05	0.28	N.S.	2.11	1.78	0.505	0.59	0.52

mum weed-crop competition. The dry matter accumulation is largely a function of photosynthetic surface which has also more under these treatments resulting in increased biological productivity and finally dry matter accumulation. Similar results were obtained by Hooda *et al.* (2007). Grain and straw yield of wheat were higher in weed free situation followed by metsulfuron-methyl 4 g/ha. Weedy check recorded the lowest grain and straw yield. Low yield in check may be due to poor root growth and higher weed population could have competed with wheat crop for space, water and nutrients, thereby adversely affecting grain and straw yields. Similar trends were given by Pandey *et al.* (2001) and Pandey *et al.* (2006).

Maximum gross monetary return was observed in weed free treatment due to effective weed control. While highest net monetary returns and B : C ratio was recorded with treatment metsulfuron-methyl 4 g/ha$^-$ may be due to higher yield and comparatively lower cost of cultivation as compared to weed free treatment. These results were in conformity with Jat *et al.* (2003) and Pandey *et al.* (2006).

SUMMARY

An average decrease in grain yield by 15.42 % was observed due to season-long weed-crop competition. Lowest monocot and dicot weeds were observed with weed free treatment. The best weed control efficiency in case

of monocot (90.8%) and dicot (82.8%) was achieved with metsulfuron-methyl and metribuzin, respectively compared to other herbicides namely pendimethalin, carfentrazone, fenoxaprop and 2,4-D. All the treatments except fenoxaprop, carfentrazone, 2,4-D and mixture of metribuzin and fenoxaprop application gave significantly higher grain yield compared to weedy check. However , higher additional net return (` 31,359) was obtained with metsulfuron-methyl followed by metribuzin (` 30,907).

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Short communication

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Productivity and economics of late-sown wheat under different sowing methods and weed management practices

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Key words: Economics, Sowing methods, Weeds, Weed Management, Wheat, Yield

Rice–wheat system is dominant cropping system of the Uttar Pradesh, which is widely practiced by the farmers. Late transplanting of rice, use of long-duration varieties and heavy rains during later phase of rice crop are the main reasons for delayed sowing of wheat. A rise in temperature during early spring inducing early maturity is also a key yield-reducing factor in late-sown wheat (Yasmeen *et al.* 2012). Several methods of weed control are being practiced by the farmers. The manual weeding besides being expensive and troublesome, cannot be practiced until weeds put forth sufficient vegetative growth. Adoption of suitable combination of sowing method and weed management practice can substantially contribute to reduce the weed density and increase the productivity of late-sown wheat.

A field experiment was conducted at Agronomy Research Farm of NDUA&T, Faizabad during *Rabi* 2008-09. The soil was silt loam in texture, low in organic C (0.32%), available N (160 kg/ha) and available P (19 kg/ha) and medium in available K (234 kg/ha) content. The experiment was layout in split-plot design and replicated three times. The main plots included three sowing methods, *viz.* line sowing, cross sowing, and broadcasting; and six weed management practices, *viz.* isoproturon 1.0 kg/ha + 2,4-D 500 g/ha, clodinafop 60 g/ha, metribuzin 200 g/ha, sulfosulfuron 25 g/ha, weedy check and weed-free check as subplot treatments. After the rice crop was har-vested, field was prepared by cultivator and planking, and 125 kg/ha seeds of variety *'UP 2425'* was sown in 20 December, 2008. Fertilizer (120 kg/ha N, 60 kg/ha P_2O_5, 40 kg/ha K_2O) was applied to the crop. A one-third dose of N and full dose of P and K was applied before sowing, and the re-maining N was top-dressed in two equal splits at the first node and booting stages.

Differences in growth and yield attributes were observed due to sowing methods and weed management practices (Table 1). The significantly higher plant height (77.5 cm), number of shoots/m^2 (376), dry matter accumulation (882.5 g/m^2), spike/m^2 (317), spike length (9.3 cm) and number of grains/spike (37.8) were recorded in cross sowing than broadcasting; however, these were was at par with line sowing. This might be due to optimum plant population and poor weed growth due to smothering effect. The significantly higher plant height (85.9 cm) was recorded in weed-free check than rest of the treatments; however, it was at par with isoproturon 1.0 kg/ha + 2,4-D 500 g/ha and metribuzin 200 g/ha in respect of number of shoots/m^2 and dry matter accumulation.. The more growth and yield attributes in weed-free check followed by isoproturon at 1.0 kg/ha + 2,4-D 500 g/ha was due to lower weed competition for water, sunlight and greater availability of nutrients, which resulted in profuse growth of plants and effective control of both grassy and broadleaved weeds (Tiwari *et al.* 2011).

Productivity in terms of grain and straw yield differed significantly due to different sowing methods and weed control treatments (Table 2). The maximum grain and straw yields of 3.8 and 5.5 t/ha, respectively, were recorded with cross sowing, which were significantly more than line sowing and broadcasting. The higher values of grain yield may be ascribed to marked decrease in weed population and weed dry weight, and thereby better growth and yield attributes. These results are in conformity with the findings of Saquib *et al.* (2012). Maximum net returns and B:C ratio were obtained in cross sowing followed by line sowing. Weed-free check recorded maximum net returns and B:C ratio, followed by isoproturon 1.0 kg/ha + 2,4-D 500 g/ha

SUMMARY

A field experiment was conducted during *Rabi* season of 2008-09 at Faizabad to study the effect of sowing methods and weed management practices on growth and productivity of wheat. Cross sowing recorded significantly higher growth, yield attributes in terms of plant height, number of shoots/m^2, dry matter accumulation, number of spike/m^2, spike length, number of grains/spike and grain (3.8 t/ha) and straw (5.5 t/ha) yields. The val-

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Table 1. Effect of sowing methods and weed management practices on growth and yield attributes of wheat

Treatment	Plant height (cm) at harvest	No. of shoots /m^2 at harvest	Dry matter accumulation (g/m^2)	No. of spike /m^2	Spike length (cm)	No. of grains /spike	1000-grain weight (g)
Sowing methods							
Line sowing	74.3	372	877.7	312	9.1	37.2	40.8
Cross sowing	77.5	376	882.5	317	9.3	37.8	41.0
Broadcasting	65.9	343	818.8	294	8.7	34.9	40.6
LSD (P=0.05)	3.2	16.1	36.3	11.4	0.4	1.64	NS
Weed management							
Isoproturon 1.0 kg/ha + 2,4-D @ 500 g/ha	79.2	382	903.9	332	9.4	39.8	41.2
Clodinafop 60 g/ha	64.3	360	822.6	292	8.7	32.3	40.6
Metribuzin 200 g/ha	73.4	366	878.3	312	9.1	38.0	41.0
Sulfosulfuron 25 g/ha	68.3	363	841.4	301	8.7	35.6	40.6
Weedy check	61.7	327	806.3	247	8.4	30.9	40.3
Weed free check	85.9	401	905.3	364	9.6	40.3	41.3
LSD (P=0.05)	5.0	25.1	59.1	21.0	0.6	2.4	NS

Table 2. Effect of sowing methods and weed management practices on yield and economics of wheat

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Cost of cultivation (x10^3 `/ha)	Net returns (x10^3 `/ha)	B:C ratio
Sowing methods					
Line sowing	3.5	5.0	19.82	24.98	1.25
Cross sowing	3.8	5.5	20.14	28.09	1.39
Broadcasting	3.3	4.5	19.49	22.71	1.18
LSD (P=0.05)	0.17	0.23	-	-	-
Weed management					
Isoproturon 1.0 kg/ha + 2,4-D @ 500 g/ha	3.9	5.6	19.91	29.15	1.47
Clodinafop 60 g/ha	3.6	4.5	19.92	24.35	1.22
Metribuzin 200 g/ha	3.8	5.3	19.54	27.78	1.42
Sulfosulfuron 25 g/ha	3.7	5.0	19.84	25.13	1.27
Weedy check	2.5	3.9	19.05	13.35	0.69
Weed-free	4.1	6.1	20.64	31.80	1.58
LSD (P=0.05)	0.24	0.35			

ues of growth, yield attributes and grain (4.1 t/ha) and straw (6.1 t/ha) yields were higher in weed-free check. Application of isoproturon at 1.0 kg/ha + 2,4-D 500 g/ha was found best as compared to other herbicide treatments.

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Short communication

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Pollen germination assay for detection of cross resistance against acetyl coenzyme-a inhibiting herbicides in littleseed canary grass

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Key words: Herbicde resistance, Cross resistance, Clodinafop-propargyl, Fenoxaprop-p-ethyl, Pinoxaden, *Phalaris minor*, Pollen germination

Phalaris minor is an annual weed infesting winter crops across several continents. In India, the weed evolved insensitivity to urea herbicides (isoproturon), ACCase (fenoxaprop-p-ethyl, clodinafop-propargyl, pinoxaden) and ALS (sulfosulfuron) inhibiting herbicides (Malik and Singh 1995, Dhawan *et al.* 2009, Dhawan *et al.* 2010). An existence of multiple resistance in *P. minor* populations (Chokhar and Sharma 2008) makes the decision making task regarding use of alternate herbicides more difficult. A resistant population at a particular population could be resistant to one or more herbicides. Laboratory methods like seed germination assays (Murray *et al.* 1996, O' Donovan *et al.* 1996) and pollen germination assays (Richter and Powles 1993, Letouze and Gasquez 1999) have been employed for early detection of herbicide resistance and management options. While the utility of seed germination assay in *P. minor* is established in an earlier communication (Dhawan *et al*. 2010) the utility of pollen germination assay is explored in this investigation. A medium for germination of *P. minor* pollen has been identified to be raffinose, 7.5% + boric acid 20 ppm + calcium chloride, 300 ppm (Dhawan *et al.* 2013). The response of herbicides like fenoxaprop-p-ethyl, clodinafop-propargyl and pinoxaden was evaluated in pollen germination assay and a comparison was made with whole plant assay.

Six populations, *viz*. Karnal-Uchana, Karnal-Sagga, Kurukshetra-Neemwali, Kurukshetra-Chanarthal, Jind-Raseedan and Jind–Pipaltha were selected for study. Their response to fenoxaprop, clodinafop and pinoxaden was studied in a pot trial during 2012-13. Seeds were sown in pots filled with sandy loam soil in the month of November. These were thinned to 5 plants per pot after one week of emergence. For herbicide spray, the pots (4 replicates per treatment) were kept in 10 m^2 area and sprayed with a knapsack sprayer at 2-3 leaf stage. Per cent mortality was recorded after 30 days. The dose range for herbicide spray was: fenoxaprop-p-ethyl - 0, 60, 120, 240, 480 and 960 g/ha; clodinafop-propargyl - 0, 30, 60, 120 and 240 g/ha and pinoxaden - 0, 25, 50, and 100g/ha

Plants of different populations were raised in November in pots filled with sandy loam soil. Anthesis in the inflorescence proceeded basipetally with the terminal flowers of each panicle opening first followed by next flower down shortly thereafter. Pollen viability was estimated by employing TTC (triphenyl tetrazolium chloride) test. The test solution was prepared by boiling 0.5% TTC in a solution of 30% sucrose and 0.1% sodium succinate. After cooling, the pollen grains were put in a drop of the solution and kept in an oven at $30^{O}C$ for 15 minutes. The red pollen grains indicated viable pollen. Pollen germination was expressed as a percentage of viable grains.

To study the response of herbicides, stock solutions of 4000 µM each of fenoxaprop, clodinafop and pinoxaden were prepared and diluted to give final concentrations of 0.1, 1, 10, 100, 1000 1nd 2000 µM when added to the germination medium. 100µL solution was taken on a glass slide and pollen grains from one anther were tapped on to it with the help of a needle and left to germinate. These were observed under the microscope. Germinating pollen grains with long pollen tubes could be observed within 10-30 min. The number of germinated and no germinated pollen was counted in a field and percentage calculated. Observations under 10 fields per treatment were recorded and the means calculated. Data for different doses was calculated as percentage of controls. Dose response curves were drawn and ED_{50} (equivalent dose required for 50% inhibition of germination) values calculated by polynomial regression on dose response curves as described in an earlier communication (Dhawan *et al.* 2009).

None of the populations was susceptible to fenoxaprop, since the populations showed GR_{50} (herbicide dose for 50% reduction of growth) values in the range of 120-240 g/ha higher than the recommended dose (100 g/ha). The most resistant populations was identified to be Kurukshetra-Chanarthal with GR_{50} value of 240g/ha. The populations showed resistance against clodinafop-

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propargyl too. The range in GR_{50} value was found to be 50-180 g/ha. Populations from Kurukshetra- Chanarthal and Jind–Raseedan showed highest GR_{50} values of 120 and 180g/ha, respectively. These populations also showed resistance against pinoxaden with GR_{50} values of 60 and 85 g/ha (Table 1).

Pollen germination assay showed parallel results. The most resistant population against fenoxaprop was seen to be Kurukshetra-Chanarthal with ED_{50} value of 3000 µM. The most resistant populations against clodinafop were seen to be Kurukshetra-Chanarthal and Jind-Raseedan with ED_{50} value of 1000 µM each as compared to ED^{50} value of 75-100 µM in other populations. Similarly these populations showed ED^{50} value of 2100 µM against pinoxaden as compared to 500-1000uM in other populations (Table 2).

The study substantiated the earlier findings of existence of resistance against ACCase inhibiting herbicides. It also provided an indication of an expression of ACCase resistance in pollen germination behaviour of the populations. Haughen and Somerville (1986) reported that herbicide resistant trait conferred by single nuclear encoded genes could be expressed in pollen due to an insensitive target site and resistance due to detoxification mechanism may not be expressed in pollen. Since a parallel could be observed in pot culture assay and pollen assay, it may be inferred that evolution of resistance to ACCase inhibiting herbicides in these populations is due to target site alterations. This is in contrast to evolution of resistance to isoproturon which was reported to be due to metabolic detoxification of the herbicides (Singh *et al.* 1998a,b). Further work on molecular analysis of the populations could provide leads towards the mutations involved at the target site.

Table 1. The response of *Phalaris minor* populations to fenoxaprop, clodinafop and pinoxaden in whole plant assay

Herbicide / population	GR_{50} (g/ha)	Regression equation	R^2
Fenoxaprop			
Karnal-Uchana	150	$143.5 - 55.9x + 6.5x^2$	0.90
Karnal-Sagga	120	$164 - 81.1x + 10.9x^2$	0.85
Kurukshetra-Neemwali	120	$158 - 72x + 9.3x^2$	0.92
Kurukshetra-Chanarthal	240	$126 - 38.6x + 4.2x^2$	0.79
Jind-Raseedan	120	$150 - 65.3x + 8.2x^2$	0.87
Jind-Pipaltha	200	$131 - 46x + 6.2x^2$	0.64
Clodinafop			
Karnal-Uchana	95	$122.7 - 26.3x + 1.8x^2$	0.89
Karnal-Sagga	90	$141.3 - 26.8x - 0.42x^2$	0.88
Kurukshetra-Neemwali	50	$143.1 - 42.8x + 2.9x^2$	0.99
Kurukshetra-Chanarthal	120	$137.5 - 43x + 5x^2$	0.98
Jind-Raseedan	180	$130.1 - 29.1x + 2.6x^2$	0.93
Jind - Pipaltha	50	$131.7 - 32.9x + 1.6x^2$	0.94
Pinoxaden			
Karnal-Uchana	24	$177.2 - 96.7x + 14.7x^2$	0.85
Karnal-Sagga	22	$188.3 - 106x + 16.7x^2$	0.89
Kurukshetra-Neemwali	20	$210.3 - 134.1x + 21x^2$	0.95
Kurukshetra-Chanarthal	60	$93.2 + 25.6x - 12.2x^2$	0.89
Jind-Raseedan	85	$-8.8 + 176.7x - 44.2x^2$	0.62
Jind-Pipaltha	20	$187 - 101x + 140x^2$	0.99

SUMMARY

Pollen germination was tested in six *Phalaris minor* populations in a germination medium consisting of raffinose (7.5%) + boric acid (20 ppm) + calcium chloride (300ppm) supplemented with 0.1–2000 µM of fenoxaprop-p-ethyl, clodinafop-propargyl and pinoxaden. The populations were also tested in a pot culture assay. A parallel response was observed with regard to the level of resistance in the two systems. The method showed the possibility of a rapid screening test for resistant populations.

Table 2. The response of *Phalaris minor* populations to fenoxaprop, clodinafop and pinoxaden in pollen

Herbicde /population from different places	GR_{50} (µm)	Regression equation	R^2
Fenoxaprop			
Karnal-Uchana	900	$108.1 – 8.5x -1.7 x^2$	0.90
Karnal-Sagga	950	$97.1 -9.2 x -0.55 x^2$	0.57
Kuruukshetra-Neemwali	700	$125.1 – 31.2 x + 2.4 x^2$	0.81
Kurukshetra-Chanarthal	3000	$76.1 + 26.8 x - 4.3 x^2$	0.77
Jind-Raseedan	750	$118.4 – 16.9 x -0.46 x^2$	0.93
Jind- Pipaltha	1100	$123.1 – 13.8 x -0.86 x^2$	0.93
Clodinafop			
Karnal-Uchana	75	$122.7 – 26.3 x + 1.8 x^2$	0.62
Karnal-Sagga	90	$141.3 – 26.8 x -0.42 x^2$	0.82
Kuruukshetra-Neemwali	80	$143.1 – 42.8 x + 2.9 x^2$	0.92
Kurukshetra-Chanarthal	1000	$137.5 - 43 x +5 x^2$	0.68
Jind-Raseedan	1000	$130.1 – 29.1 x + 2.6 x^2$	0.96
Jind-Pipaltha	100	$131.7 – 32.9 x + 1.6 x^2$	0.97
Pinoxaden			
Karnal-Uchana	500	$132.8 – 39.2 x + 3.7 x^2$	0.95
Karnal-Sagga	1000	$125.6 – 25.6 x +2.1 x^2$	0.95
Kuruukshetra-Neemwali	600	$119.3 – 28 x + 2.2 x^2$	0.83
Kurukshetra-Chanarthal	2100	$93.7 + 5.5 x -1.9 x^2$	0.82
Jind-Raseedan	2100	$71.2 + 42 x – 8.1 x^2$	0.93
Jind-Pipaltha	900	$98.6 – 10 x – 0.75 x^2$	0.78

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Short communication

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Integrated weed management in chickpea

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Key words: Chickpea, Pendimethalin, Quizalofop-P-ethyl, Weed management

Chickpea is used in salad and to cook various dishes. The yield of chickpea has fallen due to various biotic and abiotic factors. Weeds cause loss in yield by competing for space, nutrients, water and light. The crop is a poor competitor of weeds because of slow growth rate and limited leaf development at early stage of crop growth, resulting in yield loss of 40-87%. Further, the crop is generally grown on marginal and sub-marginal soils under rainfed conditions with low inputs. The information on weed management in Krishna zone is negligible. Hence, this investigation was taken to find out most suitable weed management practice for control of weeds in chickpea.

A field experiment was conducted during 2010-11 at experimental farm, College of Agriculture, Marathwda Krishi Vidyapeeth, Parbhani. The soil of the experimental field was loamy in texture, low in organic C and N, and medium in P and K, having pH 8.0 and EC 0.93 dS/m. The chickpea variety '*Vijay*' was sown on 20 December, 2010. Nitrogen 25 kg/ha and P_2O_5 50 kg/ha were applied through urea and single super phosphate. Nine treatments were laid out in randomized block design and replicated three times. The net plot size was 4.5 x 4.2 m. Sowing was done manually at a spacing of 45 x 10 cm and dibbling of two seeds at 10 cm distance in a row at depth 5-6 cm.

Weed-free (weeding for first 80-90 DAS) resulted in significant increase in number of pods/plant, weight of pod/plant, seeds/pod, seeds/plant, 100-grain weight. Pendimethalin 0.75 kg/ha as pre-emergence was found significantly superior to rest of chemicals. Kachhadiya *et al.* (2009) observed similar results. Weed-free recorded the highest seed and straw yield, followed by one hoeing at 30 DAS + 2 hand weedings, two hand weedings and pendamethalin 0.75 kg/ha. These findings were in agreement with Jadhav (2013). Application of trifluralin 1.0 kg/ha as pre-emergence recorded the highest harvest index, followed by weed-free. Monetary returns were the highest with weed-free, followed by pendimethalin 0.75 kg/ha + cultural treatment. Benefit : cost ratio was the highest with pendimethalin 0.75 kg/ha.

Table 1. Yield attributes, yield and economics as influenced by different weed management treatments

Treatment	Number of pods/plant	No. of seeds/pod	100-grain weight (g)	Seed yield (t/ha)	Cost of cultivation (x10^3 `/ha)	Net monetary returns (x10^3 `/ha)	B:C ratio
Pendimethalin 0.75 kg/ ha (PE)	78.3	1.13	15.7	2.16	15.46	34.44	3.20
Trifluralin 1.0 kg/ ha (PE)	66.0	0.96	13.3	1.64	14.93	25.03	2.67
Imazethapyr 0.75 kg/ha (POE)	63.3	0.92	12.8	1.58	14.53	24.09	2.67
Quizalofop-p-ethyl 40 g/ha (POE)	67.0	0.97	13.5	1.69	14.51	25.58	2.76
Propaquizafop 0.75 kg/ ha (POE)	66.0	0.89	13.3	1.64	14.52	25.40	2.74
1 hoeing at 30 DAS + 2 hand weedings	79.3	1.14	15.9	2.25	21.03	33.60	2.59
Two hand weedings	79.0	1.14	15.8	2.23	20.43	33.17	2.60
Weed-free	80.0	1.15	15.9	2.32	27.43	29.00	2.05
Weedy check	62.0	0.91	12.7	1.51	13.43	23.54	2.75
LSD (P=0.05)	5.80	0.11	1.14	0.23	-	3.741	-

SUMMARY

In a study on chickpea at Parbhani, two hand weedings resulted in the highest plant height, plant spread, branches, root nodules and dry matter followed by one hoeing + 2 hand weedings, pendimethalin 0.75 kg/ha as pre-emergence, and quizalofop-p-ethyl 40 g/ha as post-emergence. Among the herbicidal treatments, the pre-emergence application of pendimethalin 0.75 kg/ha was effective in recording higher growth parameters followed by quizalofop-p-ethyl 40 g/ha as post-emergence. The highest grain and straw yields were recorded with one hoeing + two hand weedings, followed by 2 hand weedings.

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Author Index

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