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Effect of pre-emergence herbicides on weed growth and physiological traits of transplanted rice

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ABSTRACT

Weed management practices in rice consisted of weedy check, hand weeding at 30 and 60 DAT, butachlorat 1.5 kg/ha and anilofos at 0.5 kg/ha. The experiment was part of a long term trial in rice – wheat cropping system conducted in a split plot design with three replications. Data on weed dry weight, crop growth and yield parameters were recorded at different growth stages. Herbicides were effective in reducing the growth of several weeds and improving the physiological status of the crop. Hand weeding twice recorded lowest weed dry weight at both 60 and 90 DAT during both the years (7.44 and 13.64g/m^2, respectively). Butachlor and anilofos treatments recorded lower weed dry weight at 60 and 90 DAT as compared to weedy plot. Physiological parameters such as chlorophyll content and photosynthetic rate of the crop were higher in the herbicide treatments.

Key words: Herbicides, Physiological traits, Weed growth

Rice-wheat cropping system (RWS) is one of the widely practised cropping systems in India occupying an area of about 12.33 mha. About 10 mha of this land is in the Indo-Gangetic plains and represents about 75% of the total area under rice cultivation (Prasad and Nagarajan 2004). In spite of a huge cultivated land and large food value, the productivity of rice in the country is quite low (2.8 t/ ha) as against world average (3.9 t/ha). Proliferation of weeds is one such limiting factors that may show manifold negative effects (Singh *et al.* 2013). A poor weed control can affect the crop yield, weed flora and their intensity (Peer *et al.* 2013). Rice growers use different pre- and post-emergence herbicides to manage weeds. There is very little information on the effects of herbicides on these parameters. Therefore, the present investigation was carried out to evaluate the effects of herbicides applied in rice on some physiological attributes as well as their effect on weed and crop yield.

MATERIALS AND METHODS

The field study was conducted during the rainy seasons of 2009 and 2010 at the N. E. Borlaug Crop Research Centre, G B Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. Geographically, the site lies in Tarai plains about 30 km southwards of foothills of Shivalik range of the Himalayas at 29° N latitude, 79° 29'E longitude and at an altitude of 243 meter above the mean sea level. The experimental plot had a sandy loam textured soil. Experiment was laid out in split plot design with four treatments as main plot treatments in rice-while wheat treatments constituted the sub-plot treatments. Treatments in rice crop consisted of weedy check, hand weeding twice at 30 and 60 DAT, butachlor at 1.5 kg kg/ha and anilofos at 0.5 kg/ha. The herbicides were applied three days after transplanting. The rice variety used was '*Narendra 359*'.

The weed flora was recorded at 30, 60 and 90 days after transplanting (DAT) and their dry weights were recorded subsequently. The leaf area of rice was measured by using a portable leaf area meter (LiCOR LI-3000A) at 30, 45 and 60 DAT and was expressed as cm^2/plant and the leaf area index was calculated by the method of Palanisamy and Gomez, (1974). Plant height, tiller numbers and crop dry matter (g/plant) were recorded at different growth stages (30, 45, 60, 75, 90 DAT). Specific leaf weight and relative leaf area growth rate were calculated from 30 to 60 DAT. Leaf area index, leaf area (cm^2/ plant), leaf area ratio were calculated at 30, 45 and 60 DAT. Net photosynthetic rate (P_n) of rice leaves was measured 24 hrs after herbicide spraying from each plot by Infra Red Gas Analyzer (IRGA) (TPS-2, PP system, USA). Chlorophyll estimation was done according to Hiscox and Israelstam, (1979). Biological yield and grain yield of rice from each plot were recorded at harvest. The means were tested at P > 0.05 by using split plot design. The data on main plots are presented in the tables and discussed.

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RESULTS AND DISCUSSION

Crop establishment considerably varied during different years. In the first week after transplanting in 2009, the experimental field received maximum 77.6 mm of rainfall while in 2010, it was 396mm. Average weed density, four weeks after transplanting was higher in 2010 than 2009. The high weed density observed during 2010 was the result of excess rainfall. The temperature ranged normal until harvest during both the years.

Weed flora and dry weight

The weed density was recorded at different growth stages, *viz.* 30, 60 and 90 DAT. The weed flora consisted of grasses, sedges and broad-leaf weeds. Major grasses included *Echinochloa crusgalli*, *Echinochloa colona*, *Leptochloa chinensis* and *Paspalum distichum* while the broad-leaf weeds were *Caesulia axillaris*, *Alternanthera sessilis* and *Ammenia* spp. Among the sedges, *Cyperus iria* and *Cyperus difformis* were the dominant species. Hand weeding treatment recorded distinctly lower weed dry weight at all the growth stages. Both the herbicide treatments (butachlor and anilofos) recorded significantly lower weed dry weight at 30 and 60 DAT as compared to weedy plot (Table 1).

Table 1. Weed dry weight at different growth stages in rice under different weed management practices in a rice- wheat cropping system (pooled data of two years)

Treatment	Weed dry weight (g/m²)		
	30 DAT	60 DAT	90 DAT
Weedy check	21.47	44.86	36.07
Hand weeding (30, 60 DAT)	20.34	7.44	13.64
Butachlor (1.5 kg/ha)	16.53	32.25	29.15
Anilofos (0.5 kg/ha)	20.85	23.28	31.24
LSD (P=0.05)	3.92	9.43	9.25

Leaf area, leaf area index and leaf area ratio of rice crop

Leaf area differed significantly among all rice treatments and gradually increased up to 60 DAT. At 30 and 45 DAT, significantly higher leaf area and leaf area index was observed in anilofos treated plot while butachlor and hand weeding recorded statistically similar leaf area. At 60 DAT, higher leaf area and leaf area index was recorded in hand weeding and both the herbicides recorded statistically similar leaf area and leaf area index (Table 2). Leaf area ratio of rice (LAR) was higher at 45 DAT among all the growth stages and decreased at 60 DAT (Table 2). At all the growth stages, hand weeding recorded significantly lower LAR.

Plant height and tiller number

Plant height increased from 30 DAT up to harvest but there was no significant difference in plant height among the treatments (Table 3). Tiller number gradually increased from 30 to 60 DAT and declined thereafter. At 60 and 75 DAT, number of tillers was similar in all the treatments but productive tillers (at 90 DAT) were significantly higher in hand weeding and was at par with butachlor (Table 4).

Table 3. Plant height at different growth stages under different weed management practices in rice-wheat cropping system (pooled data of 2 years)

Treatment	Plant height (cm) at different days after transplanting				
	30	45	60	75	90
Weedy check	62.67	74.51	91.79	102.7	103.3
Hand weeding (30, 60 DAT)	63.61	77.44	93.57	103.3	104.8
Butachlor (1.5 kg/ha)	63.31	76.34	92.87	103.5	104.1
Anilofos (0.5 kg/ha)	62.27	74.62	93.33	103.5	103.9
LSD (P=0.05)	NS	NS	NS	NS	NS

Table 4. Tiller number at different growth stages under different weed management practices in a rice crop (pooled data of 2 years)

Treatment	Tiller number (per plant) at different days after transplanting				
	30	45	60	75	90*
Weedy check	9.17	10.78	12.39	12.96	7.69
Hand weeding (30, 60 DAT)	9.22	11.10	12.64	13.47	9.24
Butachlor (1.5 kg/ha)	9.20	11.19	12.93	12.93	8.79
Anilofos (0.5 kg/ha)	9.74	13.38	12.25	12.82	8.20
LSD (P=0.05)	NS	1.07	NS	NS	0.66

*Productive tillers

Table 2. Leaf area index, leaf area and leaf area ratio of rice under different weed management practices in a rice-wheat cropping system (pooled data of 2 years)

Treatment	Leaf area index			Leaf area (cm^2/plant)			Leaf area ratio		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
Weedy check	1.31	3.47	5.96	393.3	1045.4	1803.8	13.25	23.50	13.65
Hand weeding (30, 60 DAT)	1.37	3.78	6.59	411.1	1134.8	1989.4	10.56	20.50	12.75
Butachlor (1.5 kg/ha)	1.38	3.65	6.37	412.8	1101.3	1914.1	13.68	23.11	13.15
Anilofos (0.5 kg/ha)	1.42	3.99	6.40	426.8	1194.5	1929.4	13.71	23.60	14.11
LSD (P=0.05)	0.01	0.02	0.05	3.9	16.4	15.8	0.18	0.17	0.20

Table 5. Crop dry weight (g/plant) at different growth stages under different method of weed management (pooled data of two years)

Treatment	Days after transplanting												
	30		45		60			75			90		
	Leaf	Culm	Leaf	Culm	Leaf	Culm	Ear	Leaf	Culm	Ear	Leaf	Culm	Ear
Weedy check	2.85	4.00	3.49	5.38	9.83	11.58	4.12	9.70	19.10	5.30	7.28	22.28	23.81
Hand weeding (30, 60 DAT)	3.76	4.59	4.92	6.13	11.90	14.93	4.51	10.22	22.36	5.46	8.76	26.46	31.09
Butachlor (1.5 kg/ha)	3.10	3.97	3.92	5.46	11.42	13.52	3.79	11.48	20.51	6.50	9.04	24.80	29.44
Anilofos (0.5 kg/ha)	3.10	4.08	4.02	5.79	9.85	13.50	3.61	10.78	19.44	4.81	9.23	26.17	25.60
LSD (P=0.05)	0.41	0.18	0.15	0.42	0.59	1.02	0.34	1.66	2.12	0.88	0.79	2.51	1.43

Table 6. Specific leaf weight, relative leaf area growth rate, photosynthetic rate and total chlorophyll of rice under different weed management practices in a rice-wheat cropping system (pooled data of 2 years)

Treatment	Specific leaf weight			Relative leaf area growth rate		Photosynthetic rate	Total chlorophyll (mg/g fr. Wt)
	30 DAT	45 DAT	60 DAT	30-45	45-60		
Weedy check	6.85	3.52	5.89	0.0281	0.0158	12.25	1.116
Hand weeding (30, 60 DAT)	9.48	4.67	6.21	0.0292	0.0163	16.04	1.367
Butachlor (1.5 kg/ha)	6.92	3.86	6.16	0.0280	0.0164	15.71	1.269
Anilofos (0.5 kg/ha)	6.72	3.53	5.27	0.0297	0.0140	14.71	1.228
LSD (P=0.05)	0.48	0.03	0.11	0.0003	0.00015	1.48	0.105

Crop dry weight (g/plant)

Crop dry weight was separated into leaf, culm and ear dry weight at different growth stages. Dry matter accumulation was found to be higher in between 30 to 60 DAT (Table 5). Crop dry weight was significantly higher in hand weeding at all the growth stages and lower in unweeded control.

Specific leaf weight, relative leaf area growth rate, net photosynthetic rate and total chlorophyll

Specific leaf weight of the rice was distinctly higher at 30 and 45 DAT in hand weeding. At 60 DAT, SLW was significantly higher and comparable in hand weeding and butachlor treatments (Table 6). Significant difference was recorded in P_n rate and chlorophyll content among the treatments (Table 6). Hand weeding and both the herbicide treatments recorded higher P_n rate over unweeded control. Hand weeding, being at par with butachlor, recorded significantly higher total chlorophyll content followed by anilofos. Distinctly lower chlorophyll content was recorded in unweeded control.

Biological yield and grain yield

Biological yield was significantly higher in butachlor and was comparable with anilofos and hand weeding. All the treatments recorded significantly higher biological yield and grain yield over weedy check. Hand weeding recorded significantly higher grain yield which was at par with butachlor and anilofos (Table 7).

Table 7. Biological and grain yield of rice under different weed management practices in a rice wheat cropping system (pooled data of 2 years)

Treatment	Biological yield (t/ha)	Grain yield (t/ha)
Weedy check	11.72	3.58
Hand weeding (30, 60 DAT)	13.62	4.27
Butachlor (1.5 kg/ha)	13.72	4.02
Anilofos (0.5 kg/ha)	13.30	3.91
LSD (P=0.05)	0.62	0.62

Leaf area was found to be positively correlated with total chlorophyll, biological yield and grain yield (Table 8). At the same time, it was noted that the positive correlation between the leaf area and leaf area index was highly significant. Similarly, leaf area index was positively correlated with total chlorophyll, biological yield and grain yield. A positive correlation was also established between leaf dry weight and leaf area index. Positive correlation of total chlorophyll was also found with grain yield.

Evaluating such attributes at different stages of a crops' life span gives us an idea about the initial stand establishment as well as of final crop yield. The present study therefore considered how different herbicide applications affected different aspects of growth and development of rice crop. Interestingly, they were found to be as effective as hand weeding in lessening the weed number. Leaf area and the associated indices are among the important growth parameters to study being suggestive of higher

Table 8. Correlation coefficient of total chlorophyll and photosynthetic rate with biological and grain yield

Characters	Leaf area index	Total chlorophyll	Biological yield	Grain yield
Leaf Area	0.998**	0.416ns	0.750ns	0.517ns
Leaf area index	-	0.503ns	0.517ns	0.537ns
Leaf dry weight	0.709ns	-	-	-
Total chlorophyll			0.870ns	0.999**

**on values = highly significant, *on values = significant correlation, ns = non-significant

photosynthetic efficiency of crop and eventually a greater yield (Channappagoudar *et al.* 2013a). A higher leaf area index (leaf area per unit ground area) implies a greater photon flux density (PFD) captured by canopy leading to higher chlorophyll content and photosynthetic production (Manzoor and Goutam 2014). Higher dry matter accumulation under weed management practices is also indicative of the better utilization of resources (Channappagoudar *et al.* 2013b).

The weed management practices in the present study decreased crop weed competition with enhanced availability of nutrients and there by increased the LAR, particularly at later growth stages of crop, which subsequently resulted in higher yield (Varshney *et al.* 2012). Data on grain yield and biological yield revealed that the herbicide treated plots were similar to that obtained from hand weeding.

This study conclusively revealed that the recommended dose of pre-emergence herbicides in rice have been found as effective as hand weeding in controlling the weeds without any phytotoxic effect on crop.

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Management of composite weed flora of transplanted rice by herbicides

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ABSTRACT

The experiment comprising of twelve treatments was laid out in a randomized block design with three replications. Prominent weeds were *Echinochloa colona* and *Digitaria sanguinalis* among the grasses; *Cyperus iria,* among the sedges and *Spilanthes acmella* and *Ludwigia parviflora* among the broad-leaved weeds throughout the cropping period. Fenoxaprop-p-ethyl at 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl at 4 g/ha at 25 DAT effectively controlled the grasses, broad-leaved and sedges at 50 DAT which was statistically at par with the azimsulfuron at 40 g/ha at 20 DAT. The loss of grain yield of rice due to weed infestation was to the tune of 35-38%. Lower values of weed density, total weed dry weight and higher values of weed control efficiency, yield and net return of rice were registered with combined application of fenoxaprop-p-ethyl at 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl at 4 g/ ha at 25 DAT and was followed by sole application azimsulfuron at 40 g/ha at 20 DAT. These treatments may be recommended for managing composite weed flora and obtaining higher yield and net return of transplanted *Kharif* (wet) rice in the lateritic belt of West Bengal, India.

Key words: Azimsulfuron, Metsulfuron-methyl+chlorimuron-ethyl, Pretilachlor, Transplanted rice, Weed management

Rice is the most important cereal crop grown in tropical and subtropical regions of the world and is staple food for more than 60% of the world population (Parthipan *et al*. 2013). India has the largest area (44 million hectares) among the rice growing countries, and it is the second largest producer (131 million tonnes) of rice next to China (197 million tonnes) (Govindan and Chinnusamy 2014). The yield reduction due to weed growth may vary from 28-45% in transplanted rice (Kumar *et al.* 2008, Yadav *et al.* 2009). For the last many years, a number of herbicides like butachlor and pretilachlor are being applied as pre-emergence but these herbicides are effective against narrow spectrum of weeds. New generation herbicides like azimsulfuron and ethoxysulfuron have been launched recently which are effective against broad spectrum of weeds with very low dose (Pal *et al*. 2008). But the information on their efficacy in transplanted wet rice is not adequate. With this perspective, the present experiment was conducted to study the effect of azimsulfuron and combined application of other herbicides on weed growth and productivity of wet season transplanted rice in red and lateritic belt of West Bengal.

MATERIALS AND METHODS

Field experiments were conducted during wet season of 2010 and 2011 on the lateritic soil of Agricultural Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, with rice variety '*IR-36*'. The experimental field was situated at about 23^{0}392` N latitude and 87$^0$422` E longitude with an average altitude of 58.9 m above the mean sea level. The soil of the experimental field was sandy loam in texture having acidic in reaction (pH 5.8), low in organic C (0.4%) and available N (148.6 kg/ha), high in available P (27.42 kg/ha) and medium in available K (127.85 kg/ha). Twelve treatments comprising of three different doses of azimsulfuron at 30, 35 and 40 g/ha at 20 DAT, butachlor at 1.25 kg/ha at 3 DAT, pretilachlor at 1.0 kg/ha at 3 DAT, pyrazosulfuron-ethyl at 25 g/ha at 5 DAT, metsulfuron-methyl + chlorimuron-ethyl at 4 g/ha at 10 DAT, combined application of ethoxysulfuron at 15 g/ha + fenoxaprop-p-ethyl at 60 g/ha at 25 DAT, ready mix mixture of fenoxaprop-p-ethyl at 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl at 4 g/ha at 25 DAT, 2,4-D (Na-salt) at 500 g/ha + fenoxaprop-p-ethyl 60 g/ha at 25 DAT, weed free check and unweeded control were assigned in a randomized block design replicated thrice.

The recommended dose of fertilizers *viz.* 60 kg N, 30 kg P_2O_5 and 30 kg K_2O /ha were applied through urea, 10:26:26, respectively. One third quantity of nitrogen and full amount of phosphorus and potassium were applied in each plot as basal during the final land preparation. Rest two third quantity of N was applied in two splits as top dressing

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i.e. one third of nitrogen was top dressed at 25 DAT and rest one third of nitrogen was top dressed at 45 DAT. All the herbicides alone or in combination were applied uniformly in the experimental plots with the help of knapsack sprayer fitted with flat fan nozzle using a spray volume of 500 l/ha. All the recommended agronomic and plant protection measures were adopted to raise the crop. The data on weed density and dry weight were recorded at different growth stages of rice crop. These were subjected to square root transformation to normalize their distribution. Weed control efficiency (%) was computed using the dry weight of weeds. Grain yield of rice along with other yield-attributing characters like number of panicles/m^2, grains/panicle were recorded at harvest.

RESULTS AND DISCUSSION

Major weed flora of the experimental field comprised of grasses (*Echinochloa colona, Digitaria sanguinalis*), sedges (*Cyperus iria, Fimbristylis miliacea*) and broad-leaved (*Spilanthes acmella, Sphenoclea zeylanica*, *Ludwigia parviflora*) during both the years. Besides these, *Lindernia ciliata, Alternanthera sessilis* were also observed as major weeds during 2011.

The lowest density as well as dry weight of grasses, sedges, broad-leaved and total weeds was recorded in weed free treatment during both the years. Fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT significantly reduced the number and dry weight of grasses at 50 DAT which was statistically at par with the azimsulfuron 40 g/ha at 20 DAT and ethoxysulfuron 15 g/ha + fenoxaprop-p-ethyl 60 g/ha at 25 DAT during both the years. Among all the herbicides fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT registered the lowest number of broad-leaved weeds in both the years 50 DAT which was at par with azimsulfuron 40 g/ha at 20 DAT (Table 1). Similar trend was observed in case of dry weight of broad-leaved weeds. Application of azimsulfuron at 40 g/ha at 20 DAT effectively controlled the sedges and recorded the lowest number as well as dry weight at 50 DAT but it was statistically at par with fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT. During both the years of 2010 and 2011, combined application of fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT registered the lower number and dry weight of total weeds which was statistically at par with sole application of azimsulfuron 40 g/ha at 20 DAT (Table 2). Among the herbicidal treatments, azimsulfuron 40 g/ha at 20 DAT registered the highest weed control efficiency (93.28 and 93.47%) at 50 DAT but was very close (90.36 and 93.36%) to fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl (Almix) 4 g/ha at 25 DAT (Fig 1). The lower value of weed index was recorded with application of fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT and azimsulfuron 40 g/ha at 20 DAT (Fig 2). Similar results were reported by Pinna *et al.* (2007), Yadav *et al.* (2008) and Jayadeva *et al.* (2009).

Effect on crop

Weed free treatment recorded the highest number of panicles/m^2 and number of grains/panicle. Among the herbicidal treatments the highest number of panicles/m^2 and number of grains/panicle were recorded in the treatment with application of fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT which was statistically at par with azimsulfuron 40 g/ha at 20 DAT. Similarly, the highest test weight was registered with azimsulfuron 40 g/ha at 20 DAT which was statistically at par with fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha. Yield reduction due to weed competition in transplanted *Kharif* rice was to the extent of 35-38%. Similar yield reduction in wet season rice due to weed competition in the lateritic belt of West Bengal was also reported by Duary (2014) and Teja *et al.* (2015). During both the years the highest grain yield was recorded under the weed free treatment but it was statistically at par with fenoxaprop-p-ethyl at 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl at 4 g/ha at 25 DAT and azimsulfuron at 40 g/ha at 20 DAT (Table 3). The results were in conformity with the findings of Jayadeva *et al.* (2009). Combined application of fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT recorded the

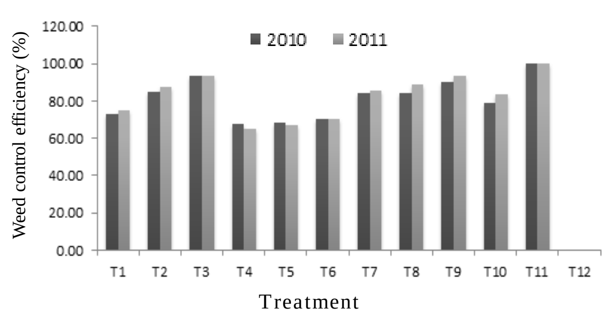

Fig 1. Effect of treatments on weed control efficiency in transplanted rice at 50 DAT

Table 1. Effect of treatments on density of weeds in transplanted rice at 50 DAT

Treatment	Weed density (no./m^2)							
	Grass		Broad-leaved		Sedge		Total	
	2010	2011	2010	2011	2010	2011	2010	2011
Azimsulfuron 30 g/ha at 20 DAT	3.96	4.04	7.06	7.49	4.64	4.81	9.30	9.74
	(15.3)	(16.0)	(49.7)	(55.7)	(21.0)	(22.7)	(86.0)	(94.3)
Azimsulfuron 35 g/ha at 20 DAT	3.69	3.94	6.03	5.99	2.48	2.35	7.46	7.47
	(13.3)	(15.0)	(36.3)	(35.3)	(5.7)	(5.0)	(55.3)	(55.3)
Azimsulfuron 40 g/ha at 20 DAT	2.97	3.23	5.11	4.02	0.71	1.35	5.87	5.24
	(8.3)	(10.0)	(25.7)	(15.7)	(0)	(1.3)	(34.0)	(27.0)
Butachlor 1.25 kg/ha at 3 DAT	3.94	4.29	6.91	7.49	5.26	5.55	9.51	10.22
	(15.3)	(18.0)	(47.3)	(55.7)	(27.3)	(30.3)	(90.0)	(104.0)
Pretilachlor 1.0 kg/ha at 3 DAT	3.95	4.17	6.96	7.22	5.24	5.31	9.55	9.86
	(15.7)	(17.3)	(48.0)	(51.7)	(27.0)	(27.7)	(90.7)	(96.7)
Pyrazosulfuron-ethyl 25 g/ha at 5 DAT	3.92	4.17	6.92	7.20	4.97	5.18	9.33	9.76
	(15.0)	(17.0)	(47.7)	(51.3)	(24.3)	(26.3)	(87.0)	(94.7)
Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 10	3.79	3.57	6.18	6.04	3.81	3.54	8.13	7.80
DAT	(14.0)	(12.3)	(37.7)	(36.0)	(14.0)	(12.0)	(65.7)	(60.3)
Ethoxysulfuron 15 g/ha + fenoxaprop-p-ethyl 60 g/ha	2.90	3.22	5.04	4.45	4.12	3.85	7.07	6.65
at 25 DAT	(8.0)	(10.0)	(25.0)	(19.3)	(16.7)	(14.3)	(49.7)	(43.7)
Fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl +	2.26	2.86	4.54	3.89	2.96	2.74	5.82	5.46
chlorimuron-ethyl 4 g/ha at 25 DAT	(4.67)	(7.7)	(21.3)	(14.7)	(8.3)	(7.0)	(34.3)	(29.3)
2,4-D (Na-salt) 500 g/ha + fenoxaprop-p-ethyl 60 g/ha	3.84	3.89	5.59	5.18	4.18	4.06	7.95	7.60
at 25 DAT	(14.7)	(15.0)	(31.3)	(26.3)	(17.0)	(16.0)	(63.0)	(57.3)
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Unweeded control	4.94	5.41	8.43	8.93	7.77	7.60	12.47	12.89
	(24.0)	(29.0)	(71.0)	(79.3)	(60.0)	(57.3)	(155.0)	(165.7)
LSD (P=0.05)	0.85	0.78	1.18	1.09	0.58	0.65	0.93	0.86

Figures in parentheses are the original values. The data was transformed to SQRT $\sqrt{x+0.5}$ before analysis

Table 2. Effect of treatments on dry weight of weeds in transplanted rice at 50 DAT

Treatment	Weed dry weight (g/m^2)							
	Grass		Broad-leaved		Sedge		Total	
	2010	2011	2010	2011	2010	2011	2010	2011
Azimsulfuron 30 g/ha at 20 DAT	3.06	2.59	3.22	3.50	2.55	2.63	5.04	5.00
	(8.97)	(6.36)	(9.84)	(11.74)	(6.04)	(6.43)	(24.86)	(24.53)
Azimsulfuron 35 g/ha at 20 DAT	2.59	2.18	2.58	2.57	1.48	1.45	3.82	3.53
	(6.27)	(4.27)	(6.15)	(6.09)	(1.71)	(1.59)	(14.13)	(11.95)
Azimsulfuron 40 g/ha at 20 DAT	1.85	1.79	1.93	1.75	0.71	1.25	2.58	2.62
	(2.93)	(2.72)	(3.23)	(2.57)	(0)	(1.06)	(6.16)	(6.34)
Butachlor 1.25 kg/ha at 3 DAT	3.18	3.24	3.55	3.99	2.79	2.94	5.43	5.84
	(9.75)	(10.08)	(12.13)	(15.45)	(7.46)	(8.12)	(29.34)	(33.65)
Pretilachlor 1.0 kg/ha at 3 DAT	3.07	3.12	3.62	3.91	2.80	2.86	5.42	5.68
	(8.95)	(9.29)	(12.60)	(14.77)	(7.37)	(7.67)	(28.92)	(31.73)
Pyrazosulfuron-ethyl 25 g/ha at 5 DAT	3.12	3.04	3.44	3.61	2.70	2.83	5.27	5.42
	(9.24)	(8.88)	(11.32)	(12.53)	(6.86)	(7.51)	(27.43)	(28.92)
Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 10	2.15	2.22	2.65	2.61	2.05	1.92	3.87	3.81
DAT	(4.16)	(4.49)	(6.50)	(6.32)	(3.83)	(3.17)	(14.48)	(13.98)
Ethoxysulfuron 15 g/ha + fenoxaprop-p-ethyl 60 g/ha	2.38	1.91	2.21	2.10	2.27	2.11	3.83	3.39
at 25 DAT	(5.17)	(3.15)	(4.38)	(3.91)	(4.67)	(3.95)	(14.22)	(11.01)
Fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl +	2.05	1.69	1.85	1.65	1.63	1.53	3.05	2.64
chlorimuron-ethyl 4 g/ha at 25 DAT	(3.70)	(2.37)	(2.92)	(2.23)	(2.22)	(1.85)	(8.84)	(6.44)
2,4-D (Na-salt) 500 g/ha + fenoxaprop-p-ethyl 60 g/ha	2.87	2.43	2.67	2.46	2.37	2.31	4.47	4.04
at 25 DAT	(7.76)	(5.42)	(6.63)	(5.55)	(5.14)	(4.86)	(19.53)	(15.83)
Weed free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Unweeded control	4.05	4.29	7.32	7.59	4.74	4.71	9.59	9.88
	(16.21)	(18.21)	(53.09)	(57.16)	(22.39)	(21.72)	(91.68)	(97.09)
LSD (P=0.05)	0.51	0.50	0.68	0.56	0.54	0.60	0.56	0.56

Figures in parentheses are the original values. The data was transformed to SQRT $\sqrt{x+0.5}$ before analysis

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

Treatment	No. of panicles/ m^2		No. of grains/ panicle		Test weight (g)		Grain yield (t/ha)		Net return (x10_3 `/ha)		BC ratio	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Azimsulfuron 30 g/ha at 20 DAT	393	419	64	70	23.4	22.9	4.19	4.35	25.89	26.15	1.24	1.17
Azimsulfuron 35 g/ha at 20 DAT	424	448	68	74	23.5	23.0	4.66	4.88	30.65	31.46	1.46	1.40
Azimsulfuron 40 g/ha at 20 DAT	472	501	77	84	24.0	24.2	5.09	5.32	35.22	36.06	1.66	1.59
Butachlor 1.25 kg/ha at 3 DAT	358	365	64	67	23.3	22.8	3.85	4.04	23.34	23.61	1.16	1.10
Pretilachlor 1.0 kg/ha at 3 DAT	370	373	64	68	23.7	23.3	3.97	4.20	24.09	24.89	1.18	1.14
Pyrazosulfuron-ethyl 25 g/ha at 5 DAT	381	393	66	69	23.8	23.3	4.10	4.34	25.84	26.68	1.28	1.24
Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 10 DAT	407	418	69	77	23.5	23.1	4.47	4.64	29.98	30.08	1.50	1.40
Ethoxysulfuron 15 g/ha + fenoxaprop-p-ethyl 60 g/ha at 25 DAT	431	468	74	80	23.7	23.2	4.73	4.94	31.93	32.46	1.54	1.46
Fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT	489	507	76	82	23.9	23.7	5.08	5.35	35.32	36.55	1.69	1.63
2,4-D (Na-salt) 500 g/ha + fenoxaprop-p-ethyl 60 g/ha at 25 DAT	415	442	72	77	23.3	22.9	4.55	4.61	30.17	29.36	1.48	1.35
Weed free	492	513	79	86	24.0	24.2	5.19	5.46	34.33	35.06	1.47	1.38
Unweeded control	277	305	57	61	22.4	21.9	3.21	3.53	17.03	19.03	0.88	0.91
LSD (P=0.05)	68.3	57.5	8.3	10.1	0.84	0.73	0.63	0.47	-	-	-	-

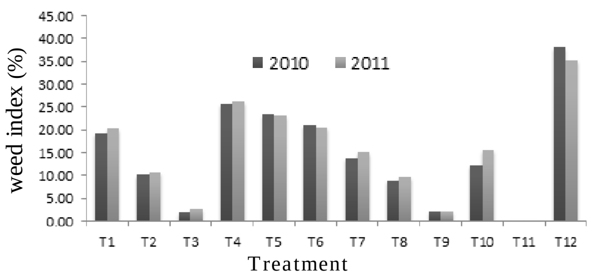

Fig. 2. Effect of treatments on weed index of transplanted rice

highest values of net return and benefit-cost ratio which was closely followed by azimsulfuron at 40 g/ha at 20 DAT (Table 3).

It was concluded that combined application of fenoxaprop-p-ethyl 60 g/ha + metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 25 DAT or sole application of azimsulfuron at 40 g/ha at 20 DAT may be recommended for managing composite weed flora and obtaining higher yield and net return of transplanted *Kharif* (wet) rice in the lateritic belt of West Bengal.

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Herbicides for broad-leaved weeds management in wheat

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ABSTRACT

Field and pot studies were conducted to identify the effective broad-leaf herbicides for wheat crop. In field study, pre-mix combination (1:4 w/w) of metsulfuron-methyl + carfentrazone-ethyl (Ally-express 50 DF) 22.5 to 25 g/ha with 0.2% (v/v) non-ionic surfactant (NIS) was better than without NIS and sole application of metsulfuron (4 g/ha), carfentrazone (20 g/ha) and 2,4-D-amine (750 g/ha). Carfentrazone was poor in controlling *Lathyrus aphaca* (meadow peavine), whereas metsulfuron was ineffective against *Malva parviflora* (little mallow) and *Solanum nigrum* (black nightshade). Metsulfuron-methyl + carfentrazone-ethyl effectively controlled these weeds, leading to increased wheat yield than metsulfuron and carfentrazone. In pot studies, growth regulator herbicide, 2,4-D-E was ineffective against *S. nigrum* and *Physalis minima* (groundcherry) but controlled by another growth regulator herbicide, dicamba. Carfentrazone 20 g, isoproturon 1000 g, metribuzin 250 g, dicamba 360 g and topramezone 50 g/ha effectively controlled *S. nigrum* and *P. minima*. Additional herbicides, effective against *P. minima* were metsulfuron 4 g, mesosulfuron + iodosulfuron 12 + 2.4 g/ha, pyroxsulam 18 g and sulfosulfuron 25 g/ha. Auxin herbicide, halauxifen-methyl-ester in combination with florasulam 12.76 (6.51 + 6.25) g/ha was also poor against *S. nigrum* and *P. minima. Rumex dentatus* control with 2,4-D (ester, amine and sodium) was poor, whereas, halauxifen + florasulam 12.76 g, metsulfuron 4 g and metsulfuron + carfentrazone 4 + 20 g/ha provided complete control.

Key words: Broad-leaf weeds, Chemical control, Herbicide mixture, Surfactant, Wheat

Wheat (*Triticum aestivum* L. emend. Fiori and Paol) is an important staple food crop for billions people of the world and among cereals, it occupies maximum area (219.04 m/ha) globally (FAO 2014). For food security, its assured production and supply are necessary. Weed infestation is one of the major biotic factors limiting wheat production and productivity. The losses caused by weeds depend on their type, abundance and environmental factor (Chhokar *et al.* 2012). The estimated yield loss worldwide caused by weeds varied between 7.7 to 23.9% depending on the region (Oerke 2006, Kosina *et al.* 2007).

Wheat is infested with diverse weed flora, as it is grown in diverse agro-climatic conditions, under different cropping sequence, tillage and irrigation regimes (Chhokar *et al.* 2012). The crop rotations, tillage and herbicides have pronounced effect on the type of weed flora (Anderson and Beck 2007, Chhokar *et al.* 2007a). Reduced tillage or No-till (NT) wheat with higher moisture, in rice-wheat system favours the infestation of *Rumex dentatus* L. (toothed dock) and *Malva parviflora* L. (little mallow) (Chhokar *et al.* 2007a). Some parts of eastern and far eastern India have severe problem of *Solanum nigrum* L. (black nightshade) and *Physalis minima* (groundcherry) (Chhokar *et al.* 2012), where growers mostly depend on 2,4-D, which is not effective against these weeds.

Broad-leaf weeds are becoming a problem in area where grassy herbicides (clodinafop, fenoxaprop and pinoxaden) without supplementing with broad-leaf weed herbicides are used continuously. For control of broad-leaf weeds in wheat, three major herbicides used in India are metsulfuron 2,4-D and carfentrazone (Chhokar *et al.* 2007b). Generally, a herbicide is more effective against some of the weeds and less or not effective against others. Also, some of the post-emergent contact herbicides like carfentrazone-ethyl, are less effective on weeds having advanced stage, as well as, unable to control the subsequent weeds emerging after application due to its lack of residual activity (half life of carfentrazone is 2-5 days) in soil (Lyon *et al.* 2007, Willis *et al.* 2007). To broaden the spectrum of weed kill and to provide the long term residual weed control, the use of herbicide mixture/ combinations is advisable. Herbicide mixture besides providing control of complex weed flora will also help in managing and delaying the herbicide resistance problem.

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Further, the efficacy of herbicide and herbicide mixtures can be improved with the use of surfactant (Chhokar *et al*. 2011). Therefore, this study was planned with the objectives (1) to evaluate the efficacy of ready-mix combination of metsulfuron-methyl + carfentrazone-ethyl 40% (Ally Express 50 DF) with and without surfactant against important broad-leaf weeds in wheat crop (2) to determine the herbicide carry over effect on succeeding greengram (*Vigna radiata* L. Wilczek.) and maize (*Zea mays* L.) after wheat, and (3) to identify the effective herbicides against major problematic broad-leaf weeds of wheat namely *L. aphaca, M. denticulata, R. dentatus, P. minima,* and *S. nigrum*, so that weed specific herbicidal solutions can be recommended.

MATERIALS AND METHODS

Field and pot experiments were conducted at Resource Management Block, ICAR- Indian Institute of Wheat and Barley Research, Karnal, Haryana, India to evaluate the efficacy of pre-mix combination of metsulfuron + carfentrazone against broad-leaf weeds as well as to identify the additional effective herbicides for control of major broad-leaf weeds of wheat.

Field study: efficacy of pre-mix combination of metsulfuron + carfentrazone

An experiment involving 12 weed control treatments (Table 1) was conducted for two *Rabi* seasons of 2009-10 and 2010-11 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 0.40%. Wheat CV. '*DBW-17*' was sown on 16th November, 2009 and 12th November 2010 during first and second year, respectively, at 20 cm row spacing using a seed rate of 100 kg/ha.

The herbicide treatments comprised of four doses of ready mix combination (1:4 w/w) of metsulfuron + carfentrazone at 17.5, 22.5, 25.0 and 30.0 g/ha with and without surfactant, carfentrazone 20 g, metsulfuron 4 g and 2,4-D amine 750 g/ha. Non-ionic surfactant (iso-octyl-phenoxy-polyxethanol 12.5%) was used as 0.2% of spray solution volume with metsulfuron and ready mix combination of metsulfuron + carfentrazone. The herbicides were sprayed at 31-35 DAS (days after sowing) with knapsack sprayer fitted with flat fan nozzles using 350 litres water/ha. To control the grassy weeds, a blanket application of clodinafop 60 g/ha was made 10 days after broad-leaf herbicide application. Fertilizer and irrigation applications were done according to recommended package of practice for wheat. Broad-leaf weed population count and dry weight were taken at around 60 and 115 DAS, respectively. Weeds enclosed in quadrat (0.25 m^2) were counted randomly from two places in each plot and species wise density was recorded as average no./m^2 at 60 DAS, whereas, at 115 DAS, the enclosed weeds were harvested for recording dry weight. The crop was manually harvested on 11 April 2010 in first year and 12 April 2011 during second. The observations were also recorded on yield and yield attributes of wheat crop.

After wheat harvest, greengram and maize were grown in the same fixed plots under no tillage conditions, to evaluate the herbicide residual effect, if any, on these crops. After applying pre-seeding irrigation, the sowing of greengram (cv '*SML 668*') and maize (cv. '*African Tall*') was done on 15 April 2010 and 20 April 2011, during first and second year, respectively. The row to row spacing was 40 cm for greengram and 20 cm for maize. Irrigation and fertilization were done as per the standard recommendations for these crops. Maize crop was harvested for fodder on 40 DAS, whereas, greengram was harvested for grain yield.

Data were analyzed by using the General Linear Model (GLM) procedure of Statistical Analysis System (SAS, version 9.2). Treatment means were compared by using the DMRT (Duncan's Multiple Range Test) and Fisher's protected LSD (least significant difference) test at P=0.05. Prior to analysis, weed density and dry weight data were square root transformed $(\sqrt{x+1})$ and based on the transformed data, the letters were assigned to original data using DMRT for comparison of weed data.

Pot studies

Pot experiments were conducted to determine the effect of surfactant in improving the efficacy of metsulfuron and its combination with carfentrazone against *M. denticulata* and *L. aphaca* as well as to identify the effective herbicides for control of *L. aphaca, S. nigrum* and *P. minima*.

Pot study 1: Effect of surfactant on efficacy of metsulfuron and its mixture with carfentrazone against *M. denticulata* and *L. aphaca:* The graded doses of metsulfuron (1, 2 and 4 g/ha) and its combination with carfentrazone (1:4 w/w) were evaluated with and without surfactant against *L. aphaca* and *M. denticulata* (Fig. 1 and 2). In two set of experiments *L. aphaca* and *M. denticulata* (40 seeds/pot) were sown separately and finally 10 plants/pot were maintained for herbicide spraying.

Non-ionic surfactant (iso-octyl-phenoxy-polyxethanol 12.5%) was used as 0.2% of spray solution volume.

Pot study 2: Identifying effective herbicides for control of *L. aphaca, R. dentatus, S. nigrum* and *P. minima*

Lathyrus aphaca: About 20 seeds of *L. aphaca* were sown in each pot and 10 plants/pot were maintained before herbicide spraying. Different herbicides evaluated were metsulfuron 4 g, carfentrazone 20 g, mesosulfuron-methyl 3% + iodosulfuron-methyl sodium 0.6% WDG at 12.0 + 2.4 g/ha, sulfosulfuron 25 g, dicamba 480 g, 2,4-D-E 500 g, pyroxsulam 18 g, isoproturon 1000 g, triasulfuron 20 g, topramezone 50 g and metribuzin 175 g/ha (Fig. 3). Surfactants, 1250 ml/ha, 625 ml/ha, polyglycol 26-2N (1000 ml/ha) and methylated seed Oil (1500 ml/ha) were used with sulfosulfuron, mesosulfuron-methyl + iodosulfuron-methyl sodium, pyroxsulam and topramezone, respectively. Non ionic surfactant (625 ml/ha) was used with metsulfuron, and triasulfuron. At the time of herbicide spraying, *L. aphaca* was of about 7 cm height.

Solanum nigrum* and *Physalis minima: *S. nigrum* and *P. minima* berries (5 berries/pot) were sown in pots of 4.5 kg soil capacity and after germination 7 plants/pot were maintained for spraying herbicides. The herbicides used were metsulfuron 4 g, carfentrazone 20 g, metsufuron + carfentrazone 4 + 20 g, mesosulfuron + iodosulfuron 12.0 + 2.4 g/ha, sulfosulfuron 25 g, pyroxsulam 18 g, isoproturon 1000 g, metribuzin 250 g, halauxifen-methyl ester 10.4% + florasulam 10% W/W -20.4 WG at 12.76 g, topramezone 50 g, dicamba 360 g, 2,4-D-E 500 g, 2,4-D-E + carfentrazone 500 + 20 g, 2,4-D-E + metsulfuron 500 + 4 g, dicamba + metsulfuron 360 + 4 g, and dicamba + carfentrazone 360 + 20 g/ha (Fig. 4 and 5). *S. nigrum* and *P. minima* were 3-4 leaf stages at the time of herbicide spraying. Surfactants as mentioned for *L. aphaca* were used with metsulfuron, mesosulfuron-methyl + iodosulfuron-methyl sodium, sulfosulfuron, pyroxsulam, triasulfuron and topramezone and with halauxifen + florasulam ready mixture, polyglycol was used at 500 ml/ha.

Rumex dentatus: Fifty seeds of *R. dentatus* were sown in each pot and finally 10 plants/pot were maintained for herbicide spraying. The herbicide treatments (Fig. 6) assessed were 2,4-D Na (250 and 500 g/ha), 2,4-D-E (250 and 500 g/ha), 2,4-D-amine (250 and 500 g/ha), ready mixture of halauxifen-methyl ester + florasulam 12.76 (6.51 + 6.25) g/ha + surfactant polyglycol 26-2N 500 ml/ha, metsulfuron (2 and 4 g/ha) with NIS 625 ml/ha, carfentrazone (10 and 20 g/ha) and metsulfuron + carfentrazone 4 + 20 g with NIS 625 ml/ha. At the time of herbicide spraying weed was of 4 leaf stage.

In all the above pot experiments, herbicide spraying was done using knap-sack sprayer fitted with flat fan nozzles. Each treatment was replicated at least thrice and experiment was conducted in CRD and repeated to confirm the results. Fresh weight per pot was recorded 28-30 days after herbicide spraying. The results of repetition of the experiments were similar, so pooled analysis was performed. Differences among treatment means were determined using ANOVA and when the F test was significant means were compared with LSD test at 5% level of significance.

RESULTS AND DISCUSSION

Field study: Efficacy of pre-mix combination of metsulfuron + carfentrazone

Major weeds infesting the experimental plots were: *Rumex dentatus, Medicago denticulata, Coronopus didymus,* (lesser swinecress), *Lathyrus aphaca* and *Malva parviflora*. Among these, the most dominant weed species was *R. dentatus* and the dry matter accumulated by this weed in untreated control during first and second year was 362.2 and 262.1 g/m^2, respectively (Table 2 and 4). The maximum broad-leaf dry weight was recorded under weedy check (471.7 and 344.6 g/m^2). Compared to weedy check, all the herbicide treatments caused significant reduction in total density and dry weight of weeds (Table 1, 2, 3 and 4). Among different weeds, *R. dentatus* and *C. didymus* showed high sensitivity to various herbicides and their population and dry weight was drastically reduced with metsulfuron, carfentrazone, metsulfuron + carfentrazone and 2,4-D amine. Similarly, effectiveness of metsulfuron, carfentrazone and 2,4-D against *Rumex* spp. has already been reported by Balyan and Malik (2000) and Chhokar *et al.* (2007b).

The reduction in population and dry weight of *M. denticulata* was more with pre-mix combination of metsulfuron + carfentrazone applied with non ionic surfactant (NIS) than without NIS. The beneficial effect of surfactant was more clearly evident with density and dry weight of *L. aphaca*. Metsulfuron + carfentrazone at 25 and 30 g/ha with 0.2% NIS had significantly lower density of *L. aphaca* compared to sole application of metsulfuron or carfentrazone as well as without surfactant (d” 25 g/ha during first year and up to 30 g/ha during second year) application of ready mixture (Table 1, 2, 3 and 4). The improvement in efficacy of sulfonyl urea herbicide with surfactant has been reported earlier also (Singh *et al.* 2008, Chhokar *et al.* 2011).

Carfentrazone at 20 g/ha was significantly poor against *L. aphaca* and was significantly better in controlling *M. parviflora* compared to metsulfuron and 2, 4-D amine application, which failed to control *M. parviflora*. The densities of *L. aphaca* under carfentrazone application during first and second year were 14.0 and 26.0 plants/m^2 with the corresponding dry weight of 15.3 and 29.3 g/m^2. All treatments involving carfentrazone provided excellent control of *M. parviflora* (Table 1 to 4). Chhokar *et al.* (2007b) also reported effective control of *M. parviflora* with carfentrazone-ethyl. Carfentrazone alone and in combination had very fast action and toxicity symptoms appeared on the next day of herbicide application. Brosnan *et al.* (2012) also reported that carfentrazone accelerates ground ivy (*Glechoma hederacea* L.) and khaki weed (*Alternanthera pungens* Kunth) control with metsulfuron.

The ready-mix combination, metsulfuron + carfentrazone was better against the diverse weed flora compared to sole usage of metsulfuron, carfentrazone or 2,4-D amine. The total weed density and dry matter accumulation reduced as the dose of metsulfuron + carfentrazone (premix) increased. The total weed density was significantly less with metsulfuron + carfentrazone at 25 and 30 g/ha with 0.2% NIS compared to lower doses with and without surfactant as well as alone application of metsulfuron 4 g, carfentrazone 20 g or 2,4-D amine 750 g/ha.

The advantage of combination of metsulfuron and carfentrazone over metsulfuron or carfentrazone alone will be in situations having the diverse infestation of broad-leaved weeds particularly the *M. parviflora, S. nigrum and L. aphaca* (Table 1 to 4, Fig. 4). Metsulfuron and 2,4-D are not effective against *M. parviflora* and *S. nigrum*, whereas, carfentrazone is not effective against *L. aphaca*. The ready mix combination of metsulfuron + carfentrazone will provide the control of these weeds.

Similarly, Singh *et al.* (2011) reported better control of *R. spinosus* (92%) with metsulfuron + carfentrazone tank mixture compared to sole application of either metsulfuron (85%) or carfentrazone (78%). This mixture was better than 2,4-D formulations as none of the 2,4-D formulations was effective against *R. spinosus*. Although, carfentrazone causes temporary injury due to speckling on wheat leaves, which recover within 2-3 weeks without any reduction in yield (Howatt 2005) but its major advantage is its compatibility with grass herbicides.

Based on pooled analysis of two years data (Table 5), among various weed control treatments, the lowest yield (3.53 t/ha) was recorded in untreated weedy control. The presence of weeds throughout the crop season reduced the grain yield by 38.6%. Compared to weedy control, all the weed control treatments resulted in significant wheat grain yield improvement due to effective control of broad-leaf weeds. The yield in metsulfuron + carfentrazone at 25 g/ha without surfactant was inferior to its

Table 1. Effect of metsulfuron methyl + carfentrazone-ethyl and weed populatin on weed density at 60 DAS in wheat (2009-10)

Treatment	Dose (g/ha)	Weed population(no./m^2)						
		Rumex dentatus	*Coronopus didymus*	*Medicago denticulata*	*Malva parviflora*	*Lathyrus aphaca*	Others	Total weeds
Metsulfuron + carfentrazone	17.5 (3.5+14.0)	10.7^{C}	1.3^{B}	10.0^{B}	0.0^{C}	12.0^{BC}	0.7^{B}	34.7^{BC}
Metsulfuron + carfentrazone	22.5(4.5+18.0)	4.7^{DEF}	0.7^{B}	7.3^{BC}	0.0^{C}	10.0^{BC}	0.0^{B}	22.7^{D}
Metsulfuron + carfentrazone	25(5.0+20.0)	3.3^{EFG}	0.0^{B}	6.7^{BC}	0.0^{C}	8.0^{CDE}	0.0^{B}	18.0^{DE}
Metsulfuron + carfentrazone	30(6.0+24.0)	1.3^{FG}	0.0^{B}	2.7^{CD}	0.0^{C}	5.3^{EF}	0.0^{B}	9.3^{FG}
Metsulfuron + carfentrazone+NIS*	17.5(3.5+14.0)+0.2%	7.3^{CDE}	0.0^{B}	4.0^{CD}	0.0^{C}	6.0^{DE}	1.3^{B}	18.7^{D}
Metsulfuron + carfentrazone+NIS	22.5(4.5+18.0)+0.2%	4.0^{DEFG}	0.0^{B}	2.7^{CD}	0.0^{C}	4.7^{EF}	1.3^{B}	11.3^{EF}
Metsulfuron + carfentrazone+NIS	25(5.0+20.0)+0.2%	2.0^{FG}	0.0^{B}	0.7^{D}	0.0^{C}	2.7^{FG}	0.0^{B}	5.3^{GH}
Metsulfuron + carfentrazone+NIS	30(6.0+24.0)+0.2%	0.7^{G}	0.0^{B}	0.7^{D}	0.0^{C}	1.3^{G}	0.0^{B}	2.7^{H}
Metsulfuron + NIS	4+0.2%	6.7^{CDE}	0.0^{B}	6.0^{BC}	2.7^{A}	9.3^{CD}	0.7^{B}	25.3^{CD}
Carfentrazone	20	8.7^{CD}	8.7^{B}	7.3^{BC}	0.0^{C}	14.0^{B}	0.7^{B}	33.3^{BC}
2,4-D amine	750	22.7^{B}	0.0^{B}	12.7^{B}	1.3^{B}	5.3^{EF}	0.7^{B}	42.7^{B}
Untreated control	-	96.7^{A}	88.7^{A}	44.7^{A}	1.3^{B}	20.0^{A}	12.0^{A}	263.3^{A}
p-Value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

*NIS= Non ionic surfactant; **Original values were square root transformed $(\sqrt{x+1})$ for statistical analysis and based on which the upper-case letters have been mentioned with original values for interpretation. Means within column having at least one letter common are not significantly different according to DMRT (Duncan's Multiple range Test) at 5% level of significance

Table 2. Effect of metsulfuron-methyl + carfentrazone-ethyl and on weed dry weight in wheat (2009-10)

Treatment	Dose (g/ha)	Weed dry weight (g/m^2)					
		Rumex dentatus	*Medicago denticulata*	*Lathyrus aphaca*	*Malva parviflora*	Others	Total weeds
Metsulfuron + carfentrazone	17.5 (3.5+14.0)	8.0^{B}	4.0^{BC}	14.5^{AB}	0.4^{D}	3.5^{C}	30.4^{B}
Metsulfuron + carfentrazone	22.5(4.5+18.0)	0.7^{C}	0.7^{D}	11.4^{BC}	0.0^{D}	0.2^{D}	12.9^{CD}
Metsulfuron + carfentrazone	25(5.0+20.0)	0.0^{C}	0.3^{D}	7.9^{CD}	0.0^{D}	0.0^{D}	8.3^{D}
Metsulfuron + carfentrazone	30(6.0+24.0)	0.0^{C}	0.1^{D}	6.2^{DE}	0.0^{D}	0.0^{D}	6.3^{DEF}
Metsulfuron + carfentrazone + NIS*	17.5(3.5+14.0)+0.2%	0.1^{C}	1.3^{CD}	7.2^{CD}	0.0^{D}	0.0^{D}	8.6^{D}
Metsulfuron + carfentrazone + NIS	22.5(4.5+18.0)+0.2%	0.0^{C}	0.9^{CD}	5.3^{DE}	0.0^{D}	0.0^{D}	6.2^{DE}
Metsulfuron + carfentrazone + NIS	25(5.0+20.0)+0.2%	0.0^{C}	0.1^{D}	0.7^{F}	0.0^{D}	0.0^{D}	0.7^{EF}
Metsulfuron + carfentrazone + NIS	30(6.0+24.0)+0.2%	0.0^{C}	0.0^{D}	0.5^{F}	0.0^{D}	0.0^{D}	0.5^{F}
Metsulfuron + NIS	4+0.2%	0.1^{C}	0.7^{D}	5.1^{DE}	8.7^{A}	8.7^{A}	23.2^{BC}
Carfentrazone	20	2.9^{BC}	7.1^{B}	15.3^{AB}	0.0^{D}	0.2^{D}	25.4^{B}
2,4-D amine	750	9.7^{B}	0.7^{D}	2.3^{EF}	5.9^{B}	4.3^{C}	22.8^{BC}
Untreated control	-	362.2^{A}	79.4^{A}	21.4^{A}	2.0^{C}	6.3^{B}	471.7^{A}
p-Value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Table 3. Effect of metsulfuron-methyl + carfentrazone-ethyl and weed populatin on weed density at 60 DAS in wheat (2010-11)

Treatment	Dose (g/ha)	Weed population (no./m^2)**						
		Rumex dentatus	*Coronopus didymus*	*Medicago denticulata*	*Malva parviflora*	*Lathyrus aphaca*	Others	Total weeds
Metsulfuron + carfentrazone	17.5 (3.5+14.0)	6.0^{BCD}	1.3^{CD}	4.0^{BC}	0.0^{C}	22.7^{B}	1.3	35.3^{BC}
Metsulfuron + carfentrazone	22.5(4.5+18.0)	3.3^{CDE}	0.0^{D}	3.3^{BC}	0.0^{C}	19.3^{BC}	0.7	26.7^{CD}
Metsulfuron + carfentrazone	25(5.0+20.0)	0.7^{EF}	0.0^{D}	2.0^{BCD}	0.0^{C}	13.3^{CD}	0.7	16.7^{EF}
Metsulfuron + carfentrazone	30(6.0+24.0)	0.7^{EF}	0.0^{D}	0.7^{CD}	0.0^{C}	11.3^{D}	0.0	12.7^{F}
Metsulfuron + carfentrazone + NIS*	17.5(3.5+14.0)+0.2%	2.0^{EF}	0.0^{D}	2.0^{BCD}	0.0^{C}	11.3^{D}	0.0	15.3^{EF}
Metsulfuron + carfentrazone + NIS	22.5(4.5+18.0)+0.2%	0.7^{EF}	0.0^{D}	1.3^{BCD}	0.0^{C}	9.3^{D}	0.0	11.3^{F}
Metsulfuron + carfentrazone + NIS	25(5.0+20.0) +0.2%	0.7^{EF}	0.0^{D}	0.7^{CD}	0.0^{C}	3.3^{E}	0.0	4.7^{G}
Metsulfuron + carfentrazone + NIS	30(6.0+24.0) +0.2%	0.0^{F}	0.0^{D}	0.0^{D}	0.0^{C}	2.0^{E}	0.0	2.0^{G}
Metsulfuron + NIS	4+ 0.2%	2.7^{DEF}	1.3^{CD}	5.3^{B}	3.3^{A}	8.0^{D}	0.0	20.7^{DE}
Carfentrazone	20	7.3^{BC}	3.3^{C}	4.7^{B}	0.0^{C}	26.0^{AB}	0.0	41.3^{B}
2,4-D amine 58% SL	750	12.0^{B}	10.7^{B}	5.3^{B}	2.0^{B}	10.7^{D}	0.0	40.7^{B}
Untreated control	-	72.0^{A}	74.0^{A}	24.0^{A}	1.3^{B}	34.7^{A}	5.3	211.3^{A}
p-Value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.1093	<0.0001

Table 4. Effect of metsulfuron-methyl + carfentrazone-ethyl on weed dry weight in wheat (2010-11)

Treatment	Dose (g/ha)	Weed dry weight (g/m^2)**				
		Rumex dentatus	*Medicago denticulata*	*Lathyrus aphaca*	Others	Total weeds
Metsulfuron + carfentrazone	17.5 (3.5+14.0)	10.8^{BC}	3.4^{BC}	22.0^{BC}	0.0^{C}	36.2^{BC}
Metsulfuron + carfentrazone	22.5(4.5+18.0)	5.9^{CDE}	0.6^{D}	17.3^{C}	0.0^{C}	23.8^{DE}
Metsulfuron + carfentrazone	25(5.0+20.0)	3.9^{DEF}	0.1^{D}	10.3^{D}	0.0^{C}	14.3^{F}
Metsulfuron + carfentrazone	30(6.0+24.0)	1.1^{FGH}	0.0^{D}	7.3^{DE}	0.0^{C}	8.5^{F}
Metsulfuron + carfentrazone + NIS*	17.5(3.5+14.0)+0.2%	6.0^{CDE}	1.1^{CD}	8.3^{DE}	0.0^{C}	15.5^{EF}
Metsulfuron + carfentrazone + NIS	22.5(4.5+18.0)+0.2%	2.7^{EFG}	0.5^{D}	6.0^{DE}	0.1^{C}	9.3^{F}
Metsulfuron + carfentrazone + NIS	25(5.0+20.0)+0.2%	0.1^{EFGH}	0.0^{D}	2.2^{F}	0.0^{C}	2.4^{G}
Metsulfuron + carfentrazone + NIS	30(6.0+24.0)+0.2%	0.0^{H}	0.0^{D}	2.0^{F}	0.0^{C}	2.0^{G}
Metsulfuron + NIS	4+0.2%	5.8^{CDE}	1.1^{CD}	5.6^{E}	0.1^{BC}	12.7^{F}
Carfentrazone	20	7.4^{CD}	6.0^{B}	29.3^{B}	1.1^{B}	43.8^{B}
2,4-D amine	750	15.3^{B}	0.6^{D}	8.7^{DE}	0.6^{BC}	25.2^{CD}
Untreated control	-	262.1^{A}	38.0^{A}	38.9^{A}	5.6^{A}	344.6^{A}
p-Value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

*NIS= Non ionic surfactant; **Original values were square root transformed $(\sqrt{x+1})$ for statistical analysis and based on which the upper-case letters have been mentioned with original values for interpretation. Means within column having at least one letter common are not significantly different according to DMRT (Duncan's Multiple range Test) at 5% level of significance application with surfactant. The ready mixture applied with surfactant had statistically similar yields. The application of ready mixture with NIS produced more grain yield compared to alone application of metsulfuron and carfentrazone as well as 2,4-D amine. The improvement in wheat grain yield under various weed control treatments was due to improvement in yield attributes (tillers and 1000 grain weight) as a result of effective weed control. The results show that for better efficacy of the ready-mix combination of metsulfuron- + carfentrazone, its application with a surfactant is a must. Similarly, Chhokar *et al.* (2011) also reported better weed control and wheat productivity when ready-mix combination of carfentrazone + sulfosulfuron was applied with surfactant than without surfactant application as well as alone application of either carfentrazone or sulfosulfuron. Similarly, the broad spectrum weed control and higher wheat yield were observed with combination of sulfosulfuron + metsulfuron over alone usage of either sulfosulfuron or metsulfuron (Chhokar *et al.* 2007a)

After wheat harvest, greengram and maize were grown to evaluate the herbicide carry over effect. No effect on germination (data not shown) and growth (Table 5) was observed indicating that carfentrazone, metsulfuron and premix combination of metsulfuron methyl + carfentrazone ethyl are safe for maize/greengram included in wheat based system.

Pot study 1: Surfactant effect on efficacy of metsulfuron and its mixture with carfentrazone: The efficacy of metsulfuron and metsulfuron + carfentrazone against *Lathyrus aphaca* and *M. denticulata* was improved when applied with external NIS compared to without surfactant (Fig. 1 and 2). However, the magnitude of improvement was compartively less in *M. denticultata* to *L. aphaca*. The differential response is due to differential nature of weeds and herbicides. Hodgson (1973) reported differential 2,4-D sensitivity in quack grass due to wax coating on the cuticular surface and in different ecotypes of *Circium arvense* due to variation in the wax content and amount of leaf lipid. Malik *et al.* (1989) reported significant improvement in efficacy of urea herbicides with surfactant, Selwet at 0.1% against *Lathyrus aphaca* L. and *Vicia sativa* L.

The combination, metsulfuron + carfentrazone was better compared to alone application of carfentrazone or metsulfuron. Carfentrazone 20 g/ha was better than its lower doses (5 and 10 g/ha) as well as with surfactant application of metsulfuron 1 g/ha and metsulfuron + carfentrazone (1 + 4 g/ha) (Fig. 1). With NIS, the lowest dose of metsulfuron alone (1 g/ha) and in combination with carfentrazone (1+ 4 g/ha) were equally effective in reducing the fresh weight of *M. denticulata* as their respective 2 and 4 times doses without surfactant (Fig. 1). The improvement in herbicide efficacy with surfactant has been earlier reported by many research workers (Chhokar *et al.* 2011, Malik *et al.* 1989, Singh *et al.* 2008).

Table 5. Effect of metsulfuron + carfentrazone on wheat and succeeding maize and greengram (pooled data of two years)

Treatment	Dose (g/ha)	Wheat yield and yield attributes				Carry over effect on succeeding crops	
		Tillers/ m^2	Biomass (t/ha)	1000 grain wt (g)	Grain yield (t/ha)	Maize fresh biomass (fodder) (t/ha)	Greengram grain yield (t/ha)
Metsulfuron + carfentrazone	17.5 (3.5+14.0)	462^{B}	12.89^{B}	37.1^{A}	5.33^{C}	12.84	1.12
Metsulfuron + carfentrazone	22.5(4.5+18.0)	476^{AB}	13.53^{AB}	37.3^{A}	5.44^{BC}	12.28	1.10
Metsulfuron + carfentrazone	25(5.0+20.0)	478^{AB}	13.39^{AB}	36.9^{A}	5.55^{ABC}	13.03	1.10
Metsulfuron + carfentrazone	30(6.0+24.0)	486^{AB}	13.36^{AB}	37.1^{A}	5.65^{AB}	12.16	1.05
Metsulfuron + carfentrazone +NIS*	17.5(3.5+14.0)+0.2%	478^{AB}	13.44^{AB}	37.1^{A}	5.60^{ABC}	12.00	1.06
Metsulfuron + carfentrazone + NIS	22.5(4.5+18.0)+0.2%	488^{A}	13.85^{A}	37.1^{A}	5.75^{A}	12.63	1.09
Metsulfuron + carfentrazone + NIS	25(5.0+20.0)+0.2%	482^{AB}	13.59^{AB}	37.4^{A}	5.73^{AB}	12.47	1.16
Metsulfuron + carfentrazone + NIS	30(6.0+24.0)+0.2%	482^{AB}	13.77^{A}	37.7^{A}	5.72^{AB}	12.67	1.13
Metsulfuron + NIS	4+0.2%	478^{AB}	13.34^{AB}	37.0^{A}	5.58^{ABC}	12.07	1.09
Carfentrazone	20	488^{A}	13.20^{AB}	37.3^{A}	5.32^{C}	12.42	1.10
2,4-D amine	750	467^{AB}	12.87^{B}	36.9^{A}	5.45^{BC}	12.44	1.17
Untreated control	-	379^{C}	10.09^{C}	34.5^{B}	3.53^{D}	12.52	1.11
p-Value		<0.0001	<0.0001	0.0038	<0.0001	0.9921	0.9905
LSD (0.05)		25.6	0.81	1.22	0.29	NS	NS

*NIS= Non ionic surfactant; ** Means in column having at least one letter common are not significantly different using DMRT (Duncan's Multiple Range Test) at 5% level of significance

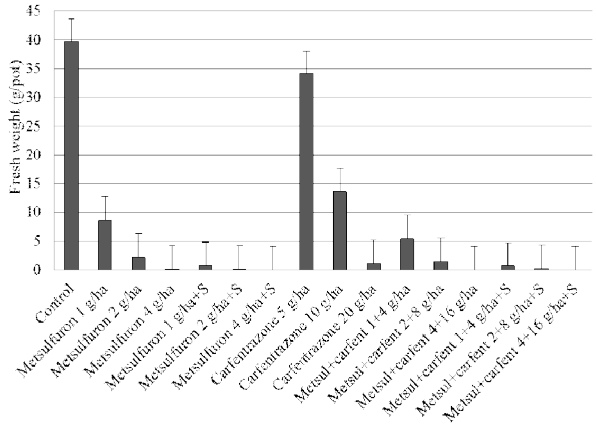

Fig. 1. ***Medicago denticulata*** **fresh weight as affected by herbicide and surfactant. Vertical bars represent LSD (P=0.05)**

Among, metsulfuron, carfentrazone and metsulfuron + carfentrazone treatments, carfentrazone had the least effect on *L. aphaca*. Carfentrazone 20 g/ha application reduced the *L. aphaca* fresh weight by 37.3% compared to untreated control (Fig. 2). The NIS significantly improved the efficacy of metsulfuron and metsulfuron + carfentrazone. The lowest dose of metsulfuron alone 1 g/ha and metsulfuron + carfentrazone 1 + 4 g/ha with NIS were equally effective to their respective highest doses 4 g/ha and 4 + 16 g/ha without NIS.

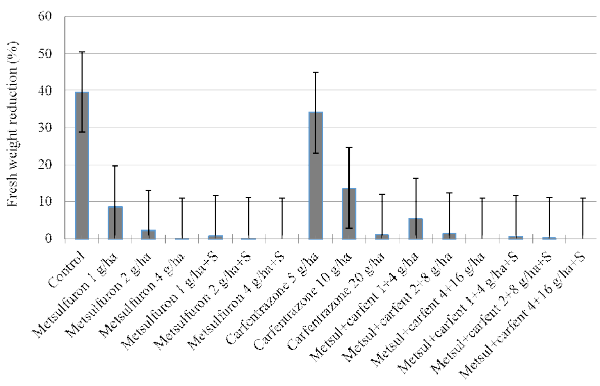

Fig. 2. ***Lathyrus aphaca*** **fresh weight reduction as affected by herbicide and surfactant. Vertical bars represent ± LSD (P=0.05)**

Pot study 2: Herbicides for control of *L. aphaca, Rumex dentatus, S. nigrum* and *P. minima*

***L. aphaca* control**: In another pot experiment, carfentrazone 20 g/ha was ineffective against *L. aphaca*, as the fresh weight accumulated by *L. aphaca* in carfentrazone and control was 22.9 and 19.9 g/pot, respectively. Dicamba 480 g/ha and topramezone 50 g/ha were the most effective treatments providing complete control of *L. aphaca*.

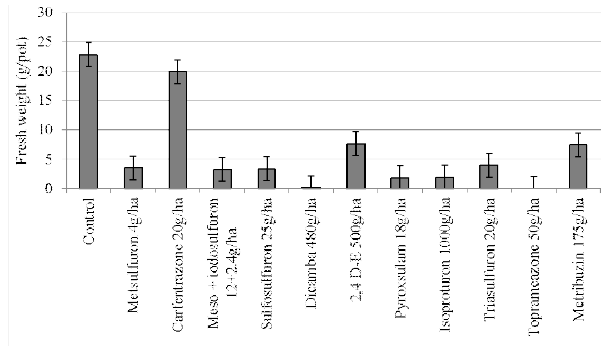

Fig. 3. Effect of herbicides on *Lathyrus aphaca*. Vertical bars represent ±LSD (P=0.05)

Metribuzin 175 g and 2,4-D-E 500 g/ha were inferior to metsulfuron, Atlantis, sulfosulfuron, pyroxsulam, isoproturon and triasulfuron (Fig. 3).

***S. nigrum* control:** All the herbicide treatments reduced the fresh weight of *S. nigrum* (Fig. 4) compared to control (100%). Metsulfuron 4 g/ha was least effective in controlling *S. nigrum* followed by halauxifen methyl + florasulam 12.76 g/ha and sulfosulfuron 25 g with respective reduction in *S. nigrum* fresh weight of 22.0, 29.2 and 39.8%. Application of 2,4-D-E 500 g/ha alone provided 58.8% control of *S. nigrum*. However, another growth regulator herbicide *i.e.* dicamba 360 g/ha was highly effective (99.2%) in controlling *S. nigrum*. The most effective control of *S. nigrum* was with isoproturon 1000 g/ha (100.0%), topramezone 50 g/ ha (100.0%), dicamba 360 g/ha, and tank mix application of carfentrazone (20 g/ha) with metsulfuron (4 g/ha), 2,4-D-E (500 g/ha) and dicamba (360 g/ha).

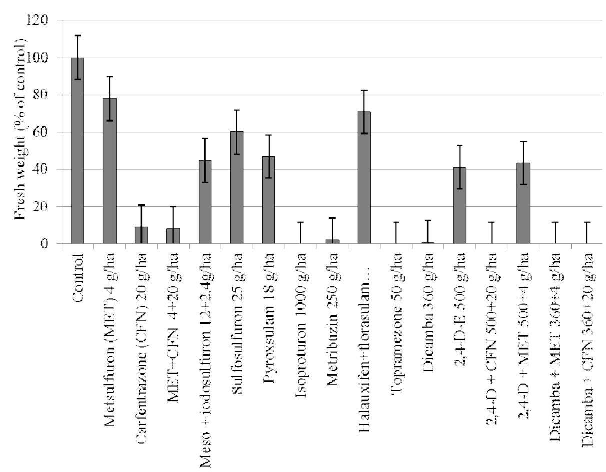

Fig. 4. ***Solanum nigrum*** **fresh weight as affected by herbicide. Vertical bars represent ±LSD (P=0.05)**

***P. minima* control:** The fresh weight of *P. minima* was significantly reduced with various herbicides. Among different herbicides, 2,4-D-E 500 g/ha was least effective in controlling *P. minima* followed by halauxifen methyl + florasulam 12.76 g/ha (Fig 5). Metsulfuron 4 g, carfentrazone 20 g, metsulfuron + carfentrazone (4+20 g/ha), pyroxsulam 18 g, isoproturon 1000 g, metribuzin 210 g, dicamba 360 g, topramezone 50 g, 2,-4-D-E+carfentrazone 500 + 20 g, 2,4-D-E+ metsulfuron 500 + 4 g/ha were quite effective in controlling *P. minima* and the fresh weight reduction by these herbicide was 98.4 to 100.0%. However, the genotype/crop selectivity to metribuzin and topramezone should be examined before use as differential crop tolerance to these herbicides can occur.

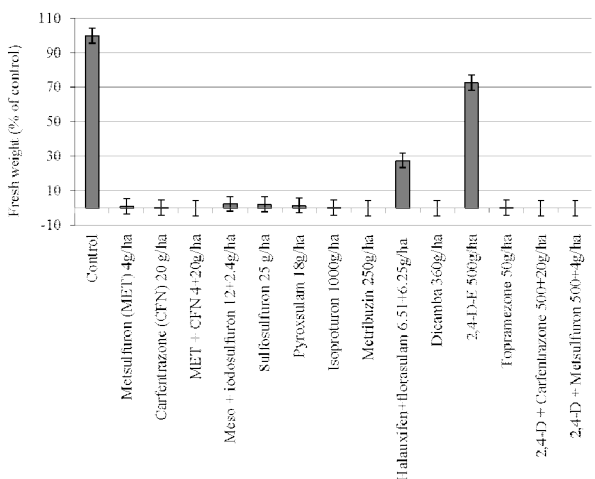

Fig. 5. *Physalis minima* fresh weight as affected by herbicide. Vertical bars represent ± LSD (P=0.05)

***Rumex dentatus* control:** Its control was poor with all the 2,4-D formulations (Fig. 6). The effectiveness of three formulations was in order 2,4-D-Amine, 2,4-D-E and 2,4-D-Na. Singh *et al.* 2011 also reported ineffectiveness of 2,4-D formulations for *Rumex spinosus* control. Metsulfuron, carfentrazone, metsulfuron + carfentrazone and halauxifen methyl + florasulam were effective in controlling the *Rumex dentatus*. Metsulfuron 2 to 4 g/ha and halauxifen methyl +florasulam 12.76 g/ha provided 100% control.

In the present study, herbicide combinations, 2,4-D E + carfentrazone 500 + 20 g/ha and dicamba 360 g + carfentrazone 20 g/ha effectively controlled the *P. minima* and *S. nigrum* and no antagonistic effect was observed. Lyon *et al.* (2007) also reported that carfentrazone at 18 g/ha tank mixed with 2,4-D amine or dicamba improved *Salsola iberica, Kochia scoparia* and *Helianthus annuus* control without

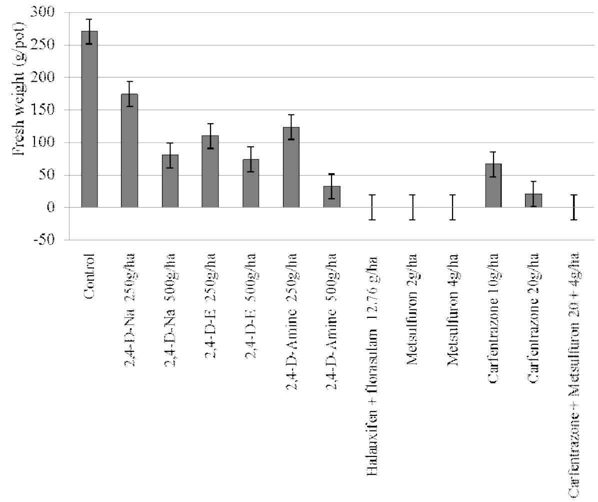

Fig. 6. *Rumex dentatus* fresh weight as affected by herbicide. Vertical bars represent ± LSD (P=0.05)

injury on proso millet (*Panicum miliaceum* L.) and foxtail millet (*Setaria italica* L.) in Nebraska. Contrary to it, Singh *et al.* (2008) reported tank mix application of carfentrazone with 2,4-D as antagonistic against some broad-leaf weeds, but not with tribenuron. However, care has to be taken while using 2,4-D and should be used at right dose and time. Its application at sensitive stages (seedling, spike initiation/flowering stage) as well as on sensitive cultivars and at higher rates can lead to yield reduction due to earhead malformation (Pinthus and Natowitz 1967). In addition, 2,4-D butyl ester application often results in injury to adjacent sensitive broad-leaf crops, due to its volatilization and solution drifting (Li *et al.* 2002, Zhang *et al.* 2005).

The control of broad-leaf weeds is easy as compared to grassy weeds in wheat crop. However, due to more diversity of broad-leaf weeds, still many broad-leaf weeds escape control with usage of single herbicide. Also, continuous use of herbicides having the same mechanism of action can result in the wide spread evolution of herbicide resistance in weeds and build up of tolerant weeds (Powles and Yu 2010). Repeated application of tribenuron in China has resulted in serious sulfonylurea resistance in main weed species *Descurainia sophia* (Cui *et al.* 2008). *L. aphaca, F. parviflora* and *Rumex spinosus* are becoming major weeds in light soils of North Western India. Whereas, *Malva parviflora, Solanum nigrum* and *Rumex dentatus* are increasing in abundance in no-till wheat fields of rice-wheat system. The increasing abundance of a particular weed is as a result of ineffectiveness of particular herbicide used. Metsulfuron and 2,4-D are ineffective against some of the weeds like *Malva parviflora* and *S. nigrum*.

2,4-D is also not effective against *R. spinosus* and carfentrazone is poor against *Lathyrus aphaca*. Combination of metsulfuron or 2,4-D with other herbicides like carfentrazone can provide control of diverse weed spectrum as observed here in field and pot studies. Herbicide mixture will also lower the selection pressure being imposed by the repeated use of same herbicide. Therefore, for broad spectrum weed kill, two or three herbicides combinations need to be tried. Although, wheat growers prefer herbicide over other method of weed control yet there is need to integrate the non-chemical methods with chemical for efficient weed management and sustainable crop production.

Present study suggests that fields having diverse infestation of weeds require herbicides combination. Metsulfuron-methyl + carfentrazone (premix) at 25 g/ha + 0.2% NIS was effective against diverse broad-leaf weeds in wheat. A combination of two or more herbicides, besides broadening the weed control also helped in reducing the cost of weed control. Therefore, future studies need to be directed towards evaluating the compatibility/suitability between different broad-leaved herbicides and broad-leaf and grass herbicides. The effectiveness of grass herbicides was generally reduced when mixed with broad-leaf herbicides (Damlas 2004).

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Metribuzin + clodinafop-propargyl effects on complex weed flora in wheat and its residual effect on succeeding crop

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ABSTRACT

A field experiment was carried out at Norman E. Borlaug Crop Research Centre of G.B.P.U.A&T, Pantnagar during *Rabi* seasons of 2010-11 and 2011-12 to test the efficacy of different dosses of metribuzin 42% + clodinafop propargyl 12% WG against weeds in wheat. The soil of the experimental field was clay loam in texture, medium in organic carbon (0.67%), available phosphorus (29.6 kg/ha) and potassium (176.4 kg/ha) with pH 7.2. Results revealed that metribuzin + clodinafop-propargyl at 500-600 g/ha were as effective as two hand weeding at 30 and 50 DAS in reducing the weed density of *Phalaris minor* and *Chenopodium album*, *Cornopus didymus*, *Melilotus* spp., *Rumex* spp. and *Fumaria parviflora* at 30 and 60 days after application as compared to rest treatments. Maximum grain yield was recorded in metribuzin + clodinafop-propargyl WG at 600 g/ha which was statistically at par with its lower dose of 500 g/ha due to effective control of grassy and broad-leaved weeds in wheat.

Key words: Clodinafop-propargyl, Efficacy, Metribuzin, Residual effect, Wheat

Wheat (*Triticum aestivium*) is heavily infested with *Phalaris minor*, *Avena ludoviciana*, *Chenopodium album*, *Medicago denticulata*, *Melilotus alba*, *Melilotus indica*, *Fumaria parviflora*, *Vicia hirsuta*, *Vicia sativa*, *Coronopus didymus* and *Rumex acetocella.* Uncontrolled weeds are reported to cause upto 66% reduction in wheat grain yield (Angiras *et al.* 2008, Kumar *et al.* 2009 and Kumar *et al.* 2011) or even more depending upon the weed density, type of weed flora and duration of infestation. Chemical weed control is a preferred practice due to scarce and costly labour as well as lesser feasibility of mechanical or manual weeding especially in broadcast wheat. Combination of isoproturon and 2,4-D as tank mixture has been recommended against complex weed flora. This combination has been found promising in the situation where isoproturon was effective against *Phalaris minor*. However against complex weed flora dominated by *Avena ludoviciana*, *Lolium temulentum* and *Poa annua*, combination of isoproturon and 2,4-D was not so effective.Under such situation, a suitable combination of clodinafop and pinoxaden with some broad-spectrum herbicides like metribuzin is needed. Hence, the present investigation was carried out to evaluate the efficacy of metribuzin in combination with recommended clodinafop against mixed weed flora in wheat.

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MATERIALS AND METHODS

A field trial was carried out during *Rabi* of 2010-11 and 2011-12 at Pantnagar to evaluate the bio-efficacy of metribuzin 42% + clodinafop propargyl. The soil of the experimental field was clay loam in texture, medium in organic carbon (0.67%), available phosphorus (29.6 kg/ha) and potassium (176.4 kg/ha) with pH 7.2**.** Ten treatments were evaluated in randomized block design with three replication. The treatments comprised of three doses of metribuzin + clodinafop-propargyl WG at 400, 500 and 600 g/ha as test product and isoproturon 75% WP at 1333.3 g/ha, metribuzin 70% WP at 300 g/ha, sulfosulfuron 75% at 33.3 g/ha, clodinafop-propargyl at 400 g/ha, mesosulfuron-methyl 3% + idosulfuron-methyl sodium 0.6% WG at 400 g/ha weeding at 30 and 50 days after sowing (DAS) and untreated control. The wheat variety '*UP- 2565*' was sown on November 23, 2010 and November 18, 2011, respectively. Recommended package of practices were followed to raise the wheat. The data on density and dry weight of total weeds were taken at 30 and 60 DAS and grain yield (kg/ha) was recorded at the time of harvesting.

In addition of bio-efficacy, a separate experiment was also carried out to observe the phytotoxicity effect of metribuzin 42% + clodinafop propargyl 12% WG on wheat crop, *viz.* yellowing, necrosis, epinasty, hyponasty and scorching and to see the residual effect on succeeding crops 'maize'.

Metribuzin + clodinafop-propargyl at 500 and 1000 g/ha were applied at 35 days after sowing of wheat crop using prescribed volume of water and surfactant. Phytotoxicity symptoms, *viz.* yellowing, necrosis, epinasty, hyponasty and scorching were recorded at 7, 15 and 30 days after treatment using rating scale of 0-10 where, where, 0= no effect on plant and 10= complete death of the plant.

Maize crop was planted by dibbling method after one week of harvesting of wheat crop in the plots which was treated with metribuzin + clodinafop propargyl at 500 and 1000 g/ha in wheat to see the residual effect on germination and growth of maize crop. Untreated check was also maintained for comparison. The maize crop was raised as per the standard agronomical practices of the university.

RESULTS AND DISCUSSION

Effect on weeds

Experimental field was naturally dominated with *Phalaris minor* (5.74 and 40.7%) as a grassy weed and C*henopodium album* (2.8 and 13.3%), *Cornopus didymus* (2.8 and 10.4%), *Melilotus indica,* (2.5 and 9.4%) *Rumex* spp., (2.0 and 4.8%) and *Fumeria parviflora* (1.8 and 3.8%), were major broad-leaf weeds infesting experimental area during 2010 and 2011, respectively.

Efficacy against grassy weeds

Metribuzin + clodinafop-propargyl at 500 g/ha and metribuzin + clodinafop-propargyl at 600 g/ha were significantly at par with two hand weeding at 30 and 50 days after sowing of wheat which recorded the lowest weed density at 30 and 60 days after application as compared to rest of the treatments. Application of sulfosulfuron 75% at 33.3 g/ha and mesosulfuron-methyl + idosulfuron-methyl sodium at 400g/ha were however significantly superior over untreated control plot but found to be least effective against *P. minor* as compared to rest of the herbicidal treatments when observed at 30 and 60 days after treatment. Efficacy of clodinafop propargyl 15% WP at 400 g/ha against *P. minor* were at par to metribuzin 42% + clodinafop propargyl 12% WG at 400 g/ha (Table 1 and 2).

Efficacy against broad-leaf weeds

The data on efficacy of the herbicides on the density of broad-leaf weeds recorded at 30 and 60 days after treatment, respectively (Table 1 and 2), Metribuzin + clodinafop-propargyl at 600 g/ha at 500 g/ha was at par with its higher dose *i.e.* at 600 g/ha and mesosulfuron-methyl + idosulfuron-methyl sodium at 400 g/ha, metribuzin at 300 g/ha and two hand weeding at 30 and 50 days after sowing against broad-leaf weeds, *viz.* C. *album, C. didymus,*

Table 1. Effect of metribuzin + clodinafop-propargyl and other herbicides on density of weeds at 30DAS during 2010 and 2011.

Treatment	Product dose (g/ha)	Surfactant volume (ml/ha)	Weed density*/m^2 at 30 DAS											
			P. minor		*C. didymus*		*C. album*		Rumex spp.		*M. indica*		*F. parviflora*	
			2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Metribuzin + clodinafop-propargyl	400	1250	19.3	4.28	5.3	2.54	4.0	2.49	4.0	2.49	2.3	2.08	3.0	1.83
			(4.5)	(17.3)	(2.5)	(6.7)	(2.2)	(5.3)	(2.2)	(5.3)	(1.8)	(4.0)	(2.0)	(2.7)
Metribuzin + clodinafop-propargyl	500	1250	7.7	2.75	0.3	1	0.0	1	1.0	1.42	0.0	1.42	0.0	1.0
			(2.9)	(6.7)	(1.1)	(0.0)	(1.0)	(0.0)	(1.4)	(1.3)	(1.0)	(1.3)	(1.0)	(0.0)
Metribuzin + clodinafop-propargyl	600	1250	2.3	1.83	15.7	4.43	14.3	5.97	5.3	3.40	11.3	3.60	7.0	3.20
			(1.8)	(2.7)	(4.1)	(18.7)	(3.9)	(34.7)	(2.5)	(10.7)	(3.5)	(12.0)	(2.8)	(9.3)
Isoproturon	1333.3		32.0	5.29	1.0	1.0	0.0	1.0	0.0	1.0	0.0	1.42	1.0	1.0
		-	(5.7)	(27)	(1.4)	(0.0)	(1.0)	(0.0)	(1.0)	(0.0)	(1.0)	(1.3)	(1.4)	(0.0)
Metribuzin	300		33.0	5.13	4.7	2.08	3.7	1.83	3.7	2.49	1.7	1.42	1.0	1.42
		-	(5.8)	(25.3)	(2.4)	(4.0)	(2.2)	(2.7)	(2.2)	(5.3)	(1.6)	(1.3)	(1.4)	(1.3)
Clodinafop-propargyl	400	-	3.7	1.83	1.7	1.42	1.0	1.42	2.3	1.83	1.3	1.83	0.7	1.83
			(2.2)	(2.7)	(1.6)	(1.3)	(1.4)	(1.3)	(1.8)	(2.7)	(1.5)	(2.7)	(1.3)	(2.7)
Mesosulfuron-methyl + idosulfuron-methyl sodium + surfactant	400	500	0.0	1.0	0.0	1.0	0.0	1.0	1.0	1.0	0.7	1.0	0.7	1.42
			(1.0)	(0.0)	(1.0)	(0.0)	(1.0)	(0.0)	(1.4)	(0.0)	(1.3)	(0.0)	(1.3)	(1.3)
Sulfosulfuron + surfactant	33.3	1250	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.0	1.0
			(1.0)	(0.0)	(1.0)	(0.0)	(1.0)	(0.0)	(1.0)	(0.0)	(1.0)	(0.0)	(1.4)	(0.0)
Hand weeding at 30 and 50 DAS	-		0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0	1.0	1.0	0.0	1.0
		-	(1.0)	(0.0)	(1.0)	(0.0)	(1.0)	(0.0)	(1.0)	(0.0)	(1.4)	(0.0)	(1.0)	(0.0)
Untreated control	-		72.0	8.15	13.7)	4.87	17.0	5.85	6.0	3.78	13.0	3.40	6.3	3.58
		-	(8.5)	(65.3)	(3.8	(22.7)	(4.2)	(33.3)	(2.6)	(13.3)	(3.7)	(10.7)	(2.7)	(12.0)
LSD (P=0.05)			0.46	0.69	0.41	1.06	0.23	0.70	0.53	0.73	0.43	1.01	0.47	0.84

* Figures in parentheses indicates original values

Table 2. Effect of metribuzin + clodinafop-propargyl and other herbicides on density of weeds at 60 DAS during 2010 and 2011

Treatment	Product dose (g/ha)	Surfactant volume (ml/ha)	Weed density*/m^2 at 60 DAS											
			P. minor		*C. didymus*		*C. album*		Rumex spp.		*M. indica*		*F. parviflora*	
			2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Metribuzin + clodinafop-propargyl	400	1250	17.0 (4.2)	3.95 (14.7)	7.0 (2.8)	2.49 (5.3)	3.0 (2.0)	2.08 (4.0)	3.3 (2.1)	2.08 (4.0)	5.0 (2.4)	2.08 (4.0)	2.0 (1.7)	1.83 (2.7)
Metribuzin + clodinafop-propargyl	500	1250	5.0 (2.4)	2.08 (4.0)	0.3 (1.1)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	1.7 (1.6)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)
Metribuzin + clodinafop-propargyl	600	1250	3.3 (2.1)	1.83 (2.7)	16.7 (4.2)	4.10 (16.0)	18.3 (4.4)	4.57 (20.0)	5.0 (2.4)	2.54 (6.7)	10.3 (3.4)	3.32 (10.7)	5.0 (2.4)	2.54 (6.7)
Isoproturon	1333.3	-	29.7 (5.5)	4.86 (22.7)	0.0 (1.0)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	1.0 (1.4)	1.00 (0.0)
Metribuzin	300	-	25.0 (5.1)	4.43 (18.7)	4.7 (2.4)	1.83 (2.7)	6.7 (2.8)	1.83 (2.7)	4.0 (2.2)	2.08 (4.0)	1.0 (1.4)	1.82 (2.7)	0.0 (1.0)	1.00 (0.0)
Clodinafop-propargyl	400	-	3.7 (2.2)	1.83 (2.7)	0.7 (1.3)	1.42 (1.3)	1.7 (1.6)	1.42 (1.3)	1.0 (1.4)	1.42 (1.3)	1.0 (1.4)	1.42 (1.3)	0.7 (1.3)	1.00 (0.0)
Mesosulfuron-methyl + idosulfuron-methyl sodium + surfactant	400	500	0.7 (1.3)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	0.7 (1.3)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	0.7 (1.3)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)
Sulfosulfuron + surfactant	33.3	1250	0.7 (1.3)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	0.3 (1.1)	1.00 (0.0)	1.0 (1.4)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)
Hand weeding at 30 and 50 DAS	-	-	2.0 (1.7)	1.83 (2.7)	0.3 (1.1)	1.42 (1.3)	1.0 (1.4)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)	0.7 (1.3)	1.00 (0.0)	0.0 (1.0)	1.00 (0.0)
Untreated control	-	-	65.3 (8.1)	7.64 (57.3)	15.0 (4.0)	3.87 (14.7)	14.0 (3.9)	4.43 (18.7)	6.7 (2.8)	2.54 (6.7)	11.0 (3.5)	3.73 (13.3)	6.0 (2.6)	2.49 (5.3)
LSD (P=0.05)			0.52	0.91	0.28	0.98	0.42	0.84	0.71	NS	0.51	0.89	0.40	0.89

Figures in parentheses indicates original values

Table 3. Effect of metribuzin + clodinafop-propargyl and other herbicides on dry weight of weeds at 30 and 60 DAS (mean of 2010 and 2011)

Treatment	Product dose (g/ha)	Surfactant (ml/ha)	Weed dry weight (g/m^2) 30 DAS			WCE (%)	Weed dry weight (g/m^2) 60 DAS			WCE (%)
			GW	BLW	Total		GW	BLW	Total	
Metribuzin + clodinafop-propargyl	400	1250	2.0	7.9	9.9	93.8	4.8	8.9	13.7	93.4
Metribuzin + clodinafop-propargyl	500	1250	0.0	1.3	1.3	99.2	0.0	0.0	0.0	100.0
Metribuzin + clodinafop-propargyl	600	1250	0.0	0.0	0.0	100.0	0.0	0.0	0.0	100.0
Isoproturon	1333.3	-	12.6	23.0	35.6	77.7	26.3	37.5	63.8	69.5
Metribuzin	300	-	5.2	3.1	8.3	94.8	6.7	1.7	8.4	96.0
Clodinafop-propargyl	400	-	1.7	52.3	54.0	66.1	4.5	93.5	98.0	53.1
Mesosulfuron-methyl + idosulfuron-methyl sodium + surfactant	400	500	23.8	2.3	26.1	83.4	40.8	3.3	44.1	78.9
Sulfosulfuron + surfactant	33.3	1250	21.3	13.5	34.8	78.2	29.9	20.9	50.8	75.7
Hand weeding at 30 and 50 DAS	-	-	0.0	0.0	0.0	100.0	4.0	3.4	7.4	96.5
Untreated control	-	-	74.1	85.4	159.5	0. 0	117.5	91.7	209.2	0.0
LSD (P=0.05)			11.8	5.8	13.1	-	35.2	5.3	35.0	-

GW= Grassy weeds, BLW= Broad-leaf weeds

Melilotus spp., *Rumex* spp., and *F. parviflora* with recorded lowest density of weeds at 30 and 60 days after treatment. Clodinafop-propargyl at 400 g/ha found to be ineffective against broad-leaf weeds. Excellent control of complex weed flora in wheat was observed with the tank mix application of clodinafop + metsulfuron (15:1 ratio) at 60 g/ha (Punia *et al*. 2004).

Weed dry matter production

Weed management treatments significantly reduced the population and dry matter of grassy as well as broad-leaved weeds as compared to weedy check (Table 3). At 30 and 60 DAS, significantly lowest dry weed weight of grassy was recorded with metribuzin + clodinafop-propargyl at 500 g/ha which was at par with its higher dose *i.e*. 600 g/ha and mesosulfuron-methyl + idosulfuron-methyl sodium at

Table 4. Effect of metribuzin + clodinafop propargyl and other herbicides on yield attributed characters and grain yield of wheat during 2010 and 2011

Treatment	Product dose (g/ha)	Surfactant (ml/ha)	Plant height (cm)		No. of spikes /m^2		1000 grain wt (g)		Grain yield (t/ha)	
			2010	2011	2010	2011	2010	2011	2010	2011
Metribuzin + clodinafop-propargyl	400	1250	100.6	100.4	258.7	255.0	46.0	44.7	5.61	5.56
Metribuzin + clodinafop-propargyl	500	1250	101.9	101.3	256.0	251.7	45.4	45.1	5.60	5.54
Metribuzin + clodinafop-propargyl	600	1250	101.9	100.9	268.0	259.3	45.1	44.9	5.64	5.59
Isoproturon	1333.3	-	100.5	100.7	257.0	235.3	44.7	43.2	5.35	5.41
Metribuzin	300	-	102.2	102.3	266.0	247.0	46.6	43.9	5.57	5.47
Clodinafop-propargyl	400	-	101.3	101.7	261.7	245.3	45.6	44.3	5.54	5.49
Mesosulfuron-methyl + idosulfuron-methyl sodium + surfactant	400	500	99.8	101.3	248.7	231.7	44.1	42.9	4.90	5.12
Sulfosulfuron + surfactant	33.3	1250	100.1	99.8	259.0	224.0	44.5	42.3	5.32	4.89
Hand weeding at 30 and 50 DAS	-	-	100.1	100.3	260.0	240.0	46.5	43.5	5.57	5.47
Untreated control	-	-	103.2	103.3	241.3	157.7	42.1	41.8	4.27	3.15
LSD (P=0.05)			NS	NS	14.4	29.4	2.3	1.3	0.06	0.09

400 g/ha, metribuzin at 300 g/ha and twice hand weeding at 30 and 50 days after sowing.Similiar trend was observed in case of dry matter accumulation in broad-leaved weeds at both the stages of observations *i.e.* at 30 and 60 DAS during 2010 and 2011.

Weed control efficiency

Among the herbicidal treatments, hundred per cent weed control efficiency of grassy and broad leaf weeds were recorded with application of metribuzin + clodinafop propargyl g/ha followed by its lower dose applied at 500 g/ha at 30 and 60 DAS, respectively. However lowest weed control efficiency was recorded with alone application of metribuzin at 300 g/ha at both the stages of observations *i.e.* at 30 and 60 DAS

Effect on crop

Unchecked weed growth reduced grain yield of wheat by 43% when compared with metribuzin + clodinafop-propargyl at 600 g/ha. Maximum yield (5.64 and 5.59 t/ha) was recorded from metribuzin + clodinafop-propargyl at 600 g/ha, which was followed by its lower dose at 500 g/ha (4.15 t/ha) and twice hand weeding at 30 and 50 DAS (5.60 and 5.54 kg/ha). Higher grain yield with metribuzin + clodinafop propargyl at 600 g/ha was due to more number of effective tillers and number of grains/ear.

Phytotoxicity

There was no phytotoxic effect of metribuzin + clodinafop-propargyl at 500 and 1000 g/ha on wheat crop.

Residual effect on succeeding crops

Residues of metribuzin + clodinafop-propargyl applied in wheat even at 500 and 1000 g/ha did not cause any adverse effect on crop growth and germination of succeeding maize crop.

On the basis of field study, it can be concluded that metribuzin + clodinafop-propargyl at 500 g/ha was found optimum dose in wheat for effective control of weeds and to attain higher grain yield of wheat without any phyto-toxicity to wheat or on maize, which were planted as succeeding crops after harvesting of wheat crop.

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Conservation tillage and weed management effect on soil microflora of soybean–wheat cropping system

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ABSTRACT

A field experiment was conducted during 2013-14 and 2014-15 at Jabalpur to assess the effect of conservation tillage and weed management practices on the total bacteria, fungi, actinomycetes and dehydrogenase activity under soybean - wheat cropping system in vertisols. The results of the investigation revealed that tillage systems to influence significantly the microbial population. Among the tillage treatments, zero tillage + crop residue (soybean) *fb* zero tillage + crop residue (wheat) had higher bacterial, fungal population and dehydrogenase activity during both the seasons. But actinomycetes population was higher in zero tillage + crop residue (soybean) *fb* zero tillage (wheat) during both seasons. However, there was no adverse effects of herbicides use in soybean-wheat cropping system on microbial population during both crop seasons except *Rabi* season 2014 -15 in which bacterial population was reduced by 27.3% when mesosulfuron (12 g/ha) + iodosulfuron (2.4 g/ha) mixture was applied in wheat following application of pendimethalin (750 g/ha) *fb* imazethapyr (100 g/ha) in preceding soybean crop.

Key words: Actinomycetes, Bacteria, Conservation tillage, Dehydrogenase activity, Fungi, Herbicide

Tillage systems influence physical, chemical and biological properties of soil and have a major impact on soil productivity and sustainability. It alter the organic matter content in soil, which ultimately affects the microbial population and their activity. Conventional tillage practices may adversely affect long–term soil productivity due to erosion and loss of organic matter in soil. Suitable soil management can be practiced through conservation tillage (including zero tillage), high crop residue return and crop rotation. In conservational - tilled farming, microbial biomass and diversity are usually greater under zero tillage or reduced tillage than under conventional tillage (Carpenter-Boggs et al. 2003). Weeds are one of the major biological constraints in conservation agriculture system. Weeds can be effectively controlled by tillage operations, which uproot and bury deep into the soil. Due to lack of tillage, weeds grow and flourish in CA. Weed control technology integrates preventive, cultural, mechanical, chemical and biological means, in which the use of herbicides is most important for weed management. The ultimate destination of herbicidal chemicals is the soil system where they come in contact with different micro flora which are responsible for different biochemical transformations related to mineral nutrition of plants. 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 population (Rajendran and Lourduraj 1999). The ill effects of herbicide on non-target organisms may reduce the performance of important and critical soil functions such as organic matter decomposition, nitrogen fixation and phosphate solubilization which support the soil health, plant growth and in turn crop productivity. Some herbicides may even stimulate the growth and activities of the soil microflora. Most of the studies which were focused on effects of single application of herbicides on soil microorganisms for a short period, may not provide a realistic evaluation of such effects in cyclic application of herbicides in different cropping systems. Therefore, knowledge of long term application of herbicides on soil microbes is highly essential. Hence, present investigation entitled influence of tillage and weed management practices on micro flora of soybean- wheat cropping system under conservation agriculture system was carried out.

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MATERIALS AND METHODS

A field experiment was conducted during 2013-14 and 2014-15 at DWR, Jabalpur (M.P.) to study the influence of tillage and weed management practices on soil microflora of soybean- wheat under conservation agriculture system. Five tillage as main plot treatments, consisting of conventional tillage in soybean - conventional tillage in wheat, conventional tillage in soybean - zero tillage in wheat, zero tillage + residue in soybean - zero tillage in wheat, zero tillage in soybean - zero tillage + residue in wheat, zero tillage + residue in soybean - zero tillage + residue in wheat and these were imposed with three sub plot treatments namely weedy check, pendimethalin 750g/ ha *fb* imazethapyr 100g/ha in soybean during *Kharif* and mesosulfuron 12 g/ha +iodosulfuron 2.4 g/ha in wheat during *Rabi*, metribuzin 0.5 kg/ha+1HW at 45DAS in soybean during *Kharif* and Clodinofop 60 g/ha + metsulfuron 4 g/ha in wheat during *Rabi* season.

Enumeration of microorganisms

The soil samples were collected from 0-15cm surface soil in all the plots at the time of harvest of soybean and wheat during *Kharif* and *Rabi* season respectively. The soil samples were soaked into 90 ml deionized water at the rate of 10 g, later this mixture was shaken for 10 minute and kept for 5 minute. Thereafter, 1ml of the supernatant was diluted twice and inoculated in the diluted water at the constant temperature of 30°C. All samples were performed in triplicate, and were used for enumeration of microorganisms. The viable microbial counts were analyzed by the standard technique of serial dilution and dour plating. Enumeration of bacteria and fungi was carried out in soil extract agar medium (James 1958) and Rose Bengal Agar medium (Parkinson *et al.* 1971). The Kenknight's Agar medium (Wellingtonn and Toth 1963) was used for enumeration of actinomycetes. After allowing for development of discrete microbial colonies during incubations under suitable conditions, the colonies were counted and the number of viable bacteria, fungi and actinomycetes [expressed as colony forming units (cfu)] per gram dry weight of soil was estimated by taking into account the soil dilutions.

Estimation of dehydrogenase activity

The method for the assay of dehydrogenase as developed by Casida *et al.* (1964) was used. This method is based on the reduction of 2,3,5-triphnyltetrazolium chloride (TTC) to triphenyl formazan (TPF). Each soil sample was treated with 0.1 g of CaCO3 and 1 ml of 0.18 mm aqueous solutions of TTC and incubated for 24 hours at 30oC. The TPF formed was extracted with methanol from the reaction mixture and assayed at 485 nm in spectrophotometer (UV- Thermoscientific).

RESULTS AND DISCUSSION

Effect of tillage

Different tillage systems appreciable influenced the soil microorganism (Table 1). The bacterial population was significantly higher in soybean and wheat rhizosphere (6.3 x 10^6 and 7.5 x 10^6 cfu/g), when zero tillage was done in both crop components in presence of residues of preceding crop during *Kharif* as well as *Rabi* season, followed by zero tillage in soybean–zero tillage in wheat in presence of residues of preceding crop, zero tillage in soybean in presence of residues of preceding crop – zero tillage in wheat and conventional tillage in soybean–zero tillage in wheat being the minimum under conventional tillage to both the crop components during first year. However, the bacterial population was increased significantly under former treatment during second year of experimentation in *Rabi* season 2014-15 and proved significantly superior over

Table 1. Effect of conservation tillage and weed management practices on bacterial population

Treatment		Bacteria (10^6 cfu/g dry weight of soil)			
		Kharif 2013	*Rabi* 2013-14	*Kharif* 2014	*Rabi* 2014-15
Tillage practices					
Kharif	*Rabi*				
CT	CT	4.4	6.7	15.2	14.6
CT	ZT	4.9	6.9	15.8	33.6
ZT + R	ZT	5.2	7.4	18.3	35.8
ZT	ZT + R	5.3	6.9	19.8	41.6
ZT + R	ZT + R	6.3	7.5	23.3	50.0
LSD(P=0.05)		1.3	NS	6.5	13.3
Weed management					
Weedy check	Weedy check	5.5	7.2	20.1	40.6
Pendimethalin 750g/ha *fb* imazethapyr 100g/ha	Mesosulfuron 12 g/ha + iodosulfuron 2.4 g/ha	5.1	6.9	17.5	29.5
Metribuzin 0.5kg/ha+1HW at 25DAS	Clodinofop 60 g/ha + metsulfuron 4 g/ha	5.2	7.2	17.8	35.2
LSD(P=0.05)		NS	NS	NS	8.8

conventional tillage to both soybean and wheat, conventional tillage in soybean – zero tillage in wheat and zero tillage in soybean in presence of residues of preceding crop – zero tillage in wheat but at par to zero tillage in soybean – zero tillage in wheat in presence of residues of preceding crop. Higher bacterial population under zero tillage in both the crop components in presence of residues of preceding crop during *Kharif* (soybean) and *Rabi* (wheat) crops, caused more accumulation of organic matter on the soil surface and as a consequence increased the abundance of microbial population particularly bacteria (Mathew 2012). On the contrary, reverse was true in case of conventional tillage to both crop components (soybean – wheat) during both the years because conventional tillage was done in both the crops without any crop residues of previous crops and whatever the quantity of crop residues left over after harvesting of the preceding crop, was incorporated in the soil during tillage and later decomposed by the organism. There after, the bacterial population was less under conventional tillage to both the crop components (Younesabadi *et al.* 2014).

Similar trend was observed in case of fungal population during both the years (Table 2). The actinomycetes population was significantly higher in soybean and wheat rhizosphere when zero tillage was done in both the crop components in presence of residues of preceding crop during *Kharif* season only followed by zero tillage in soybean in presence of residue of preceding – zero tillage in wheat in presence of residue of preceding crop , zero tillage in soybean–zero tillage in wheat in presence of residues preceding crop being the minimum under conventional tillage to both the crop components during first year of field experimentation closely followed by conventional tillage in soybean-zero tillage in wheat (Table 3). However, actinomycetes population was increased significantly under former treatment during second year of experimentation in *Rabi* season 2014-15 and proved significantly superior over conventional tillage to both soybean and wheat and conventional tillage in soybean – zero tillage in wheat but at par to zero tillage in soybean in presence of residues of preceding crop – zero tillage in soybean in presence of residues of preceding crop in wheat and zero tillage – zero tillage in wheat in presence of residues of preceding crop. Higher actinomycetes population under zero tillage in both crop component in presence of residues of preceding crop in soybean or wheat and in both crops caused accumulation of organic matter, which increased soil aeration, cooler and wetter condition and higher carbon content in soil surface. Thus, inch up the population of actinomycetes. Minimum actinomycetes population was recorded in case of conventional tillage to both crop components (Soybean – wheat) during both the years. Similar observations were also made by Younesabadi *et al.* (2014) and Govindan and Chinnusamy (2014).

Higher dehydrogenase activity was observed when zero tillage was done in both crop components in presence of residues of preceding crop during *Kharif* as well as *Rabi* season, followed by zero tillage in soybean in presence of residues preceding crop – zero tillage in wheat , zero tillage in soybean – zero tillage in wheat in presence of residue of preceding crop, and conventional tillage in soybean – zero tillage in wheat being the minimum under conventional tillage to both the crop components during first year of field experimentation (Table 4).

Table 2. Effect of connservation tillage and weed management practices on fungal population

Treatment		Fungi (10^4 cfu /g dry weight of soil)			
		Kharif 2013	*Rabi* 2013-14	*Kharif* 2014	*Rabi* 2014-15
Tillage practices					
Kharif	*Rabi*				
CT	CT	3.1	4.0	4.8	8.9
CT	ZT	4.0	4.3	6.8	9.1
ZT + R	ZT	4.2	4.3	9.3	11.0
ZT	ZT + R	4.3	4.4	12.3	15.1
ZT + R	ZT + R	4.4	4.7	18.3	15.9
LSD(P=0.05)		NS	0.2	0.6	1.7
Weed management					
Weedy check		4.2	4.4	11.1	13.3
Pendimethalin 750g/ha *fb* imazethapyr 100g/ha	Mesosulfuron 12 g/ha +iodosulfuron 2.4 g/ha	3.8	4.3	9.5	12.7
Metribuzin 0.5 kg/ha+1 HW at 25DAS	Clodinofop 60 g/ha + metsulfuron 4 g/ha	4.1	4.3	10.3	9.9
LSD(P=0.05)		NS	NS	NS	NS

Table 3. Effect of conservation tillage and weed management practices on actinomycetes population

Treatment		Actinomycetes (10^3 cfu /g dry weight of soil)			
		Kharif 2013	*Rabi* 2013-14	*Kharif* 2014	*Rabi* 2014-15
Tillage practices					
Kharif	*Rabi*				
CT	CT	3.4	4.5	7.2	14.1
CT	ZT	3.7	5.5	9.9	17.0
ZT + R	ZT	4.0	5.7	13.6	39.4
ZT	ZT + R	3.7	5.5	10.8	32.7
ZT + R	ZT + R	3.7	5.5	11.9	33.2
LSD(P=0.05)		NS	0.8	4.3	8.5
Weed management					
Weedy check	Weedy check	3.8	5.3	11.1	28.7
Pendimethalin 750 g/ha *fb* imazethapyr 100 g/ha	Mesosulfuron 12 g/ha +iodosulfuron 2.4 g/ha	3.5	5.4	10.2	25.4
Metribuzin 0.5 kg/ha+1HW at 25DAS	Clodinofop 60 g/ha + metsulfuron 4 g/ha	3.7	5.4	10.7	27.7
LSD(P=0.05)		NS	NS	NS	NS

Table 4. Effect of conservation tillage and weed management practices on dehydrogenase activity

Treatment		Dehydrogenase activity (µg TPF/g soil/24 hr)			
		Kharif 2013	*Rabi* 2013-14	*Kharif* 2014	*Rabi* 2014-15
Tillage practices					
Kharif	*Rabi*				
CT	CT	22.5	22.5	26.8	31.1
CT	ZT	24.3	26.6	29.7	31.4
ZT + R	ZT	24.3	31.2	31.3	35.5
ZT	ZT + R	25.9	34.5	29.8	34.2
ZT + R	ZT + R	26.1	35.3	32.3	36.7
LSD(P=0.05)		1.8	4.04	2.5	5.2
Weed management					
Weedy check	Weedy check	24.8	29.1	30.7	34.7
Pendimethalin 750 g/ha *fb* imazethapyr 100 g/ha	Mesosulfuron 12 g/ha + iodosulfuron 2.4 g/ha	24.8	29.7	28.9	32.5
Metribuzin 0.5 kg/ha+1HW at 25DAS	Clodinofop 60 g/ha + metsulfuron 4 g/ha	24.2	31.4	30.3	34.1
LSD(P=0.05)		NS	NS	NS	NS

But dehydrogenase activity was increased identically, during second year of experimentation during *Rabi* season 2014-15 being the maximum under the former treatment and proved significantly superior over conventional tillage to both soybean and wheat and conventional tillage in soybean–zero tillage in wheat but at par to zero tillage in soybean in presence of residues of preceding crop–zero tillage in wheat and zero tillage in soybean–zero tillage in wheat in presence of residues of preceding crop. Kladivko (2001) stated that most of the classes of organisms showed higher presence of their biomass in non-treated soil (conservation tillage) than treated (conventional tillage).

Weed management practices

Weed management practices did not affect the soil microbial population (bacteria, fungi and actenomycetes) and dehydrogenase activity significantly during the both years except *Rabi* 2014-15 in which bacterial population was reduced by 27.3% when mesosulfuron (12 g/ha) + iodosulfuron (2.4 g/ha) mixture was applied in wheat following application of pendimethalin (750g/ha) *fb* imazethapyr (100g/ha) in preceding soybean crop. This is because of abundance of herbicides (mixture of mesosulfuron and iodosulfuron) on the soil surface due to slow rate of degradation on account of lower values of maximum and minimum temperature during *Rabi* 2014-15 over mean maximum and minimum

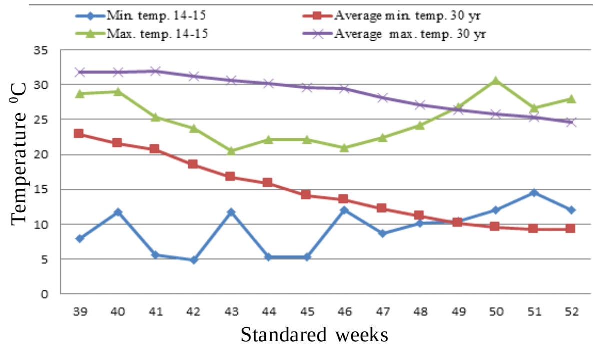

Fig. 1. Relative minimum and maximum temperature during *Rabi* 2014-15

temperature of 30 years. As a consequence the bacterial population was less during Rabi season 2014-15 (Fig. 1). Rajendran and Lourduraj (1999) also made similar observation. Numerically higher soil microbial population and dehydrogenase activity under weedy check plot was attributed to large increase in microbial biomass, as it is positive by correlated with weed biomass because of high decomposability (Wardle *et al.* 1999).

It was concluded that soil microbial population and dehydrogenase activity were significantly higher when zero tillage was done in both soybean and wheat in presence of residues of preceding crop. Weed management practices involving herbicide in soybean – wheat cropping did not reduce the population of soil microorganism and dehydrogenase activity except bacteria, which population was reduced during *Rabi* 2014-15 due to lower values of temperature (maximum and minimum) over temperature of 30 years. Similarly weed management practice involving pre-emergence application of metribuzin (0.5 kg/ha) + 1 HW in soybean and post-emergence application of clodinofop (60 g/ha) + metsulfuron (4 g/ha) mixture to wheat was found safe for soil microorganism and dehydrogenase activity.

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Influence of pinoxaden in combination with other herbicides on nutrient depletion by weeds in wheat

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ABSTRACT

Pinoxaden 50 g/ha alone and as tank mixture with and before metsulfuron-methyl 4 g/ha, carfentrazone ethyl 20 g/ha and 2, 4-D 500 g/ha was compared to isoproturon + 2, 4-D, clodinafop *fb* 2, 4-D, weed free and weedy check for nutrient depletion by weeds and wheat. *Phalaris minor* and *Anagallis arvensis* were the major weeds constituting 60.8 and 21.4% of total weed population, respectively. Pinoxaden *fb* metsulfuron-methyl (50 *fb* 4 g/ha) remaining at par with pinoxaden + metsulfuron-methyl (50 + 4 g/ha) and pinoxaden + 2,4-D (50 + 500 g/ha) resulted in significantly lower total weed dry weight over rest of the herbicidal treatments. Pinoxaden + metsulfuron-methyl (50 + 4 g/ha) and pinoxaden *fb* metsulfuron-methyl (50 *fb* 4 g/ha) were as effective as weed free in reducing N, P and K uptake by weeds. Weeds in weedy check removed 37.4 kg/ha N, 6.9 kg/ha P and 46.8 kg/ha K. Weed free remaining at par with pinoxaden + metsulfuron-methyl (50 + 4 g/ha), pinoxaden *fb* metsulfuron-methyl (50 *fb* 4 g/ha) and pinoxaden *fb* 2, 4-D (50 *fb* 500 g/ha) resulted in significantly higher wheat dry matter accumulation over rest of the treatments. Weed free gave highest grain yield. However, pinoxaden + metsulfuron-methyl (50 + 4 g/ha), pinoxaden (50 g/ha), pinoxaden + carfentrazone-ethyl (50 + 20 g/ha), pinoxaden *fb* metsulfuron-methyl (50 *fb* 4 g/ha), isoproturon + 2, 4-D (1250 + 500 g/ha), clodinafop *fb* 2, 4-D (60 *fb* 1000 g/ha), pinoxaden + 2, 4-D (50 + 500 g/ha), pinoxaden *fb* carfentrazone-ethyl (50 *fb* 20 g/ha) and pinoxaden *fb* 2, 4-D (50 *fb* 500 g/ha) were as good as weed free.

Key words: 2,4-D, Carfentrazone, Metsulfuron-methyl, Nutrient uptake, Pinoxaden, Weeds, Wheat

Among different production factors, weeds pose serious threat to the productivity of wheat. They compete with crop plants for light, water and nutrients. Isoproturon is nationwide recommended herbicide in wheat. However, continuous reliance on isoproturon resulted in a heavy build-up of *Phalaris minor* (Malik and Singh 1995). Clodinafop was recommended as alternate herbicide against isoproturon resistant *Phalaris minor* in 1998-99. But cross resistance of these herbicides (Dhawan *et al.* 2009) necessitating the search for new herbicide molecules. Pinoxaden is new herbicide belonging to phenyl pyrazolin group with acetyl-COA-carboxylase (ACCase) inhibiting action (Hoffer *et al.* 2006). It is a selective grass killer with foliar action. Since grass killers don't control the broad-leaved weeds, the present study was conducted to evaluate pinoxaden in combination with broad-leaf herbicides such as metsulfuron-methyl, carfentrazone and 2,4-D to reduce nutrient depletion by weeds and increase by wheat under mid hill conditions of Himachal Pradesh.

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MATERIALS AND METHODS

Wheat variety '*HPW 155*' was sown during the first fortnight of November for two consecutive years (2010-11 and 2011-12) with recommended package of practices except weed control. Fifteen weed control treatments, *viz*. pinoxaden (50 g/ha), metsulfuron methyl (4 g/ha), carfentrazone-ethyl (20 g/ha) and 2, 4-D (500 g/ha) alone, pinoxaden (50 g/ha) with and before carfentrazone-ethyl (20 g/ha), metsulfuron-methyl (4 g/ha) and 2, 4-D (500 g/ha), isoproturon + 2, 4-D (1250 + 500 g/ha), clodinafop *fb* 2, 4-D (60 *fb* 1000 g/ha), mesosulfuron + iodosulfuron (13 + 5 g/ha), weed free and weedy check were tested in randomized block design with 3 replications. All herbicides alone and as combination were applied as post-emergence at 28-35 DAS as per treatment with knapsack power sprayer using 750 L water per hectare. Application of the second herbicide was made two days after the first. The soil of experimental field was silty clay loam in texture, acidic in reaction, medium in available nitrogen (323 kg/ha) and high in phosphorus (26 kg/ha) and available potassium (276.4 kg/ha). Observations on weed density and biomass were recorded at 60, 90, 120 and 150 DAS and at harvest using quadrat of 0.5 x 0.5 m, placed at two random spots in each plot. Weed density and biomass data showed variation and were subjected to square root transformation ($\sqrt{(x+1)}$). Wheat grain yield and yield attributes were recorded at maturity. The crop was harvested in the first fortnight of May 2010 and 2011. Weed control efficiency or weed control index was worked out based on weed population or weed dry weight as per the formula outlined by Mani *et al*. (1973) and Mishra and Tosh (1979), respectively.

RESULTS AND DISCUSSION

Effect on weeds

Phalaris minor and *Anagallis arvensis* were the major weeds constituting 60.8 and 21.4% of total weed population, respectively. *Avena ludoviciana*, *Lolium temulentum* and *Poa annua* constituted 4.7, 3.6 and 3.0% of total weed population, respectively. The other weeds showed their little infestation but as a whole constituted 6.5% of the total weed flora.

Dry matter accumulation increased consistently up to 150 DAS, thereafter it declined gradually. The decline in weed dry weight was owed to withering of weeds (Fig. 1). Weed control treatments significantly decreased total weed dry weight as compared to weedy check (Table 1). Removing the weeds whenever they appear under the weed free treatment resulted in complete elimination of weed competition as it resulted in lowest total weed dry weight. Pinoxaden *fb* metsulfuron-methyl (50 *fb* 4 g/ha) remaining at par with pinoxaden + metsulfuron-methyl (50 + 4 g/ha) and pinoxaden + 2,4-D (50 + 500 g/ha) resulted in significantly lower total weed dry weight over rest of the herbicidal treatments. The superiority of pinoxaden + metsulfuron methyl in controlling weeds has been reported by (Kumar *et al.* 2010). Pinoxaden + carfentrazone-ethyl (50 + 20 g/ha), pinoxaden *fb* carfentrazone-ethyl (50 *fb* 20 g/ha), pinoxaden *fb* 2,4-D (50 *fb* 500 g/ha), mesosulfuron + iodosulfuron (13 + 5 g/ha), isoproturon + 2, 4-D (1250 + 500 g/ha), clodinafop *fb* 2, 4-D (60 *fb* 1000 g/ha) behaving statistically alike were the next better treatments. Owing to synergetic enhancement or additive effects, herbicidal combinations in general were better than sole application of herbicides in effectively reducing the total weed dry weight.

Weed control treatments significantly influenced the GR_w and RGR_w (Table 1). All treatments except 2, 4-D (500 g/ha) had significantly lower GR_w over weedy check. All the herbicide combinations and pinoxaden (50 g/ha) were comparable to weed free in reducing the GR_w between 90-120 DAS. Sole application of metsulfuron-methyl (4 g/ha) and carfentrazone-ethyl (20 g/ha) were less effective in influencing GR_w, though the former was superior to the later. Relative growth rate of weeds was not significantly curtailed by any of the treatments

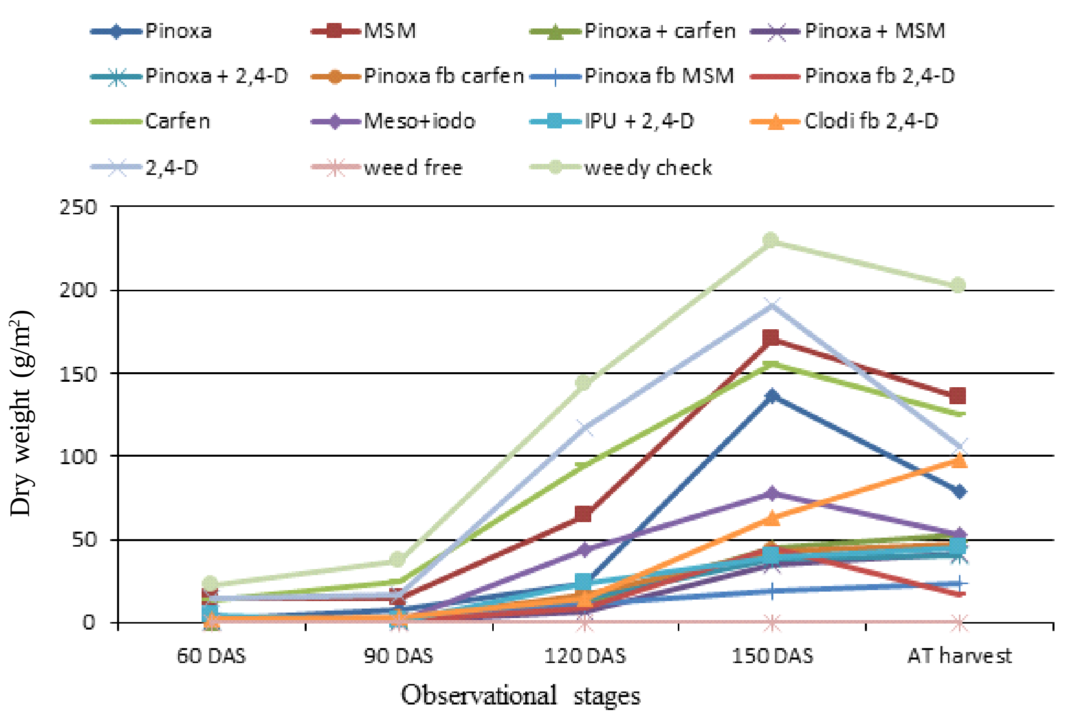

Fig. 1 Effect of weed control treatments on total weed dry matter accumulation

Table 1. Effect of weed control treatments on total weed count, total weed dry matter accumulation and weed growth analysis

Treatment	Dose (g/ha)	Weed count (90 DAS)	Weed weight (g/m^2) (150 DAS)	WCE (%)	WCI (%)	GR_w (g/m^2/day) (90-120 DAS)	RGR_w (g/g/day) (90-120 DAS)
Pinoxaden	50	10.8 (116.0)	11.6 (136.3)	69.4	49.2	0.528	0.043
Metsulfuron-methyl	4	13.8 (193.3)	13.0 (169.6)	54.4	28.0	1.635	0.048
Pinoxaden + carfentrazone-ethyl	50 + 20	6.3 (38.7)	6.7 (44.4)	91.2	77.0	0.320	0.077
Pinoxaden + metsulfuron methyl	50 + 4	3.2 (9.3)	4.3 (18.4)	95.5	82.1	0.210	0.072
Pinoxaden + 2,4-D	50 + 500	6.5 (41.3)	5.8 (37.6)	90.1	81.6	0.456	0.118
Pinoxaden *fb* carfentrazone-ethyl	50 *fb* 20	5.5 (30.7)	6.5 (42.5)	92.6	78.7	0.458	0.054
Pinoxaden *fb* metsulfuron-methyl	50 *fb* 4	4.9 (24.0)	4.8 (23.4)	93.5	89.7	0.366	0.096
Pinoxaden *fb* 2, 4-D	50 *fb* 500	6.5 (44.0)	6.5 (44.7)	90.0	85.6	0.248	0.073
Carfentrazone-ethyl	20	14.8 (222.7)	12.4 (155.0)	48.2	33.8	2.364	0.045
Mesosulfuron + iodosulfuron	13 + 5	7.6 (57.3)	8.7 (77.2)	87.2	69.2	1.402	0.143
Isoproturon + 2,4-D	1250 + 500	5.8 (34.7)	6.3 (39.6)	90.6	77.0	0.751	0.140
Clodinafop *fb* 2,4-D	60 *fb* 1000	7.2 (50.7)	8.0 (63.2)	89.3	44.8	0.374	0.077
2,4-D	500	12.4 (156.0)	13.8 (190.0)	64.4	26.9	3.338	0.067
Weed free		1.0 (0.0)	1.0 (0.0)	100.0	100.0	0.000	0.000
Weedy check		21.0 (445.3)	15.1 (228.8)	0.0	0.0	3.526	0.046
LSD		2.2	2.5	-	-	0.967	0.068

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

compared to weedy check. Pinoxaden + 2,4-D (50 + 500 g/ha), mesosulfuron + iodosulfuron (13 + 5 g/ha) and isoproturon + 2,4-D (1250 + 500 g/ha) resulted in significantly higher RGR_w between 90-120 DAS over other treatments.

Because of species-wise better control of weeds under the herbicide mixtures or sequence application, weed control efficiency or index under them was comparable to weed free. Application of herbicide alone gave poor control of weeds, therefore had lower weed control efficiency and weed control index. These results are in close conformity with findings of Yadav *et al*. (2009) and Chopra and Chopra (2005).

Effect on crop

Dry matter accumulation increased consistently with the advancement of crop growth. The rate of increase was lowest from 30-60 DAS. Then it increased consistently up to harvest. Wheat crop accumulated 1.3, 5.3, 26.0, 64.9 and 87.0% of total dry matter accumulation up to 30, 60, 90, 120 and 150 DAS, respectively.

Weed free remaining at par with pinoxaden + metsulfuron methyl (50 + 4 g/ha), pinoxaden *fb* metsulfuron methyl (50 *fb* 4 g/ha) and pinoxaden *fb* 2, 4-D (50 *fb* 500 g/ha) resulted in significantly higher dry matter accumulation over rest of the treatment (Table 2). The reduction in population and dry weight of weeds under these treatments and higher weed control efficiency/index created favourable micro-environment for growth and development of wheat crop and thus increased the dry matter accumulation of wheat. Data pertaining to crop growth rate (CGR) and relative growth rate (RGR) of wheat crop have been embodied in Table 2. Weed control treatments did not significantly influence the CGR and RGR of wheat. This showed that rate of growth of wheat remained unaffected irrespective to variation in population and dry weight of weeds.

All treatments were significantly superior to weedy check in increasing grain yield of wheat (Table 2). Weed free gave highest grain yield. However, pinoxaden + metsulfuron-methyl (50 + 4 g/ha), pinoxaden (50 g/ha), pinoxaden + carfentrazone-ethyl (50 + 20 g/ha), pinoxaden *fb* metsulfuron methyl (50 *fb* 4 g/ha), isoproturon + 2,4-D (1250 + 500 g/ha), clodinafop *fb* 2,4-D (60 *fb* 1000 g/ha), pinoxaden + 2, 4-D (50 + 500 g/ha), pinoxaden *fb* carfentrazone-ethyl (50 *fb* 20 g/ha) and pinoxaden *fb* 2,4-D (50 *fb* 500 g/ha) were as good as weed free. 2,4-D (500 g/ha), metsulfuron-methyl (4 g/ha), carfentrazone-ethyl (20 g/ha) and mesosulfuron + iodosulfuron (13 + 5 g/ha) being statistically at par were less effective in influencing grain yield of wheat. As indicated by weed index, un-interrupted growth of weeds in the weedy check reduced wheat yield by 39.5% over weed free.

All the weed control treatments significantly increased the N, P and K uptake by wheat over weedy check. Because of the higher grain and straw yield, weed free remaining at par with pinoxaden + metsulfuron-methyl (50 + 4 g/ha), pinoxaden +

Table 2. Effect of weed control treatments on total crop dry matter accumulation (g/m^2) and crop growth analysis

Treatment	Dose (g/ha)	Crop dry matter (At harvest)	CGR (g/m^2/day) (90-120 DAS)	RGRc (g/g/day) (60-90 DAS)	Grain yield (t/ha)		WI (%)
					2010-11	2011-12	
Pinoxaden	50	1073.8	12.62	0.059	3.68	3.55	6.8
Metsulfuron methyl	4	929.4	12.10	0.053	3.16	3.07	19.9
Pinoxaden + carfentrazone-ethyl	50 + 20	1051.0	14.71	0.044	3.70	3.66	5.2
Pinoxaden + metsulfuron-methyl	50 + 4	1078.0	14.09	0.058	3.84	3.81	1.6
Pinoxaden + 2, 4-D	50 + 500	1056.4	13.26	0.054	3.67	3.60	6.5
Pinoxaden *fb* carfentrazone-ethyl	50 *fb* 20	1062.0	13.34	0.052	3.59	3.50	8.8
Pinoxaden *fb* metsulfuron-methyl	50 *fb* 4	1088.4	13.30	0.056	3.74	3.76	3.5
Pinoxaden *fb* 2, 4-D	50 *fb* 500	1052.3	12.24	0.056	3.52	3.45	10.3
Carfentrazone-ethyl	20	942.9	12.69	0.052	3.07	3.16	19.9
Mesosulfuron + iodosulfuron	13 + 5	963.5	14.09	0.053	3.39	3.40	12.6
Isoproturon + 2, 4-D	1250 + 500	994.4	12.89	0.055	3.60	3.61	7.2
Clodinafop *fb* 2, 4-D	60 *fb* 1000	1036.4	14.62	0.051	3.57	3.54	8.4
2, 4-D	500	938.9	11.73	0.048	3.05	2.99	22.2
Weed free		1095.8	13.06	0.053	3.86	3.90	0.0
Weedy check		715.5	10.93	0.046	2.43	2.26	39.5
LSD		34.2	NS	NS	0.43	0.46	-

Table 3. Effect of weed control treatments on N, P and K uptake (kg/ha) by total weeds at harvest

Treatment	Dose (g/ha)	Weeds			Crop		
		N	P	K	N	P	K
Pinoxaden	50	14.9	2.7	18.3	115.9	21.3	86.1
Metsulfuron-methyl	4	25.1	4.6	31.1	98.4	17.1	74.6
Pinoxaden + carfentrazone-ethyl	50 + 20	7.9	1.4	9.8	115.1	21.1	84.5
Pinoxaden + metsulfuron-methyl	50 + 4	4.4	0.8	5.7	118.9	21.8	86.6
Pinoxaden + 2,4-D	50 + 500	5.6	1.0	7.0	114.5	20.8	84.8
Pinoxaden *fb* carfentrazone-ethyl	50 *fb* 20	8.1	1.5	10.1	113.5	20.1	85.5
Pinoxaden *fb* metsulfuron-methyl	50 *fb* 4	4.6	0.9	5.8	117.6	20.6	87.9
Pinoxaden *fb* 2,4-D	50 *fb* 500	5.7	1.1	7.0	111.9	20.1	83.9
Carfentrazone-ethyl	20	22.8	4.1	29.1	98.3	16.7	76.1
Mesosulfuron + iodosulfuron	13 + 5	9.4	1.7	11.9	105.0	19.3	76.9
Isoproturon + 2,4-D	1250 + 500	7.4	1.4	9.2	107.4	19.5	77.8
Clodinafop *fb* 2,4-D	60 *fb* 1000	15.2	2.9	18.9	110.7	20.7	82.6
2,4-D	500	19.5	3.6	24.6	97.2	16.7	75.8
Weed free		0.0	0.0	0.0	120.5	22.1	87.8
Weedy check		37.4	6.9	46.8	76.4	13.1	59.1
LSD		5.4	1.1	6.7	11.9	2.4	8.7

carfentrazone-ethyl (50 + 20 g/ha), pinoxaden + 2, 4-D (50 + 500 g/ha), pinoxaden *fb* metsulfuron methyl (50 *fb* 4 g/ha) pinoxaden *fb* carfentrazone-ethyl (50 *fb* 20 g/ha) pinoxaden *fb* 2,4-D (50 *fb* 500 g/ha) and pinoxaden (50 g/ha) alone resulted in significantly higher N, P and K uptake by crop. 2,4-D (500 g/ha), metsulfuron-methyl (4 g/ha), isoproturon + 2,4-D (1250 + 500 g/ha), carfentrazone-ethyl (20 g/ha) and mesosulfuron + iodosulfuron (13 + 5 g/ha) were less effective in influencing N, P and K uptake over other treatments (Table 3). In general, all herbicide combinations were superior to alone application of herbicides in improving the N, P and K uptake by crop. The superiority of herbicide combinations in influencing N, P and K uptake by crop has been documented (Khokhar and Nepalia 2010). Weed free resulted in 57.72, 68.70 and 48.56% higher N, P and K uptake over weedy check, respectively.

Nutrient uptake is the function of dry matter and nutrient content. Higher dry matter accumulation by wheat with application of pinoxaden + metsulfuron-methyl (50 + 4 g/ha) may be attributed to higher root spread and penetration in soil due to weed free environment. Also, lower N, P and K removal by weeds allowed wheat to grow vigorously and accumulate more biomass, which consequently led to higher uptake of these nutrients (Kumar and Das 2008). Higher dry matter accumulation by wheat under herbicidal treatments increased the nutrient uptake (Brar and Walia 2008).

The present investigation conclusively inferred that combined application of pinoxaden and metsulfuron-methyl/carfentrazone/2,4-D either as tank mixed or sequential is the better alternative to isoproturon + 2,4-D or clodinafop *fb* 2,4-D in reducing nutrient uptake by weeds and increasing it by wheat.

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Control of weeds in canola gobhi sarson cultivars and their tolerance to herbicides

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ABSTRACT

A field study was carried out at the Punjab Agricultural University, Ludhiana for two seasons to study the weed control in three canola gobhi sarson cutlivars and tolerance of these cultivars to different herbicides. Three canola gobhi sarson cultivars '*GSC 5*', '*GSC 6*' and '*Hyola PAC 401*' in main plots and five weed control treatments -fluchloralin at 0.75 and 1.5 kg and trifluralin at 0.75 and 1.5 kg/ha and hand weedings in sub-plots were evaluated in a split plot design. Fluchloralin and trifluralin at 0.75 and 1.5 kg/ha recorded effective control of annual weeds and recorded canola seed yield similar to hand weeded control. All the three cultivars of canola gobhi sarson tolerated both the herbicides at 0.75 and 1.5 kg/ha. The study indicated that fluchloralin and trifluralin could safely be used to control weeds in canola gobhi sarson cultivars '*GSC 5*', '*GSC 6*' and '*Hyola PAC 401*'.

Key words: Canola, Cultivars, Fluchloralin, Trifluralin, Weed Control

Gobhi sarson (*Brassica napus* L.) is the third most important oilseed crop in the world, after soybean and palm oil. In India also, it is one of the main oil producing crops among rapeseed and mustards. Gobhi sarson plants are very sensitive to weed competition during the initial stages of growth and weed suppression by shading only begins after the canopy has grown over the rows and covered the field. Gill *et al.* (1984) reported that yield losses due to weeds vary from 30-50%, weeds also reduce oil quality and market value. Isoproturon, fluchloralin and trifluralin have been used for controlling weeds in traditional gobhi sarson cultivars GSL 1 and GSL 2 in Punjab. Canola is a registered trade mark of Canadian Oil Association which denotes the seeds having less than 2% erucic acid in its oil and less than 30 micro-moles of glucosinolate per gram of its deoiled meal. Canola oil has the lowest level of saturated and highest level of mono and poly unsaturated fatty acids which are nutritionally desirable for human health. Recently, three canola gobhi sarson cultivars *viz.* '*GSC 5*', '*GSC 6*' and '*Hyola PAC 401*', have been recommended for cultivation under irrigated conditions in Punjab. Yield losses in canola due to weeds vary form 20-30% (Saeed *et al.* 2011). Weeds reduced canola seed quality by increasing the level of erucic acid in the extracted oil and increasing the glucosinolates content of the remaining meal (Rose and Bell 1982).

Canola cultivars are genetically different from the traditional cultivars of gobhi sarson, and may have differential weed smothering potential and tolerance to herbicides. In the absence of any information on the tolerance of these new canola cultivars to herbicides, the weeds are controlled by manual weedings, which is uneconomical and time consuming. Hugh *et al.* (2008) revealed that yellow mustard was best able to suppress weed growth, followed in decreasing order of weed competitiveness by oriental mustard and hybrid canola, open-pollinated canola, and canola quality mustard. Roshdy *et al.* (2008) recorded significant interaction between canola varieties and weed control treatments with regard to weed control and seed yield. Weeds are needed to be removed by the four leaf stage of the crop (17–38 days after emergence) to prevent more than 10% yield loss due to weed interference in spring canola (Martin *et al.* 2001). Pre-emergence herbicides are more effective than post-emergence or manual control methods (Rapparini 1996). Triflrualin recorded effective control of weeds in canola gobhi sarson (Khan *et al.* 2008). In the present study, weed smothering potential and tolerance of three canola cultivars '*GSC 5*', '*GSC 6*' and '*Hyola PAC 401*' to fluchoralin and trifluralin was evaluated.

MATERIALS AND METHODS

A field experiment was conducted at Punjab Agricultural University Ludhiana during winter seasons of 2006-07 and 2007-08. Ludhiana is situated in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangetic Alluvial plain at 30° 56' N latitude,

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75° 52' E longitude and at an altitude of 247 m above mean sea level. The maximum temperature above 38 °C is common during summer and frequent frosty spells are experienced during winters, especially in December and January. The experimental soil was loamy sand with pH 7.43 and EC 0.22 dS/m and it was low in organic carbon and available nitrogen (170 kg/ha) and medium in available phosphorus (20.5 kg/ha) and available potassium (185 kg/ha). The experimental design was split-plot with four replications. Three canola gobhi sarson cultivars (‘*GSC 5*’, ‘*GSC 6*’ and ‘*Hyola PAC 401*’) were assigned to main plots and the five weed control treatments (fluchloralin and trifluralin each at 0.75 and 1.5 kg/ha and hand weeded control) in sub-plots.

The crop was sown manually using 3.75 kg seed/ha in 45 cm spaced rows in third week of October during first year and in the first week of November during second year. The herbicides were applied before sowing and incorporated in the soil. Two hand weeding were done at 20 and 40 days after sowing (DAS) in hand weeded control treatment. The crop emergence was recorded 15 DAS. Weed population and weed dry matter accumulation was recorded at 60 DAS by using 50 x 50 cm quadrat from each plot. The samples were sun dried and then oven dried at 65 °C. The data on crop growth, yield attributes and seed yield was recorded at harvest in April. Benefit-cost ratio was calculated by dividing gross returns with variable cost of cultivation. The data were statistically analyzed by using statistical procedures as prescribed by Cochran and Cox (1967). The comparisons were made at 5 per cent level of significance.

RESULTS AND DISCUSSION

The major weed flora in the experimental field included *Phalaris minor, Rumex dentatus, Medicago denticulata, Coronopus didymus* and *Chenopodium album* (Table 1). All the three cultivars recorded similar weed count and dry matter indicating similar weed smothering potential, though ‘*Hyola PAC 401*’ plants were significantly taller than ‘*GSC 5*’ and‘*GSC 6*’, but it did not reflect in higher smothering of weeds. During first season, trifluralin and fluchloralin at both the levels recorded significantly lower polulation of *P. minor R. dentatus* and *M. denticulata* as compared to hand weeded control. Population of weeds was similar under herbicidal and hand weeded treatments during the second year. *C. didymus* was similar under herbicidal and hand weeded treatments during first year while hand weeded control was superior to herbicidal treatments during the second year. Intensity of *C. album* was similar among herbicidal and hand weeded control. The weed dry matter varied significantly among weed control treatments during first years only. The higher doses of herbicides significant reduced the weed dry matter as compared to their respective lower doses and hand weeded control; lower does were at par with hand weeded control (Table 2) The higher population of weeds in hand weeded plots was due to string trimming of the soil and they germinated in more number which increased the population as compared to herbicidal treatments during the first year; during the second year, the weed population was low as compared to first year and hence it was similar among all the weed control treatments. Higher

Table 1. Effect of canola cultivars and weed control treatments on weed population at 60 days after sowing

Treatment	Weed population/m^2								
	P. minor		*R. dentatus*		*C. didymus*		*M. denticulata*		*C. album*
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08	2007-08
Canola cultivars									
GSC 5	6.1	2.8 (8)	5.5	1.2 (1)	18.9	2.4 (6)	5.0	1.5 (2)	2.4 (5)
GSC 6	6.2	3.3 (11)	7.9	1.1 (0)	32.8	2.7 (8)	6.3	2.0 (4)	2.4 (5)
Hyola PAC 401	7.9	3.3 (10)	7.4	1.9 (1)	27.3	2.7 (8)	8.3	1.9 (4)	2.5 (5)
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed control									
Fluchloralin 0.75 kg/ha	3.3	2.9 (8)	4.0	1.1 (0)	35.9	2.8 (7)	5.6	1.7 (3)	2.2 (4)
Fluchloralin 1.5 kg/ha	3.8	3.2 (9)	4.2	1.1 (0)	27.8	3.2 (9)	3.1	2.1 (4)	2.7 (6)
Trifluralin 0.75 kg/ha	4.4	2.9 (8)	5.1	1.1 (0)	26.0	3.2 (10)	5.1	1.9 (4)	2.4 (5)
Trifluralin 1.5 kg/ha	5.1	2.8 (7)	6.4	1.0 (0)	22.4	3.4 (10)	4.2	1.7 (3)	2.5 (5)
Two hand weedings (20 and 40 DAS)	24.4	2.1 (4)	22.9	1.4 (1)	25.6	1.8 (3)	19.3	1.7 (2)	2.3 (5)
LSD (P=0.05)	4.0	0.7	4.3	NS	7.5	0.8	2.7	NS	NS

Figures in parentheses are means of original values. Data subjected to square root (x + 1) transformation

Table 2. Effect of herbicides on weeds, growth and seed yield of canola type of gobhi sarson

Treatment	Weed dry matter (g/m^2) at 60 DAS		Plant height at harvest (cm)		Number of branches/ plant	Number of siliqua/ plant	Canola seed yield (t/ha)		B:C ratio (mean of two years)
	2006-07	2007-08	2006-07	2007-08	2006-07	2006-07	2006-07	2007-08	
Canola cultivars									
GSC 5	22.0	30.1	125.7	95.6	5.5	214.8	1.26	1.60	1.4
GSC 6	24.4	32.2	130.9	95.6	5.4	215.3	1.38	1.79	1.5
Hyola PAC 401	24.4	28.0	143.3	126.1	6.8	222.1	1.61	1.96	1.8
LSD (P=0.05)	NS	NS	6.5	4.7	NS	NS	NS	NS	-
Weed control									
Fluchloralin 0.75 kg/ha	29.9	29.9	131.3	104.9	5.9	221.0	1.42	2.01	1.7
Fluchloralin 1.5 kg/ha	14.4	28.1	134.5	107.0	5.9	218.0	1.50	2.00	1.6
Trifluralin 0.75 kg/ha	28.8	28.0	132.0	108.7	5.6	208.2	1.40	2.08	1.7
Trifluralin 1.5 kg/ha	22.1	30.8	134.8	108.1	5.9	219.5	1.43	2.07	1.6
Two hand weedings (20 and 40 DAS)	28.7	24.4	131.1	106.2	6.0	229.0	1.44	1.91	1.3
LSD (P=0.05)	6.3	NS	NS	NS	NS	NS	NS	NS	-

germination of weeds after hand weeding increased the dry matter in this treatment as compared to herbicidal treatments. Effective weed control with triflurlain 1.5 kg and fluchloarlin 1.5 kg/ha have been reported earlier (Singh and Singh 1998, Khan *et al.* 1995). The herbicides did not influence the emergence of the crop (data not shown) indicating that fluchloralin, trifluralin at 0.75 and 1.50 kg/ha were safe to all the three cultivars of canola gobhi sarson. '*Hyola PAC 401*' attained significantly higher plant height than the other two cultivars and herbicidal treatments recorded similar plant height to that of hand weeded control. All the three canola cultivars recorded similar seed yield during both the years. Fluchloralin and triflurlain at 0.75 and 1.5 kg/ ha recorded similar seed yield to that of hand weeded control during both the years. This also indicated that both the herbicides are safe for use on all the three cultivars of canola gobhi sarosn. Beneficial effect of trifluralin on canola seed yield have been recorded earlier (Tanveer *et al.* 2005).

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Post-emergence herbicides effect on weeds, yield and economics of Bt cotton

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ABSTRACT

A total of eight treatments were evaluated in a randomized block design (RBD) with three replications. The treatments consisted of pre-emergence application of pendimethalin (30.0% EC) at 1.0 kg/ha + 1 hoeing on 45 DAS, post-emergence application of quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing, pendimethalin at 1.0 kg/ha *fb* quizalofop-ethyl 50 g/ha + 1 hoeing on 45 DAS, post-emergence application of pyrithiobac-sodium 62.5 g/ha (30 DAS) + 1 hoeing on 45 DAS, combination of pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha + 1 hoeing on 45 DAS, glyphosate 1.0 kg/ha (45 DAS) as directed spray and control plots of weed free check and unweeded check. The results revealed that application of pre-emergence herbicide pendimethalin at 1.0 kg/ha at 3 DAS followed by post-emergence herbicide (quizalofop-ethyl 50 g/ha at 30 DAS) + one hoeing or combined post-emergence application of pyrithiobac-sodium + quizalofop-ethyl + one hoeing on 45 DAS recorded lesser weed population and weed dry weight and higher weed control efficiency with lower weed index. These treatments were also comparable with pre-emergence application of pendimethalin + 1 hoeing. Higher yield attributes, *viz*. number of sympodia per plant, number of bolls per plant and boll weight and seed cotton yield were also registered by these treatments. The yield reduction due to weeds accounted 44.8 and 80.3% during 2012-13 and 2013-14, respectively The economic analysis indicated that higher total income, net income and benefit–cost ratio were associated with pre-emergence application of pendimethalin followed by post-emergence application of quizalofop-ethyl + one hoeing, combined post-emergence application of pyrithiobac-sodium + quizalofop-ethyl + one hoeing and pre-emergence application of pendimethalin + 1 hoeing in both the years of study.

Key words: Cotton, Post-emergence herbicides, Weeds, Yield

Cotton, popularly known as "King of fibre" and "White gold" is the most important fibre and commercial crop of India and also of Tamil Nadu state. The contribution of India to global cotton fibre and edible oil production is 44 and 10%, respectively. Though India has the largest area (26%) of cotton in the world, due to its lower productivity the share to the total world cotton production is only 12%. Weeds consume 5 to 6 times of N, 5 to 12 times of P and 2 to 5 times of K more than cotton crop and thus reduced the cotton yield from 54 to 85% (Jain *et al.* 1981). Cotton is very sensitive to crop-weed competition due to slow growth during early stage and wider spacing. The critical period of weed competition is up to 45 days after sowing (DAS). Though many pre-emergence herbicides are available for controlling weeds, the need for post-emergence herbicide is often realised to combat the weeds emerged during later stages of crop growth. Moreover, due to increasing problem of labour availability for cotton cultivation, use of post-emergence herbicide has greater potential for effective weed management. In this context, the present study was carried out to evaluate the post-emergence herbicides alone or/ in combination with the pre-emergence herbicide in Bt cotton.

MATERIALS AND METHODS

Two field experiment was conducted under irrigated condition during winter season of 2012–13 and 2013-14 at Cotton Research Station, Tamil Nadu Agricultural University, Srivilliputtur to evaluate the weed control efficiency of post-emergence herbicides in Bt cotton '*Mallika*'. Eight treatments were evaluated in a randomized block design (RBD) with three replications. The treatments consisted of pre-emergence application of pendimethalin (30.0% EC) at 1.0 kg/ha + 1 hoeing on 45 DAS, quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing on 45 DAS, pendimethalin 1.0 kg/ha (3 DAS) followed by (*fb*) quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing on 45

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DAS, pyrithiobac-sodium 62.5 g/ha (30 DAS) + 1 hoeing on 45 DAS, pyrithiobac-sodium 62.5 g/ha (30 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing on 45 DAS, glyphosate 1.0 kg/ha (45 DAS) as directed spray and weed free and weedy check. The hoeing was carried out on 45 DAS in the respective treatments. The data on weed density and dry weight were recorded at 50 DAS. The weed control efficiency (WCE) and weed index (WI) were calculated. The growth, yield attributes and seed cotton yield were registered and economics was also worked out.

RESULTS AND DISCUSSION

Density and dry weight of total weeds

The weed management treatments showed significant effect on weed density and weed dry weight (Table 1). The lowest total weed density and dry weight on 50 DAS was recorded by pre-emergence application of pendimethalin 1.0 kg/ha (3 DAS) followed by post-emergence application of quizalofop-ethyl 50 g/ha at 30 DAS + one hoeing. This was followed by post-emergence application of pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha (30 DAS) + one hoeing and pre-emergence application of pendimethalin at 1.0 kg/ha + 1 hoeing during both the years of study and these treatments were statistically at par with each other. The lesser weed density and weed dry weight by the post-emergence herbicide pyrithiobac-sodium in cotton was observed by Panwar *et al.* (2001). Patil (2007) observed similarly effective control of grassy weeds by the application of quizalofop-ethyl at 1.0 litre/ha on 35 DAS. Similar weed reduction due to the post-emergence herbicide in cotton was also documented by Ali *et al.* (2005). The lesser weed population with higher weed control efficiency by pre-emergence application of pendimethalin as reported by Nalini *et al.* (2011) was also in accordance with the present study.

Weed control efficiency and weed index

Among the weed control treatments, the highest WCE of 96 and 95% during 2012-13 and 2013-14 respectively were registered by pendimethalin (PRE) followed by post-emergence quizalofop-ethyl + one hoeing (Table 1). The next best effective treatment was combined post-emergence application of pyrithiobac-sodium + quizalofop-ethyl + one hoeing and pre-emergence application of pendimethalin + 1 hoeing.

Weed index reflects the reduction in seed cotton yield due to weeds. Lower weed index values were associated with the treatments pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing, pyrithiobac-sodium 62.5 g/ha (30 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing and pendimethalin at 1.0 kg/ha (pre-emergence) + 1 hoein. This indicates that the reduction of seed cotton yield was minimum in these weed management treatments. Higher weed index was found with unweeded check as evident from 44.8 and 80.3% yield reduction during 2012-13 and 2013-14, respectively. Similar result of higher weed control efficiency in Bt cotton due to the post-emergence

Table 1. Effect of weed management practices on density and dry weight of weeds and WCE and WI in Bt cotton

Treatment	Total Weed density at 50 DAS (no./m^2)		Total weed Dry weight at 50 DAS(kg/ha)		Weed control efficiency (WCE) (%)		Weed index (WI)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Pendimethalin at 1.0 kg/ha (pre-emergence) + 1 hoeing	36.6 (6.09)	28.8 (5.41)	167.5 (12.96)	32.2 (5.72)	95.12	94.64	6.12	6.76
Quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	41.1 (6.45)	35.5 (6.00)	206.4 (14.38)	37.8 (6.19)	88.20	93.67	21.58	20.33
Pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	33.5 (5.83)	22.3 (4.77)	142.8 (11.97)	30.4 (5.56)	95.79	94.91	5.41	2.70
Pyrithiobac-sodium 62.5 g/ha (30 DAS) + 1 hoeing	36.7 (6.10)	21.6 (4.70)	246.1 (15.70)	32.5 (5.74)	87.58	94.56	19.10	16.08
Pyrithiobac-sodium 62.5 g/ha (30 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	30.7 (5.59)	24.7 (5.02)	130.6 (11.45)	32.3 (5.73)	89.05	94.51	4.32	4.59
Glyphosate 1.0 kg/ha (45 DAS) as directed spray	265.7 (16.32)	235.2 (15.35)	1108 (33.30)	283.7 (16.86)	67.83	52.52	31.80	72.10
Weed free check	0.0 (0.71)	0.0 (0.71)	0.0 (0.71)	0.0 (0.71)	100.00	100.00	0.00	0.00
Weedy check	638.2 (25.27)	533.2 (23.10)	3442 (58.67)	597.5 (24.45)	0.0	0.00	44.77	80.28
LSD (P=0.05)	15.6	14.4	300.8	5.5	-	-	-	-

application of pyrithiobac-sodium was registered by Hiremath *et al*. (2014). At Raichur (Karnataka), Prabhu *et al.* (2011) registered higher weed control efficiency with pre-emergence pendimethalin followed by post-emergence herbicide quizalofop-ethyl application at 0.05 kg/ha + one hoeing. The lesser weed population with higher weed control efficiency by the application of pre-emergence pendimethalin as reported by Nalini *et al.* (2011) and Nithya and Chinnusamy (2013) is also in accordance with the present study.

Yield attributes of cotton

Different weed management practices exhibited significant influence on all the yield attributes studied (Table 2). Among them, weed free check produced higher yield attributes, *viz.* number of sympodia per plant, number of bolls per plant and boll weight, however it was at par with that of pre-emergence application of pendimethalin 1.0 kg/ ha (3 DAS) followed by post-emergence application of quizalofop-ethyl 50 g/ha + one hoeing, post-emergence application of pyrithiobac-sodium 62.5 g/ ha + quizalofop-ethyl 50 g/ha + one hoeing during both the years of study. The treatments pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing, pyrithiobac-sodium 62.5 g/ha (30 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing were also comparable with pre-emergence application of pendimethalin at 1.0 kg/ha + 1 hoeing in producing yield attributes of Bt cotton. The higher yield attributes in the above treatments were due to lesser weed competition. Unweeded check recorded the lowest values which was due to severe weed competition. Similarly superior yield attributes in Bt cotton due to pre-emergence pendimethalin followed by post-emergence herbicide quizalofop-ethyl application at 0.05 kg/ha + one hoeing were recorded earlier also (Prabhu *et al.* 2011).

Seed cotton yield

The various weed management techniques showed significant impact on seed cotton yield. (Table 2). Weed free check though registered highest seed cotton yield, it was at par with pre-emergence application of pendimethalin 1.0 kg/ha followed by post-emergence application of quizalofop-ethyl 50 g/ ha + one hoeing, post-emergence application of pyrithiobac-sodium 62.5 g/ha + quizalofop-ethyl 50 g/ha + one hoeing and pre-emergence application of pendimethalin at 1.0 g/ha + 1 hoeing in both the years of study. The high yielding weed management treatments, *viz*. pyrithiobac-sodium 62.5 g/ha (30 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing, pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing and pendimethalin at 1.0 kg/ha (pre-emergence) + 1 hoein registered seed cotton yield of 2.54, 2.52 and 2.50 t/ ha during 2012-13 and 2.02, 2.06 and 1.97 t/ha during 2013-14, respectively. The lowest yield of only 1.47 and 0.42 t/ha was recorded by unweeded check during the above period of study indicating yield reduction due to weeds accounted 44.8 and 80.3% during 2012-13 and 2013-14, respectively. The higher seed cotton yield in pyrithiobac-sodium 62.5 g/ha (30 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing, pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing and pendimethalin at 1.0 kg/ha (pre-emergence) + 1 hoein treatments was attributed to lesser weed population and weed dry weight coupled with higher yield attributes. The favourable result of effective weed control with higher cotton yield by the post-emergence herbicide pyrithiobac-sodium in cotton was reported by Panwar *et al.* (2001) and Hiremath *et al* (2014). The combination of both pre-emergence and post-emergence herbicide application resulted in higher seed cotton yield as in the case of

Table 2. Effect of weed management practices on yield attributes and yield of Bt cotton

Treatment	Sympodia (no./plant)		Bolls (no./plant)		Boll weight (g)		Seed cotton yield (t/ha)	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Pendimethalin at 1.0 kg/ha (pre-emergence) + 1 hoeing	13.75	19.75	23.20	27.73	5.19	3.09	2.50	1.97
Quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	12.50	18.02	17.95	25.11	5.01	2.85	2.09	1.68
Pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	14.55	22.05	24.45	30.13	5.22	3.28	2.52	2.06
Pyrithiobac-sodium 62.5 g/ha (30 DAS) + 1 hoeing	13.00	18.51	18.63	26.60	4.94	2.94	2.15	1.77
Pyrithiobac-sodium 62.5 g/ha (30 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	13.60	21.33	20.93	29.63	5.05	3.20	2.24	2.02
Glyphosate 1.0 kg/ha (45 DAS) as directed spray	9.80	12.67	15.20	11.07	4.73	2.63	1.81	0.59
Weed free check	14.75	23.12	25.65	31.80	5.30	3.39	2.66	211
Weedy check	9.05	11.24	11.95	8.15	4.80	2.50	1.47	0.42
LSD (P=0.05)	1.07	3.32	1.75	3.63	0.32	0.29	0.20	0.15

Table 3. Effect of weed management practices on economics of Bt cotton

Treatment	Total Cost of cultivation (x10^3 ` / ha)		Total income (x10^3 ` / ha)		Net income (x10^3 ` / ha)		Benefit cost ratio	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
Pendimethalin at 1.0 kg/ha (pre-emergence) + 1 hoeing	35.73	42.52	87.39	90.22	51.66	47.67	2.45	2.12
Quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	36.14	42.72	73.01	75.77	36.87	33.08	2.02	1.78
Pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	38.18	44.87	88.06	92.59	49.88	47.71	2.31	2.06
Pyrithiobac-sodium 62.5 g/ha (30 DAS) + 1 hoeing	35.80	44.25	72.31	79.87	36.50	35.62	2.02	1.81
Pyrithiobac-sodium 62.5 g/ha (30 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing	38.35	45.10	78.57	90.83	40.23	45.73	2.05	2.02
Glyphosate 1.0 kg/ha (45 DAS) as directed spray	34.94	25.83	63.49	26.55	28.55	-9.28	1.81	0.74
Weed free check	42.80	52.37	93.10	95.20	50.30	42.82	2.18	1.82
Weedy check	30.00	34.81	51.41	18.76	21.41	-16.05	1.71	0.53

pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing in the present study which was in confirmity with the results of Askew *et al* (2002).

Economics

The economic analysis of weed management practices (Table 3) revealed that higher total income and net income were associated with pre-emergence application of pendimethalin followed by post-emergence application of quizalofop-ethyl + one hoeing, post-emergence application of pyrithiobac-sodium + quizalofop-ethyl + one hoeing and pre-emergence application of pendimethalin + 1 hoeing in both the years of study (Table 3). Regarding benefit-cost ratio, highest B-C ratio of 2.45 and 2.12 were recorded by pre-emergence application of pendimethalin + 1 hoeing during 2012-13 and 2013-14, respectively. This was closely followed by pendimethalin 1.0 kg/ha (3 DAS) + quizalofop-ethyl 50 g/ha (30 DAS) + 1 hoeing. The higher economic benefits in these treatments were due to higher seed cotton yield. Patil (2007) obtained higher economic returns by the application of quizalofop-ethyl at 1.0 litre/ha on 35 DAS in cotton. Higher economic benefits of post-emergence herbicide application in winter irrigated cotton were also realized by Sadanki and Barik (2007).

It was concluded that pre-emergence application of pendimethalin 1.0 kg/ha + 1 hoeing was found to be a suitable and economical herbicidal weed management for winter irrigated cotton which was comparable with of pre-emergence application of pendimethalin at 1.0 kg/ha followed by post-emergence herbicide quizalofop-ethyl 50 g/ha on 30 DAS) + one hoeing or combined post-emergence application of pyrithiobac-sodium + quizalofopethyl + one hoeing.

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Chemical weed control in barley

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ABSTRACT

A field experiment was conducted during the *Rabi* season of 2008-09 and 2009-10 on sandy loam soils of research farm of Regional Station, Bathinda to find out response of different varieties of barley and various combinations of herbicides on growth, weed dry matter and grain yield of barley under semi arid conditions of Punjab. The experiment was laid out in split plot design with two varieties in main plots and 12 different herbicide combinations in sub plots. The grain yield had no significant difference with respect to two varieties but it varied significantly with various combinations of herbicides. The maximum mean grain yield *i.e.* 3.46 t/ha was recorded in pinoxaden + metsulfuron 50 + 4 g/ha (T_4) followed by metsulfuron *fb* pinoxaden 4 + 50 g/ha, metsulfuron *fb* pinoxaden 4 + 45 g/ha and lowest (2.31 t/ha) in control. The dry weight of weed flora was significantly higher in control plots as compared to other treatments during both the years and no significant difference was observed in both the varieties with respect to dry weight of weed flora .

Key words: Barley, Chemical weed control, Yield

Barley (*Hordeum vulgare* L.) is an important crop which is grown for grain and malt purpose in Punjab on an area of 14 thousand ha with production of 47 thousand tonnes with average yield of 3.47 t/ha (Anonymous 2010). Most of the barley area is confined to semi-arid region having scarcity of water due to its low water requirement. Weed management is essential for better grain yield due to their competition for nutrients, water, space and sunlight. The yield reduction in barley depends upon the type and density of associated weed flora (Walia and Brar 2001). Among the grass weeds, wild oats (*Avena ludoviciana*) can cause yield reduction in irrigated barley from 15-50% (Gill and Brar 1975). Similarly, *Chenopodium album*, *Lepidium sativa*, *Anagallis arvensis* and other broadleaf weeds also compete with this crop causing yield reduction up to 25%. The application of 2,4-D for the control of broad-leaf weeds in wheat seems to be less effective against some broad-leaf weeds (Punia *et al*. 2006). The post-emergence herbicide pinoxaden at 40-60 g/ha was very effective against *Avena ludoviciana* and resistant population of *Phalaris minor* without any phytotoxicity to barley crop (Singh and Punia 2007, Chhokar *et al*. 2008). In Punjab, both grass and broad-leaf weeds are becoming problem in barley crop. Therefore, there was dire need to test some broad spectrum herbicides so that effective weed control can be achieved in barley.

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MATERIALS AND METHODS

A field experiment was conducted during the *Rabi* season of 2008-09 and 2009-10 on sandy loam soils of research farm of Regional Station, Bathinda to find out the chemical weed control in barley. The treatments were laid out in split plot design with two varieties, *viz.* '*PL-426*' and '*DWRUB-52*' in main plots and different herbicide combinations, *viz.* pinoxaden 40 g/ha 35 DAS (T_1), pinoxaden 50 g/ha 35 DAS (T_2), pinoxaden + metsulfuron 40 + 4 g/ha 35 DAS (T_3), pinoxaden + metsulfuron 50 + 4 g/ha 35 DAS (T_4), metsulfuron *fb* pinoxaden 4 *fb* 40 g/ha (T_5), metsulfuron *fb* pinoxaden 4 *fb* 45 g/ha (T_6), metsulfuron *fb* pinoxaden 4 *fb* 50 g/ha (T_7), pinoxaden + carfentrazone 40 +20 g/ha (T_8), pinoxaden + carfentrazone 50 + 20 g/ha (T_9), carfentrazone 20 g/ha (T_{10}), weed free (T_{11}) and control (T_{12}) in sub plots with three replications. The observations for weed population and their dry matter accumulation were recorded at 90 DAS with the help of quadrat (0.5 x 0.5 m) at two random places in a plot and then converted into per m^2. These data were subjected to square root transformation to normalize their distribution before analysis. Data on yield attributes and grain yield of barley were recorded at harvest which were statistically analysed.

RESULTS AND DISCUSSION

The field had infestation of both grasses and broad-leaf weeds, with the dominance of *Phalaris minor, Avena ludoviciana, Melilotus indica*, *Chenopodium album, Chenopodium murale, Euphorbia helioscopa, Anagallis arvensis, Spergula arvensis, Convolvulus arvensis, Coronopus didymus, Rumex dentatus, Asphodelus tenuifolius, Cirsium arvense, Lathyrus aphaca* and *Vicia sativa.*

The plant height varied significantly with varieties and herbicide combinations. Significantly higher plant height was recorded in '*PL 426*' as compared to '*DWRUB 52*'. The highest plant height was recorded where metsulfuron *fb* pinoxaden 4 *fb* 50 g/ha (T_7) was applied and it was at par with other herbicide combinations during 2008-09. During 2009-10, metsulfuron *fb* pinoxaden 4 *fb* 50 g/ha (T_7) recorded higher plant height which was at par with pinoxaden + metsulfuron 50 + 4 g/ha (T_4), metsulfuron *fb* pinoxaden 4 *fb* 45 g/ha (T_6) and pinoxaden + carfentrazone 50 + 20 g/ha (T_9) and significantly higher than other treatments (Table 1).

The two varieties had no significant effect on number of tillers/m length, but herbicides combination had significant effect on it during both years. The number of tillers/m length were recorded to be higher in pinoxaden + carfentrazone 40 + 20 g/ha (T_8), metsulfuron *fb* pinoxaden 4 *fb* 45 g/ha (T_6), pinoxaden + metsulfuron 40 + 4 g/ha (T_3), pinoxaden 50 g/ha (T_2) and significantly higher than control (T_{12}). During 2008-09 and during 2009-10, application of metsulfuron *fb* pinoxaden 4 *fb* 50 g/ha (T_7) gave maximum number of tillers/m length which was significantly higher than application of Pinoxaden 50 g/ha (T_2) and pinoxaden+ metsulfuron 40 + 4 g/ha (T_3).

The number of grains/spike did not vary significantly in both the varieties during both the years of study, but herbicide combinations had significant effect on it. Metsulfuron *fb* pinoxaden 4 *fb* 50 g/ha (T_7) gave maximum number of grains/spike which was significantly higher than Pinoxaden 40 g/ha (T_1), metsulfuron *fb* pinoxaden 4 *fb* 40g/ha (T_5), pinoxaden + carfentrazone 40 + 20 g/ha (T_8) and unweeded control (T_{12}) during 2008-09. The number of grains/spike was maximum with the application of pinoxaden + metsulfuron 50 + 4 g/ha (T_4) and significantly higher than application of pinoxaden + carfentrazone 40 + 20 g/ha (T_8), pinoxaden + carfentrazone 50 + 20 g/ha (T_9), weed free (T_{11}) and control (T_{12}) and statistically at par with other herbicide combinations during 2009-10 (Table 1).

The grain yield had no significant difference with respect to two varieties but it varies significantly with various combinations of herbicides. The maximum grain yield (3.39 t/ha) was recorded in pinoxaden + metsulfuron 50 + 4 g/ha (T_4), which was at par with pinoxaden+ metsulfuron 40 + 4 g/ha (T_3), pinoxaden 50 g/ha (T_2), pinoxaden + metsulfuron 50 + 4 g/ha (T_4), metsulfuron *fb* pinoxaden 4 *fb* 45 g/ha (T_6), metsulfuron *fb* pinoxaden 4 *fb* 50 g/ha (T_7), carfentrazone 20 g/ha (T_{10}) and weed free (T_{11}), but significantly higher than pinoxaden 40 g/ha (T_1), metsulfuron *fb* pinoxaden 4 *fb* 40 g/ha (T_5), pinoxaden + carfentrazone 40 + 20 g/ha (T_8), pinoxaden +

Table 1. Effect of different varieties and herbicides on weed dry weight, growth and yield of barley

Treatment	Plant height (cm)		No. of tillers/m length		No. of grains/ spike		Biomass yield t/ha		Weed dry weight (t/ha)		Grain yield (t/ha)		
	08-09	09-10	08-09	09-10	08-09	09-10	08-09	09-10	08-09	09-10	08-09	09-10	Mean
Varieties													
V_1	70.3	64.5	73.9	71.6	57.1	35.4	6.96	7.20	0.10	0.10	3.05	3.25	3.15
V_1	88.4	71.4	77.9	73.1	59.7	41.8	7.10	8.31	0.10	0.10	3.13	3.16	3.15
LSD (p=0.05)	4.5	3.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Herbicide treatment													
T_1	78.4	67.4	74.2	75.5	57.0	39.2	7.14	7.05	0.10	1.00	2.80	2.83	2.83
T_2	80.9	63.5	74.4	63.3	58.7	41.2	6.84	7.58	0.10	1.02	3.16	3.26	3.21
T_3	81.2	68.3	75.3	64.8	58.7	40.8	7.23	8.26	0.10	1.00	3.25	3.30	3.34
T_4	79.4	73.5	77.6	73.5	60.2	41.8	7.41	8.11	0.10	1.00	3.39	3.52	3.46
T_5	78.1	68.8	77.0	71.9	57.3	39.3	6.93	7.82	0.10	1.02	2.91	3.54	3.23
T_6	78. 2	72.7	75.3	74.7	61.5	40.3	7.37	8.25	0.10	1.01	3.36	3.43	3.40
T_7	82.6	75.1	80.6	76.6	63.0	41.0	7.52	8.10	0.10	1.00	3.23	3.57	3.40
T_8	80.2	68.8	76.0	72.3	57.2	34.8	7.08	8.59	0.10	1.02	2.85	3.02	2.94
T_9	81.7	70.5	76.5	71.5	59.3	36.3	7.23	7.37	0.10	1.00	3.02	3.20	3.11
T_{10}	80.0	68.2	72.2	71.0	60.2	35.7	6.64	8.70	0.10	1.03	3.19	3.24	3.22
T_{11}	76.9	61.2	78.7	71.7	58.7	38.5	6.93	7.34	0.30	4.00	3.06	3.01	3.03
T_{12}	74.6	58.0	70.4	71.7	56.7	33.8	6.05	5.90	1.10	1.00	2.24	2.38	2.31
LSD (P=0.05)	6.9	5.8	4.5	9.1	4.5	4.2	NS	NS	0.03	0.2	0.36	0.45	

carfentrazone 50 + 20 g/ha (T_9) and control (T_{12}) during 2008-09. However, during 2009-10, metsulfuron *fb* pinoxaden 4 *fb* 50 g/ha (T_7) recorded maximum grain yield (3.57 t/ha) which was significantly higher than pinoxaden 40 g/ha (T_1), pinoxaden + carfentrazone 40 +20 g/ha (T_8), weed free (T_{11}) and control (T_{12}) and at par with other herbicide combinations (Table 1). Biomass yield (t/ ha) did not vary significantly in varieties and various herbicides combinations during both the years of study. The highest biomass yield was recorded with the application of pinoxaden + metsulfuron 50 + 4 g/ ha (T_4) and pinoxaden + carfentrazone 40 + 20 g/ha (T_8) during 2008-09 and 2009-10 respectively. The dry weight of weed flora was significantly higher in control plots than other treatments during both the years and did not vary significantly due to varieties.

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Bioefficacy and phytotoxicity of herbicides in greengram and their residual effect on succeeding mustard

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ABSTRACT

Weed flora of experimental field was dominated with *Echinochloa colona* during *Kharif* 2012 and *Trianthema portulacastrum* during *Kharif* 2013. Post-emergence application of imazethapyr at 70 g/ha and its ready mixture with imazamox at 60-80 g/ha although provided excellent (80-90%) control of weeds but caused 23-35% injury to greengram in initial stages in terms of yellowing of leaves and stunted crop growth up to 7 DAT which mitigated to 5-7% up to 45 DAS, without any yield reductions. Pre-emergence application of pendimethalin+ imazethapyr (ready mix) at 1000 g/ha provided season long control (75-82%) of weeds in greengram. During both years, seed yield was maximum (1.50 and 1.58 t/ha, respectively) in weed free treatment which was at par with post-emergence application of imazethapyr at 50 and 70 g/ha and imazethapyr + imazamox (ready mix) at 60 g/ha in 2012 but significantly higher than all herbicide treatments in 2013. Imazethapyr and its ready mix combination irrespective of dose did not cause any injury to succeeding mustard crop after harvest of greengram.

Key words: Crop injury, Greengram, Imazethapyr, Imazamox, Mustard, Residual carry over

Due to limited irrigation facilities in South-Western part of Haryana, greengram is the important *Kharif* season crop of this region. It is drought tolerant legume and excellent rotational crop with mustard, wheat, chickpea and barely. Weeds in greengram have been reported to offer serious competition and cause yield reduction to the extent of 49% (Parkash *et al*. 1988). Weed emergence in greengram begins almost with the crop emergence leading to crop-weed competition from initial stages. Critical period of crop-weed competition in greengram and urdbean is 20-40 days after sowing (Saraswat and Mishra 1993) , hence the effective use of herbicide at these critical stages play significant role in maintaining the productivity by decreasing the weed interference. Horse purslane (*T. portulacastrum*) an annual broad-leaf weed germinates at the same time as greengram crop and completes its life cycle within 30 days (Balyan 1985). Crop type and soil properties have greatest influence on the occurrence of weed species (Andreasen *et al.* 1991). The type of irrigation, cropping pattern, weed control measures and environmental factors had a significant influence on the intensity and infestation of weeds. Although pre-emergence use of pendimethalin at 1.0 kg/ha has been found effective to control weeds in greengram but a residual herbicide is needed to control second flush of weeds emerging after rains. Keeping it in view, herbicides imazethapyr alone or in combination with imazamox and pendimethalin as pre-mixture with imazethapyr were tested under pre- and post-emergence conditions and compared with pendimethalin alone. Based on weed dry weight, WCE was calculated.

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MATERIALS AND METHODS

The present studies were conducted during *Kharif* and *Rabi* seasons of 2012 and 2013 at Department of Agronomy, CCS Haryana Agricultural University, and Hisar under irrigated conditions. The soil of the experimental field was sandy loam in texture, having pH 8.1, low in organic carbon (0.3%) and nitrogen (180 kg/ha), medium in available phosphorus (18 kg/ha) and high in potassium (370 kg/ha) content. The treatments consisting of pendimethalin at 1.0 kg/ha and pendimethalin+ imazethapyr at 800-1000g/ha as pre-emergence. Post-emergence treatments included different doses of imazethapyr (ready mix) at 50, 60 and 70 g/ha, imazethapyr + imazamox (ready mix) at 60-80g/ha and compared with one or two hoeing, weed free and weedy checks were tried in randomized block design replicated thrice. Greengram cultivar '*Satya*' was sown on 17 and 10 July and harvested on 5 and 8 October during 2012 and 2013, respectively. Post-emergence herbicides were applied at 23 DAS (2-3 leaf stage of weeds) by knapsack sprayer fitted with flat fan nozzle using 500 l/ha water. Crop was raised according to package of practices of the state university. Total rainfall received during the crop season was 215 mm during 2012 where as during 2013, total 525 mm rainfall was received during *Kharif* season. Observations on weeds were recorded at 30 and 60 DAS. Phytotoxic effect of herbicides on crop in terms of yellowing, stunting and necrosis were recorded at 15, 30 and 60 DAS. Crop yield and yield parameters were recorded at maturity. Mustard crop cultivar '*RH 749*' was planted in second fortnight of October after harvest of greengram with shallow disking and planking in same layout as in *Kharif* 2012 and 2013. Data on number of leaves/plant at 30 DAS, number of mustard plants/ m.r.l., plant height of mustard at 30 and 60 DAS and seed yield was recorded at harvest.

RESULTS AND DISCUSSION

Effect on weeds

During 2012, *Echinochloa colona* was the most dominating weed constituting 98% of total weed flora where as during 2013, *Trianthema portulacastrum* constituted 99% of weed flora. Other weeds present in experimental field were *Cyperus rotundus*, *Dactyloctenium aegyptium* and *Convolvulus arvensis.*

During 2012, all weed control treatments proved very effective against *E. colona* and population of this weed in these treatments was at par with weed free check (Table 1). During 2013, all pre-emergence herbicides treatments proved very effective against predominant weed *T. portulacastrum as* shown by density of weeds at 30 DAS (Table 1). None of the treatment proved very effective against *C. rotundus* and *C. arvensis* but pendimethalin alone or in combination showed efficacy against *D. aegyptium.* Pre-emergence application of pendimethalin or pre-plant incorporation of fluchloralin or trifluralin provided excellent control of *T. portulacastrum* L. and *E. tenella* but not *Cyperus* spp. (Kaur *et al*. 2010). During 2012, post emergence application of imazethapyr at 50-70 g/ha and imazethapyr + imazamox at 60,70 and 80 g/ha proved very effective in minimizing density and dry weight of weeds particularly *E. colona,* which was significantly less over weedy check but during 2013, post-emergence application of imazethapyr and imazethapyr + imazamox at all rates of application proved less effective in minimizing density and dry weight of *T. portulacastrum* only with some suppression as evident from density and dry weight of weeds at 30 and 60 DAS. Although post emergence application of

Table 1. Effect of different treatments on weed density in greengram during 2012 and 2013

Treatment	Dose (g/ha)	Application time	Density (no./m^2) at 30 DAS				Density (no./m^2) at 60 DAS			
			2012		2013		2012		2013	
			E. colona	*Trianthema*	*C. rotundus*		*E. colona*	*Trianthema*	*D.aegypticum*	*C. rotundus*
Pendimethalin	1000	PRE	6.1(37.3)	3.4(10.7)	5.1(26)	1.7(2.0)	4.7(22)	1.6(1.7)	1(0)	3.3(10)
Imazethapyr	50	3-4 leaf stage	3.2 (12)	5.9 (1.3)	1.4(1.3)	1.8(2.3)	1.7(2)	1.2(0.7)	1.7(2)	2.9(7.3)
Imazethapyr	60	3-4 leaf stage	-	9.4 (88.3)	-	1.6(1.7)	-	1(0)	-	2.4(4.7)
Imazethapyr	70	3-4 leaf stage	1.4(1.3)	10.5(109)	1(0)	1.7(2.0)	1.9(3.3)	1(0)	1.8(3.3)	2.0(3.7)
Imazethapyr + pendimethalin (RM)	800	PRE	3.5 (14)	1.3 (21.3)	4.5 (21.3)	2.6 (6.0)	3.4 (10.7)	2.4 (5)	1 (0)	1.6(2.3)
Imazethapyr + pendimethalin (RM)	900	PRE	2.2 (3.7)	1 (0)	4 (16.7)	2.9 (7.3)	3.4 (11.3)	2.4 (5)	1 (0)	1.8 (2.7)
Imazethapyr + pendimethalin (RM)	1000	PRE	3.0 (8.7)	1 (0)	3.1 (9.3)	1.6 (1.7)	3.8 (13.3)	2 (3.0)	1.5 (1.3)	2.9 (7.3)
Imazethapyr + imazamox(RM)	50	3-4 leaf stage	-	10.3 (106)	-	1.9 (2.7)	-	1 (0)	-	2.5 (5.3)
Imazethapyr + mazamox(RM)	60	3-4 leaf stage	3.0 (9.3)	10.4 (106)	2.0 (5.3)	1.5 (1.3)	2.3 (4.7)	1 (0)	2.9 (9.3)	2.6 (5.7)
Imazethapyr + imazamox(RM)	70	3-4 leaf stage	3.2 (9.3)	11.4 (130)	3.1 (10.7)	1.8 (2.3)	1.2 (0.7)	1.3 (1)	3.4 (11.3)	2.8 (7.0)
Imazethapyr + imazamox(RM)	80	3-4 leaf stage	1.8 (2.7)	10.8 (115)	2.3 (5.3)	2.1 (3.3)	1.2 (0.7)	1 (0)	2.9 (8)	1.9 (3.3)
One hoeing	-	20 DAS	-	1 (0)	-	1 (0)	-	2.6 (7.3)	-	1.7 (2.3)
Two hoeing	-	20 & 40 DAS		1 (0)		1 (0)		2.7 (8)		2.3 (4.7)
Weed free	-	-	1.0 (0)	1(0)	1.4(1.3)	1 (0)	1.8(2.7)	1(0)	1.2(0.7)	1(0)
Weedy check	-		10.5108)	10.5 (110)	2.1(4)	1.5(2)	8.1(64)	1(0)	2.1(3.3)	2.45(5)
LSD (P= 0.05)			2.0		1.95	0.48	1.1	0.96	1.46	0.92

Transformed values ($\sqrt{x+1}$), original values are given in parenthesis DAT: Days after treatment

Table 2. Effect of different treatments on visual weed control, crop phytotoxicity, plant height, number of pods/plant and seed yield of greengram (2012 and 2013)

Treatment	Dose (g/ha)	Application time	Visual weed control (%) 45 DAS		Crop phytotoxicity (%)				Plant height (cms)		No. of pods/plant		Seed yield (t/ha)	
					2012		2013							
			2012	2013	30 DAS	45 DAS	30 DAS	45 DAS	2012	2013	2012	2013	2012	2013
Pendimethalin	1000	PRE	30.9 (26.7)	56.8 (70)	0(0)	0(0)	0(0)	0(0)	87.5	86.9	28.3	32.3	0.91	1.40
Imazethapyr	50	3-4 leaf stage	-	63.6 (80)	-		0(0)	0(0)	-	85.8	-	28.5	-	1.24
Imazethapyr	60	3-4 leaf stage	73 (91.7)	67.2 (85)	16.2 (8.3)	0(0)	0(0)	0(0)	86.3	89.1	34.5	28.0	1.44	1.22
Imazethapyr	70	3-4 leaf stage	75.2 (93.3)	71.6 (90)	28.0 (23.3)	0(0)	0(0)	0(0)	85.8	85.3	34.9	30.9	1.48	1.28
Imazethapyr + pendimethalin (RM)	800	PRE	61.8 (77.7)	50.8 (60)	0(0)	0(0)	0(0)	0(0)	85.7	86.1	34.1	34.0	1.41	1.44
Imazethapyr + pendimethalin (RM)	900	PRE	63.6 (80)	60 (75)	0 (0)	0(0)	0(0)	0(0)	85.6	85.9	33.5	34.5	1.41	1.46
Imazethapyr + pendimethalin (RM)	1000	PRE	64.7 (81.7)	60 (75)	0 (0)	0(0)	0(0)	0(0)	85.6	89.9	35.0	35.0	1.43	1.50
Imazethapyr + imazamox(RM)	50	3-4 leaf stage	-	67.2 (85)	-	-	0(0)	0(0)	-	82.1	-	32.6	-	1.32
Imazethapyr + imazamox(RM)	60	3-4 leaf stage	63.6 (80)	71.6 (90)	4.3 (1.7)	0(0)	0(0)	0(0)	86.5	82.0	36.1	33.1	1.45	1.37
Imazethapyr + imazamox(RM)	70	3-4 leaf stage	64.7 (81.7)	71.6 (90)	24.8 (18.3)	12.9 (5)	0(0)	0(0)	84.2	82.4	33.3	33.0	1.37	1.42
Imazethapyr + imazamox(RM)	80	3-4 leaf stage	79.5 (95)	69.7 (88)	33.3 (35.2)	14.7 (7)	0(0)	0(0)	83.7	80.8	33.2	33.6	1.36	1.44
One hoeing	-	20 DAS	-	56.8(70)	-	-	0(0)	0(0)	-	84.6	-	34.0	-	1.48
Two hoeing	-	20 & 40 DAS	-	71.6(90)	-	-	0(0)	0(0)	-	87.2	-	36.0	-	1.56
Weed free	-	-	90(100)	90(100)	0(0)	0(0)	0(0)	0(0)	85.8	84.3	35.8	35.8	1.50	1.58
Weedy check	-	-	0(0)	0	0(0)	0(0)	0(0)	0(0)	86.9	84.9	19.7	21.3	0.22	0.34
LSD (P=0.05)			6.8	5.4	7.9	1.64	-	-	1.3	3.0	1.8	5.0	0.07	0.03

Arc Sin transformed values, original values are given in parentheses

both these herbicides caused suppression in *Trianthema* growth but pre-emergence treatments of pendimethalin alone or in combination with imazethapyr were very effective to minimize *Trianthema* population. Although, pre-emergence application of pendimethalin proved very effective and gave 80-90% control of weeds up to 15 DAS but per cent control decreased with time and it remained 27 -70 % up to 45 DAS. Pre-emergence use of pendimethalin + imazethapyr 2% at all application rates 800-1000 g/ha was very effective up to 45 DAS without any crop suppression. At 30 DAS, WCE was more than 70-90% in all herbicide treatments except pendimethalin at 1000 g/ha but at 60 DAS, WCE decreased in all pre-emergence treatments due to second flush of weeds appeared due to frequent rains (Table 1). At 60 DAS, maximum WCE (82.-93%) was recorded with post-emergence use of imazethapyr at 70 g/ha.

Effect on crop

All weed control treatments had reflection on plant height, no. of pods per plant and seed yield of green gram. During 2012, imazethapyr + imazamox at 70 and 80 g/ha caused 18-35 % toxicity to greengram which mitigated with time and remained 5-7% up to 45 DAS resulting reduction in plant height , number of pods per plant and seed yield. Presence of weeds throughout the season caused 78-86% reduction in seed yield of green gram. During both years, seed yield was maximum (1.50 and 1.58 t/ha, respectively) in weed free treatment which was at par with post-emergence application of imazethapyr at 50 &70 g/ha and imazethapyr + imazamox at 60 g/ha in 2012 but significantly higher than all herbicide treatments in 2013 (Table 2). During 2012, in herbicidal treatments maximum grain yield (1.48 t/ha) was obtained with post-emergence use of imazethapyr at 70 g/ha and at par with its lower dose 50 g/ha, pre-emergence use of pendimethalin + imazethapyr at 900-1000 g/ha and ready mix combination of imazethapyr + imazamox at 60 g/ha.

During 2013, maximum grain yield (1.50 t/ha) was obtained with pre-emergence use of pendimethalin + imazethapyr at 1000 g/ha which was at par with its lower dose of 900 g/ha but higher than all post-emergence treatments (Table 2).

Table 3. Residual effect of different herbicides applied in greengram on succeeding mustard crop (2012-13 and2013-14)

Treatment	Dose (g/ha)	Application time	No. of plants/m.r.l. 20 DAS		Plant height (cm)				Phytotoxicity (%)				Seed yield (t/ha)	
					30 DAS		60 DAS		15 DAS		30 DAS			
			2012-13	2013-14	2012-13		2013-14		2012-13		2013-14		2012-13	2013-14
Pendimethalin	1000	PRE	8.5	8.9	23.5	22.4	164.2	161.3	0	0	0	0	1.84	2.22
Imazethapyr	50	3-4 leaf stage	8.7	9.3	24.2	20.1	165.0	158.8	0	0	0	0	1.92	2.28
Imazethapyr	60	3-4 leaf stage	8.9	10.0	22.9	22.0	163.4	153.4	0	0	0	0	1.95	2.28
Imazethapyr	70	3-4 leaf stage	9.3	8.7	22.0	20.8	164.0	159.8	5	5	0	0	1.89	2.20
Imazethapyr + pendimethalin (RM)	800	PRE	9.3	8.3	23.0	22.0	162.8	160.2	0	0	0	0	1.82	2.20
Imazethapyr + pendimethalin (RM)	900	PRE	8.9	9.7	23.4	23.4	163.7	160.6	0	0	0	0	1.84	2.26
Imazethapyr + pendimethalin (RM)	1000	PRE	8.5	9.3	23.8	21.9	163.0	162.2	0	0	0	0	1.95	2.18
Imazethapyr + imazamox (RM)	50	3-4 leaf stage	8.6	9.0	23.0	20.4	162.6	157.4	0	0	0	0	1.88	2.26
Imazethapyr + imazamox (RM)	60	3-4 leaf stage	8.3	8.7	22.2	21.3	163.0	156.3	0	0	0	0	1.88	2.18
Imazethapyr + imazamox (RM)	70	3-4 leaf stage	8.7	8.7	22.3	21.5	164.2	160.8	0	5	0	0	1.88	2.24
Imazethapyr + imazamox (RM)	80	3-4 leaf stage	8.6	8.3	23.0	21.5	163.7	152.1	5	5	0	0	1.80	2.22
One hoeing	-	20 DAS	9.0	8.7	24.0	21.0	164.0	156.7	0	0	0	0	1.86	2.20
Two hoeing	-	20 & 40 DAS	9.0	8.7	24.0	22.0	162.9	157.9	0	0	0	0	1.92	2.20
Weedy free	-	-	8.7	8.7	24.4	22.4	161.7	154.0	0	0	0	0	1.88	2.24
Weed check	-	-	9.0	8.0	24.1	20.1	162.8	160.9	0	0	0	0	1.88	2.18
LSD (P=0.05)			NS	NS	NS	NS	NS	NS	-	-	-	-	NS	NS

Residual effect of herbicides

All herbicide treatments except imazethapyr at 70 g/ha and its ready mix combination with imazamox did not cause any phytotoxic effect on mustard (Table 3). Mustard crop in these treatments showed only 5% toxicity up to 15 DAS due to residues of these herbicides applied in greengram which mitigated within one month after planting as shown by non significant variation in plant height, germination percentage, number of leaves per plant and seed yield of mustard. During *Kharif* 2012, amount of rainfall was 215 mm where as during 2013, total 525 mm rainfall was received during kharif season so little microbial dissipation due to wet conditions might have occurred which may be responsible for no residual carrying over effect on succeeding mustard crop. These finding are not in agreement with finding of Punia *et al.* (2011) who reported poor, stunted growth of mustard grown after imazethapyr used at 100 g/ha but were in agreements with the findings of Patel *et al.* (2014).

It was summarized that pre-emergence use of pendimethalin + imazethapyr at 1000 g/ha, post emergence application of imazethapyr alone at 70 g/ ha and its ready mixture with imazamox at 70 g/ha can be safely used for weed control in greengram without any residual carry over effect on mustard crop.

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Integrated weed management in chilli under rainfed condition

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ABSTRACT

A field experiment was conducted during *Kharif* 2010, 2011 and 2012 at Agricultural Research Station, Gadhinglaj under rainfed condition in sub-montane zone of Maharashtra. The experiment consisting of eight treatments, *viz*. two pre-emergence and one post-emergence herbicides alone and in combination with one hoeing and one weeding with weed free and weedy check was laid out in randomized block design with three replications. The predominant weed flora observed in the experimental field was dicot weeds. The result revealed that pre-emergence application of pendimethalin + 1 hoeing + 1 hand weeding recorded minimum weed density, weed biomass and weed index as compared with all treatments. Gross and net returns were significantly higher with pendimethalin + 1 hoeing + 1 hand weeding which was at par with butachlor + 1 hoeing +1 hand weeding and superior over rest of treatments. Higher weed control efficiency and B: C ratio were recorded by the same treatments.

Key words: Butachlor, Chilli, Fenoxaprop-p-ethyl, Pendimethalin

Chilli (*Capsicum annuum* L.) is an important commercial crop of India grown for its green fruits as vegetable and riped dried form as spice. It is the source of natural pungent compounds (capsaicin), colouring compounds (capsorubin) and vitamin C. It is known for its commercial and therapeutic value. India stands first in chilli cultivation covering 45% areas of the world, but the productivity of dry chilli is lower (0.9 t/ha) as compared to worlds average (2.0 t/ha). There is tremendous demand for Indian chillies in the international market that provides wide scope to increase export.

Severe weed problems in chilli and huge losses due to weed competition are global problem. Weeds interfere with the development of chilli upto 8 weeks after transplanting by competing for moisture, nutrient, light and space (Amador and Ramirez 2002). Owing to inherent characteristics of chilli such as upright nature of crop, wide spaced, slow initial growth and less canopy, weeds offer severe competition throughout the crop growth. Control of weeds is vitally important not only to check the losses caused by them but also to increase input use efficiency. To get effective control of complex weed flora, integrated approach of weed management is the best choice. In the present investigation, an attempt was made to test the feasibility of herbicides alone at recommended doses and with combination of hoeing and hand weeding to develop an effective and viable weed management practices for chilli.

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MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 2010, 2011 and 2012 at the Agricultural Research Station, Gadhinglaj Dist. Kolhapur (M.S.). The area is geographically situated in sub montain zone of Maharashtra. It is situated between 160 13'N latitude, 740 21' E longitude and at an altitude of about 640.24 m above msl. Average rainfall of this station is 930mm in 70 rainy days. The experimental site was medium to deep black and clayey in texture, low in medium in organic carbon (0.64%), low in available nitrogen (210.2 kg/ha) , medium in available phosphorus (20.8 kg/ha) and higher in available potash (474.8 kg/ha) and pH range is 7 to 7.5. '*Phule Sai*' variety of chilli was planted in second fortnight of June at 60 x 45 cm which was used for the study. The experiment was laid out in randomized block design with eight treatments and three replications. The treatment comprises of *viz*. butachlor 2.0 kg/ha (50 EC) pre-emergence (pre-emergence application within two days of transplanting), fenoxaprop-p-ethyl 1.0 kg/ha (9.3% w/w) (post-emergence application when weeds are in two to three leaves stage), pendimethalin 0.825 kg /ha (30 EC) pre-emergence (pre-emergence application within two days after transplanting), butachlor 2.0 kg/ha (pre-emergence) + one hoeing + one hand weeding, fenoxaprop-p-ethyl (9.3% w/w). Ec) + one hoeing + one hand weeding, pendimethalin 0.825 kg/ha (pre-emergence) + one hoeing + one hand weeding, weed free check and weedy check. The gross and net plot size were 5.40 x 4.80 m^2 and 4.50 x 3.60 m^2, respectively. Observations on weed counts (number/m^2) and weed dry weight (g/m^2) were taken by sampling randomly at 5 places with the help of 0.25 m^2 quadrants at 60 days and the data were transformed in arcsine values before statistical analysis.

RESULTS AND DISCUSSION

Effect on weed density and weed biomass

The experimental field was infested with broad-leaf and grassy weeds. The prominent weed flora where *Amaranthus spinosus*, *Parthenium hysterophorus*, *Achyranthes aspera*, *Alternanthera triandra*, *Euphorbia hirta*, *Cynodon dactylon*, *Cyperus rotundus*, *Digera arvensis*, *Phyllanthus niruri*. The experiment was dominated by dicot weeds.

Different weed control treatments significantly reduced weed density and their biomass accumulation compared to the weedy check. Significantly lower weed intensity and biomass accumulation were recorded with application of pendimethalin + 1 hoeing + 1 weeding than other treatments and was on par with butachlor + 1 hoeing + 1 weeding. As would be expected, the weed free check and weedy check recorded significantly minimum and maximum weed density and weed biomass, respectively. Weed biomass reflects the growth potential of the weeds and is better indicator of its competitive ability with the crop plants. This might be due to effective control of weeds in early stage by pendimethalin and butachlor in combination with one hoeing and one weeding. The results are analogous to those reported by Rajput *et al.* (2003) and Arvadiya *et al.* (2012)

Weed control efficiency and weed index

Weed control efficiency increased with the adoption of weed control measures over weedy check. Identical increases in weed control efficiency was noted with treatment weed free check followed by pendimethalin, butachlor and fenoxaprop-p-ethyl in combination with one hoeing and one weeding and herbicides alone in respective manner. Weed index is inversely proportional to weed control efficiency in all the treatments. This is due to lower weed population and reduced dry matter production of weeds during initial stage and effective control of later emerged weeds through hand weeding which ultimately provided weeds free environment to chilli. These results are in accordance with the findings of Singh *et al.* (1997) and Mekki *et al.* (2010).

Dry red chilli yield

All the weed control measures resulted in significantly higher dry red chilli yield than weedy check. Weed free check recorded highest values of dry red chilli yield, may be due to least competition on offered by weeds. Application of pendimethalin + 1 hoeing + 1 weeding recorded significantly more dry red chilli yield over various herbicides and its combination with mechanical method of weed

Table 1. Effect of weed control measures on weed density, weed biomass and weed control efficiency in chilli

Treatment	Weed density/m^2								Weed biomass (kg/m^2)				Weed control efficiency (%)			
	2010		2011		2012		Pooled Mean									
	Broad leaf weeds	Grassy weed	Broad -leaf weeds	Grassy weed	Broad -leaf weeds	Grassy weed	Broad -leaf weeds	Grassy weed	2010	2011	2012	Pooled Mean	2010	2011	2012	Pooled mean
Butachlor 2 kg/ha	6.18 (37.7)	2.80 (7.66)	6.09 (36.7)	3.12 (9.33)	6.69 (45.7)	3.44 (11.3)	6.32 (40.0)	3.12 (9.44)	1.07 (0.65)	1.06 (0.62)	1.15 (0.82)	1.09 (0.70)	48.2	53.9	48.6	50.2
Fenoxaprop-p-ethyl 1 kg/ha	6.64 (45.7)	4.26 (17.7)	6.67 (43.3)	4.33 (18.3)	7.10 (50.0)	5.07 (25.3)	6.80 (46.3)	4.55 (20.4)	1.14 (0.80)	1.12 (0.76)	1.20 (0.94)	1.16 (0.83)	35.6	43.8	41.4	40.5
Pendimethalin 0.825 kg/ha	4.97 (24.3)	2.70 (7.00)	5.43 (29.0)	2.43 (5.66)	6.32 (39.7)	2.26 (4.67)	5.57 (31.0)	2.46 (5.8)	1.07 (0.64)	1.03 (0.57)	1.09 (0.69)	1.06 (0.63)	49.1	58.2	57.0	55.1
Butachlor 2 kg/ha + 1 hoeing + 1 weeding	3.98 (12.3)	1.55 (2.00)	4.07 (16.3)	1.68 (2.33)	3.99 (15.7)	2.26 (4.67)	4.01 (14.8)	1.83 (3.00)	0.90 (0.31)	0.89 (0.30)	0.91 (0.33)	0.90 (0.31)	75.4	78.0	79.4	77.8
Fenoxaprop-p-ethyl 1 kg/ha + 1 hoeing + 1 weeding	7.54 (56.7)	2.66 (6.66)	7.05 (49.3)	2.41 (5.33)	7.74 (69.7)	2.67 (6.67)	7.44 (58.6)	2.58 (6.22)	0.94 (0.39)	0.94 (0.38)	1.01 (0.52)	0.96 (0.43)	69.0	72.0	67.5	69.4
Pendimethalin 0.825 kg/ha +1 hoeing + 1 weeding	3.33 (10.7)	1.77 (2.66)	3.07 (9.00)	1.68 (2.33)	3.56 (12.3)	1.86 (3.00)	3.32 (10.7)	1.77 (2.66)	0.83 (0.18)	0.84 (0.21)	0.83 (0.19)	0.83 (0.20)	85.0	84.5	88.0	86.0
Weed free check	1.85 (3.00)	1.34 (1.33)	1.77 (2.66)	1.34 (1.33)	1.95 (3.33)	1.34 (1.33)	1.85 (03.0)	1.34 (1.33)	0.76 (0.07)	0.76 (0.07)	0.76 (0.07)	0.76 (0.07)	94.2	95.0	95.6	95.0
Weedy check	9.77 (95.3)	5.42 (29.0)	1.26 (105)	5.53 (30.0)	10.15 (102.7)	6.01 (35.7)	7.06 (101.0)	5.65 (22.6)	1.32 (1.25)	1.36 (1.36)	1.45 (1.60)	1.38 (1.40)	0.00	0.00	0.00	0.00
LSD (P=0.05)	1.15	0.52	0.74	0.58	0.91	0.41	0.93	0.50	0.26	0.36	0.10	0.24	-	-	-	-

Original values are given in parentheses

Table 2. Effect of weed control measures on weed index, dry red chilli, monetary returns and B:C ratio in chilli

Treatment	Dry red chilli yield (t/ha)				Net returns (x10^3 `/ha)				B : C ratio			
	2010	2011	2012	Pooled mean	2010	2011	2012	Pooled mean	2010	2011	2012	Pooled mean
Butachlor 2 kg/ha	1.04	0.82	1.11	0.99	20.34	15.61	41.40	25.78	1.48	1.37	1.99	1.61
Fenoxaprop-p-ethyl 1 kg/ha	0.96	0.77	0.98	0.90	15.42	12.04	31.35	19.60	1.37	1.29	1.75	1.47
Pendimethalin 0.825 kg/ha	1.17	0.96	1.28	1.14	27.90	25.34	53.77	35.67	1.66	1.60	2.28	1.85
Butachlor 2 kg/ha + 1 hoeing + 1 weeding	1.45	1.19	1.76	1.46	37.16	33.88	83.22	51.42	1.76	1.69	2.70	2.05
Fenoxaprop-p-ethyl 1 kg/ha + 1 hoeing + 1 weeding	1.32	1.10	1.5	1.31	30.20	27.65	63.50	40.45	1.62	1.56	2.30	1.83
Pendimethalin 0.825 kg/ha + 1 hoeing + 1 weeding	1.59	1.12	1.88	1.56	46.16	35.84	91.85	57.95	1.94	1.73	2.87	2.18
Weed free check	1.65	1.37	2.01	1.68	29.00	25.90	80.75	45.22	1.41	1.37	2.15	1.65
Weedy check	0.64	0.40	0.65	0.56	2.22	-8.49	12.67	2.13	1.06	0.76	1.35	1.06
LSD (P=0.05)	0.30	0.16	0.25	0.24	18.46	12.28	12.39	14.38	-	-	-	-

control, while it was on par with butachlor + 1 hoeing + 1 weeding. Among the herbicides, pre-emergence application of pendimethalin was found effective for control of weeds in chilli than butachlor as a pre-emergence and fenoxaprop-p-ethyl as post-emergence. This may be due to least competition of weeds with chilli for nutrient, light, moisture and space at crucial growth stages. In pendimethalin + 1 hoeing + 1 weeding, treatment, the rate of NPK absorption cumulatively helped the crop plants to produce more surface area for high photosynthetic rate as well as maximum translocation of photosynthets from source to sink, subsequently resulted in improvement in yields. Kunti *et al.* (2012) also reported significant increase in fruit yield of chilli was recorded with pendimethalin (1 kg/ha) as pre-emergence with one hand weeding at 45 DAT over rest of herbicides combination. These finding are in agreement with the earlier result of Deshpande *et al.* (2006), Rajput (2003) and Saini and Walia (2012).

Economics

Maximum gross returns were obtained in weed free check which was at par with pendimethalin + 1 hoeing + 1 weeding and significantly superior over rest of treatments. However, significantly lower gross returns were obtained from weedy check. Pre-emergence application of pendimethalin + 1 hoeing + 1 weeding gave maximum net returns which was on par with butachlor + 1 hoeing + 1 weeding and significantly superior over rest of weed control methods except weed free check. B:C ratio was found higher in treatment pendimethalin + 1 hoeing + 1 followed by butachlor + 1 hoeing + 1 weeding while lowest values were recorded in the weedy check. Due to excellent control of complex weed flora without any adverse effect on crop growth weed free treatment registered lower monetary returns B:C ratio due to high cost involved in repeated weedings to keep crop weed free despite of having higher dry chilli yield.

It was concluded that for effective and economic weed control in chilli, use of pendimethalin + 1 hoeing + 1 hand weeding or butachlor + 1 hoeing + 1 hand weeding is the best option.

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Integrated weed management in turmeric

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ABSTRACT

Field experiments were conducted during *Kharif* 2012-13 and 2013-14 at the Research farm of Rajendra Agricultural University Bihar, Pusa to find out effective and economical approaches for weed management in turmeric. The grassy weeds present in the experimental field were *Cynodon dactylon, Echinocloa colona* and *Dactyloctenium aegyptium*. *Cyperus rotundus* was only sedge and *Chenopodium album, Cannabis sativa, Parthenium hysterophorus, Phyllanthus niruri* and *Caesulia auxillaris* were the broad-leaved weeds. The lowest weed count, weed dry weight and the highest number of tillers per plant, number of leaves per plant and rhizome yield of turmeric were recorded by the weed free (hand weeding at 25 and 45 DAS). The highest rhizome yield (52.05 t/ha) was recorded under weed free which was statistically at par with atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha+ metsulfuron 4 g/ ha (50.65 t/ha). The highest weed control efficiency (84.62%) was recorded under the treatment weed free which was closely followed by atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha+ metsulfuron 4 g/ha (78.9%) and pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha (78.6%). The highest B:C ratio was recorded with application of atrazine 0.75 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha, which was statistically at par with weed free, pendimethalin 1.0 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha and metribuzin 0.7 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4g/ ha.

Key words: Herbicide, Integrated weed management, Straw mulch, Turmeric

Turmeric (*Curcuma longa* L.) is a major spice crop, occupying 6% of the total area under spices and condiments in India. It is grown for its rhizomes, which are mainly used as a spice for flavouring and colouring many foods.Turmeric is one of the second most important spice crops after chilli. India accounts for 78% in world production and 60% in world export share (Angles *et al*. 2011). Its cultivation provides avenues for crop diversification, value addition and revenue generation. Though India leads in production of turmeric with 75% of global production, its average productivity is quite low, mainly due to the competition offered by weeds which reduce yield by 30-75% (Krishnamurthy and Ayyaswamy 2000). Slow initial growth and its poor canopy development provide an ideal environment for weeds to grow and compete with the crop. Heavy infestation of weeds comprising of grasses, sedges and broad-leaved weeds poses a big challenge for turmeric production in India. Farmers have to go for sequential weeding, which adds to the cost of weed management. Non-availability of labour hinders the timely removal of weeds. Pre-emergence herbicides *viz.* pendimethalin (Anil Kumar and Reddy 2000), atrazine (Singh and Mahey 1992) and metribuzin (Gill *et al.* 2000) help save the crop from severe weed competition at an early age. Straw mulch is another approach adopted by the farmers that conserves soil moisture and modifies soil temperature for benefit of crop, besides controlling weeds (Mahey *et al.* 1986). Mulching suppresses weed growth and improves crop yield (Hossain 2005). This necessitates developing effective and economically better integrated weed-control practices for realizing high productivity of turmeric.

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MATERIALS AND METHODS

Field experiment was conducted during *Kharif* 2012-13 and 2013-14 at the Research farm of Rajendra Agricultural University Bihar, Pusa. The experiment was carried out in randomized block design with three replications. The variety used was '*Rajendra Sonia*'. The soil of experimental field was sandy loam and low in organic carbon (0.42%) and available nitrogen (208 kg/ha), available phosphorus (18.9 kg/ha) and potassium (108.5 kg/ha) with pH 8.3. The experiment comprised of 10 weed management treatments. The treatments were metribuzin 0.7 kg/ha *fb* two hoeing, metribuzin 0.7 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4g/ha, metribuzin 0.7 kg/ha *fb* straw mulch 10 t/ha *fb* one

HW, pendimethalin 1.0 kg/ha *fb* two hoeing, pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha+ metsulfuron 4 g/ha, pendimethalin 1.0 kg/ha *fb* straw mulch 10 t/ha *fb* one HW, atrazine 0.75 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha, atrazine 0.75 kg/ha *fb* straw mulch 10 t/ha *fb* one HW, weed-free and weedy check. Meribuzin, pendimethalin and atrazine were applied as pre-emergence and fenoxaprop + metsulfuron were applied at 3-4 leaf stages of weeds. The paddy straw mulch was applied immediately after planting as per treatment. The recommended dose of fertilizer *i.e.* 150-60-120 kg N-P_2O_5-K_2O/ha along with 30 t/ha well decomposed FYM were applied during both the years. During both the years of study, healthy rhizomes were planted on 18th June at 30 x 20 cm spacing. Light irrigations were applied frequently till the crop sprouted. The recommended package and practices of turmeric cultivation was adopted. Herbicides were applied with the help of knapsack sprayer fitted with flat fan nozzle. Two hand weedings were given at 25 and 45 days after sowing. The weed population and weed dry weight were recorded at 60 days after sowing.

RESULTS AND DISCUSSION

Effect on weeds

The major weed flora observed in the experimental field predominantly consisted of three grass species, five species of broad leaved weed and a sedge weed. The grassy weeds present in the experiment were *Cynodon dactylon, Echinocloa colona* and *Dactyloctenium aegyptium. Cyperus rotundus* was only sedge and *Chenopodium album, Cannabis sativa, Parthenium hysterophorus, Phyllanthus niruri* and *Caesulia auxillaris* were the broad-leaved weeds. The lowest weed count was recorded by weed free and the lowest weed dry weight was recorded by the weed free, which was statistically at par with atrazine 0.75 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha and pendimethalin 1.0 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha. Effective control of weeds in turmeric has been reported with application of atrazine 0.62 kg/ha (Singh and Mahey 1992), pendimethalin 1.0 kg/ha (Anil Kumar and Reddy 2000) and metribuzin 0.70 kg/ha (Gill *et al.* 2000). The highest weed control efficiency (84.6%) was recorded under the treatment weed free (HW at 25 and 45 DAS), which was closely followed by application of atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ ha + metsulfuron 4 g/ha, (78.9%) and pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha (78.6%).

Effect on crop

Growth attributes like plant height, number of tiller per plant and leaf area development are the reflective process of effective utilization of resources in a better crop production environment. Conducive crop growth environment with minimum stresses due to biotic factors like less weed competition reflects further on better yield attributes of crops. Dramatic variations in growth and yield attributes of turmeric was noticed due to different weed control methods primarily associated with change in weed flora

Table 1. Effect of different weed management treatments on weed parameters, yield attributes and yield of turmeric (mean data of two years)

Treatment	Weed count (no./m^2) 60 DAS	Weed dry wt. (g/m^2) 60 DAS	WCE (%) 60 DAS	Plant height (cm)	No of tillers/ plant	No of leave/ plant	Rhizome yield (t/ha)
Metribuzin 0.7 kg/ha *fb* two hoeing	12.76	22.9	65.2	127.1	3.54	13.4	41.3
Metribuzin 0.7 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ ha	7.11	15.6	76.2	127.5	4.27	16.3	47.8
Metribuzin 0.7 kg/ha *fb* straw mulch 10 t/ha *fb* one HW	10.87	21.8	66.8	126.1	3.71	14.3	44.9
Pendimethalin 1.0 kg/ha *fb* two hoeing	12.38	23.1	64.8	128.8	3.65	13.5	42.7
Pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha	6.79	14.1	78.6	129.5	4.37	15.9	48.1
Pendimethalin 1.0 kg/ha *fb* straw mulch 10 tones /ha *fb* one HW	10.65	19.4	70.5	130.9	3.85	15.3	46.0
Atrazine 0.75 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha	6.28	13.9	78.9	129.4	4.60	16.4	50.6
Atrazine 0.75 kg/ha *fb* straw mulch 10 tones/ha *fb* one HW	9.63	17.2	73.8	125.8	4.25	15.7	47.9
Weed-free	4.21	10.1	84.6	133.9	4.71	18.0	52.0
Weedy check	36.30	65.8	-	118.8	2.62	11.3	29.8
LSD (P= 0.05)	1.30	4.9	-	8.1	0.64	3.4	3.5

composition with varying weed density and weed dry weight. The highest plant height was observed in the weed free treatment which was statistically at par with all the treatments except weedy check, which may be attributed to better weed control with favourable soil environment that might have resulted in reduced crop-weed competition for the growth factors such as light, space and nutrients which in turn helped in efficient photosynthetic activity recording taller plants. Decreasing weed density result in increased plant growth was supported by Hashim *et al.* (2003) and Jan *et al.* (2004). Weedy check showed significant reduction in plant height. This was attributed to suppressing effect of uncontrol weeds by weedy check on crop plants similar findings have been reported by Chander *et al.* (1997). From the experimental results, it is evident that high competition of weeds reduced the input availability to plants, thus reduced the plant height to a greater extent. The highest number of tillers per plant and number of leaves per pant were recorded by weed free treatment which was statistically at par with application of atrazine 0.75 kg/ha *fb* straw mulch 10 t/ha *fb* one HW, atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha, pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha+ metsulfuron 4 g/ha and metribuzin 0.7 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4g/ha and significantly superior over rest of the treatments. However, in case of number of leaves per plant, application of pendimethalin 1.0 kg/ha *fb* straw mulch 10 t/ha *fb* one hand weeding was also at par with weed free. This might be due to very effective suppression of weed flora by the pre-emergence application of herbicide at early stage of the crop and subsequent removal of late emerging weeds by weed free and post emergence application of herbicides and eventually resulted in higher number of tiller and higher number of leaves per plant. This finding is in conformity with the results of Channappagoudar *et al.* (2007). The highest rhizome yield (52.05 t/ha) was recorded under the treatment weed free which was statistically at par with atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha (50.65 t/ha) and significantly superior over rest of the treatments. The lowest rhizome yield was recorded under weedy check. Kuar *et al*. (2008) found that uncontrolled weed growth resulted in 63.9% reduction in average rhizome yield of turmeric. Weedy check reduce the rhizome yield by 80 per cent due to severe weed competition, particularly due to the presence of grasses and broad leaved weeds as weed competition could lower the number of rhizome per plant and rhizome weight considerably in turmeric.(Ratnam *et al.* 2012).

Nutrient depletion by weeds

Weeds in the weedy check remove 117.8, 21.2 and 175.3 kg/ha N, P and K respectively, which were the highest, and 63.6, 62.7 and 73.9% of total N, P and K removed by both crop and weeds. The corresponding figures were only 4.7, 5.2 and 9.6% for weed free which was closely followed by 8.8, 6.9 and 10.7% for atrazine at 0.75 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron at 4 g/ha at 20 DAS, pendimethalin at 1.0 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron at 4 g/ha at 20 DAS and metribuzin at 0.7 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron at 4 g/ ha at 20 DAS. This indicates that where the removal of nutrients by weeds was more, the corresponding uptake by the crop was less and *vice versa*. Nutrient uptake by weeds followed a similar trend as that of dry weight of weeds.

Table 2. Nutrient uptake (kg/ha) by crop and nutrient depletion by weeds (kg/ha) under different weed control treatments (mean data of two years)

Treatment	Nutrient uptake by crop						Nutrient depletion by weed		
	Rhizome			Above-ground part					
	N	P	K	N	P	K	N	P	K
Metribuzin 0.7 kg/ha *fb* two hoeing	162.4	24.2	170.9	70.3	9.1	36.5	44.2	15.6	41.1
Metribuzin 0.7 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha	169.3	30.2	175.6	75.2	11.1	40.9	33.2	7.50	32.8
Metribuzin 0.7 kg/ha *fb* straw mulch 10 t/ha *fb* one HW	165.4	26.8	172.6	73.4	9.70	37.5	39.3	12.1	37.9
Pendimethalin 1.0 kg/ha *fb* two hoeing	164.2	25.5	172.0	72.5	9.30	37.2	41.7	13.2	38.5
Pendimethalin 1.0 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha	170.7	30.8	176.4	75.8	11.3	41.6	28.6	5.10	29.3
Pendimethalin 1.0 kg/ha *fb* straw mulch 10 t/ha *fb* one HW	167.6	28.4	174.5	74.2	10.1	38.7	38.8	11.2	37.5
Atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha	172.4	31.7	178.8	77.4	12.6	42.4	24.2	3.30	26.4
Atrazine 0.75 kg/ha *fb* staw mulch 10 tone/ha *fb* one HW	168.2	29.1	175.3	74.9	10.7	39.8	35.4	9.10	34.6
Weed-free (hand weeding at 25 and 45 DAS)	175.2	34.8	180.3	178.7	14.2	43.6	17.4	2.70	23.8
Weedy check	37.7	6.5	45.3	29.6	6.10	16.7	117.8	21.2	175.3
LSD (P= 0.05)	13.6	4.8	32.7	7.6	2.2	3.3	3.10	4.20	8.90

Table 3. Economics of different weed control treatments (mean data of two years)

Treatment	Net returns (x10^3 `/ha)	B:C ratio
Metribuzin 0.7 kg/ha *fb* two hoeing	175.10	1.54
Metribuzin 0.7 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha	230.93	2.23
Metribuzin 0.7 kg/ha *fb* straw mulch 10 t/ha *fb* one HW	191.65	1.56
Pendimethalin 1.0 kg/ha *fb* two hoeing	185.40	1.63
Pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron 4 g/ha	233.53	2.26
Pendimethalin 1.0 kg/ha *fb* straw mulch 10 tone/ha *fb* one HW	199.50	1.63
Atrazine 0.75 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha	252.28	2.47
Atrazine 0.75 kg/ha *fb* staw mulch 10 tones/ha *fb* one HW	213.70	1.76
Weed-free (hand weeding at 25 and 45 DAS)	252.35	2.25
Weedy check	108.60	1.09
LSD (P= 0.05)	22.55	0.28

Nutrient uptake by crop

Weed free recorded the highest utilization of 175.2 kg N, 34.8 kg P and 180.3 kg K/ha by the rhizomes (Table 2). In the weedy check plots, rhizomes utilized 37.7 kg N, 6.5 kg P and 45.3 kg K/ha, which were only 21.5, 18.7 and 25.1% when compared with weed free treatment. Effective control of weeds over a longer period with herbicides combination and herbicide with straw mulch combination helped the crop to produce more dry matter and grab a major share of nutrients, leaving very less for the weeds. As the nutrient content did not vary among different weed control treatments, the utilization of nutrients followed a trend similar to that of rhizome yield. Nutrient uptake by above ground parts of the crop showed a trend similar to that recorded for rhizomes.

Economics

The highest net return was recorded by the weed free treatment which was statistically at par with pre-emergence application of atrazine 0.75 kg/ha followed by application of fenoxaprop at 67 g/ha + metsulfuron 4 g/ha at 3-4 leaves stage, pendimethalin 1.0 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha and metribuzin 0.7 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha. However, the highest B:C ratio was recorded with atrazine 0.75 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha which was statistically at par with weed free, pendimethalin 1.0 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4 g/ha and metribuzin 0.7 kg/ha *fb* fenoxaprop at 67 g/ha + metsulfuron 4g/ha.

It may be concluded that pre-emergence application of atrazine at 0.75 kg/ha or pendimethalin 1.0 kg/ha or metribuzin 0.7 kg/ha followed by application of fenoxaprop 67 g/ha + metsulfuron 4 g/ha at 3-4 leaves stage was adjudged very effective for controlling weeds and for attaining highest productivity and profitability in turmeric.

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Control of Italian ryegrass by pre- and post-emergence herbicides in barley

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ABSTRACT

In two glasshouse experiments, range of herbicides was applied as pre- or post-emergence to examine their effect in controlling Italian ryegrass (*Loluim multiflorum*) grown with barley. In experiment 1, treatment by one of the three herbicides named, chlorotoluron, controlled Italian ryegrass (*L. multiflorum)* \significantly (P<0.01). However, the three herbicides differed significantly (P<0.05) in their dose. Chlorotoluron gave effective control of *L. multiflorum* at dose of 2 kg/ha with less than 10% of mean of ryegrass plants/pot survived and only a slight damage on barley was observed. Isoproturon and methabenzthiazuron were less effective in controlling the weed as more than 30% of *L. multiflorum* plants survived at different doses applied while barley plants were not affected significantly by the chemicals. In experiment 2, two herbicides diclofop-methyl or pendimethalin were applied as post-emergence treatment. The herbicide diclofop-methyl achieved an effective control of Italian ryegrass associated with barley even at rates as low as 0.25 kg/ha. Mean of ryegrass numbers and fresh weight (20 plants)/pot were decreased significantly and only few plants of *L. multifloruim* survived at 1 kg/ha, however, they were very small in size and badly damaged. Barley plants were not damaged by diclofop-methyl treatments at all applied doses. Pendimethalin created a significant effect (P=0.05) on ryegrass numbers/pot or fresh weight (20 plants/pot) at doses, 0.125 or 0.25 kg/ha. However, at 1 kg/ha there was about 40% reduction in weed numbers/pot and its fresh weight (20 plants/pot), which indicate low control effect of this chemical. There was no evidence of damage to barley plants by pendimethalin at all tested rates.

Key words: Barley, Italian ryegrass, Pre- and post-emergence herbicides

Barley (*Hordeum vulgare*) is one of the oldest cultivated cereal grains in the world (Baik and Ullrich 2008). It is called the founder crop of old world Neolithic food production and one of the earliest domesticated crops. It is considered to be the main cereals of the Mediterranean belt of agriculture (Zohary and Hopf 2000, Zohary *et al.* 2012). Italian ryegrass (*Lolium multiflorum)* is one of the most troublesome weeds in winter wheat production (Nandula *et al*. 2007). It is a herbaceous annual, biennial or perennial grass that is grown for silage or as a cover crop. It is also grown as an annual lawn grass and ornamental grass (Fransen 1994). It readily naturalizes in temperate climates and can become a noxious weed in agricultural areas or an invasive species in native habitats.

Manual weeding is labor intensive and possible only on small scale while, mechanical weed control is possible in row cropping and leaves intra row weeds. Herbicides offer the most practical, effective and economical means of reducing early weed competition and crop production losses (Worthing 1991, Troxler *et al.* 2002, Brecke and Stephenson 2006).

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Therefore, present study was undertaken the find out the suitable pre- and post-emergence herbicides the manager for italian ryegrass.

MATERIALS AND METHODS

Two experiments were carried out in the glasshouse with temperature ranging between 14 to 20 ^{0}C. Ten cm^2 pots were filled with John Innes No. 1 compost. Fifty seeds/pot of *Lolium multiform* were sown on the surface and 10 seeds/pot of barley cv. '*Glost*' were sown at 2 cm deep. In experiment 1, herbicides, methabenzthiazuron, isoprotoron and chlorotoluron were applied as pre-emergence at 5 different doses, methabenzthiazuron at 0, 1, 1.5, 2, 3 kg/ha, isoproturon 0, 0.5, 1, 1.25, 1.5 kg/ha and chlorotoluron at 0, 1.5, 2, 2.5, 3 kg/ha. The chemicals were applied three days after sowing. There were four replication of each treatment with a total of 60 pots. Observations were taken two weeks from herbicides application by counting the number of plants of *L. multiflorum* and barley and taking the fresh weight/20 plants of the weed and the crop. In experiment two, herbicides diclophop-methyl and pendimethalin were applied as a post-emergence treatment at rates of 0, 0.125, 0.25, 0.5 and 1 kg/ha.

The herbicides were applied at the two leaf stage of the crop. There were four replicates of each treatment with a total of 40 pots. Observations in experiment two were taken four weeks from herbicides application by counting the number of plants of *L. multiflorum* and barley and taking the fresh weight/20 plants of the weed and the crop. In both experiments, herbicides were sprayed with a hand sprayer and were applied inside the glasshouse in a stable weather conditions. Regular watering was given during experiments. Data were analyzed statistically in SAS program.

RESULTS AND DISCUSSION

Italian ryegrass was controlled significantly ($p<0.01$) by all of the herbicides used but the three herbicides differed significantly ($p<0.05$) in their effect. The application of chlorotoluron as a pre-emergence treatment gave effective control of *L. multiflorum* specially at dose of 2 kg/ha (Fig. 1 and 2). Only four ryegrass plants emerged out from 50 sown seeds at dose of 2 kg/ha. Slight damage on barley was observed.

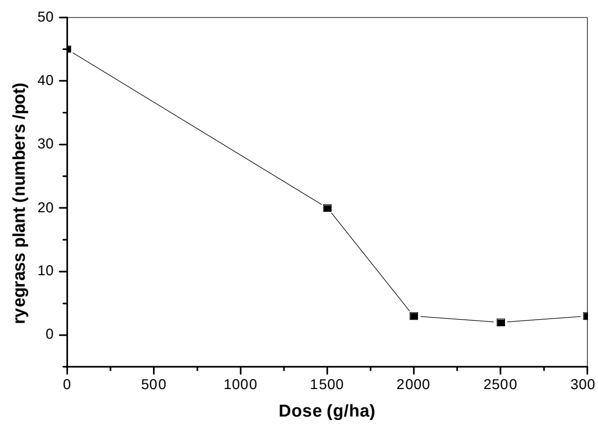

Fig. 1. Effect of chlorotoluron on annual ryegrass plants (numbers/pot)

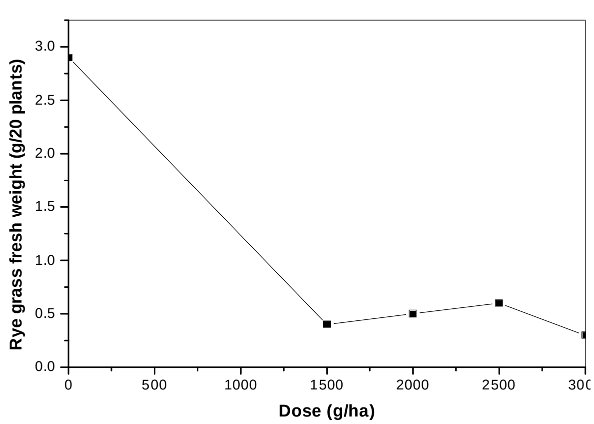

Fig. 2. Effect of chlorotoluron on annual ryegrass fresh weight (g/20 plants

Application of isoproturon as a pre-emergence herbicide gave some control to *L. multiflorum* but was less effective than the herbicide chlorotoluron as more than 30% of *L. multiflorum* seeds emerged escaping the chemical effect at different doses (Fig. 3 and 4). Barley was not affected significantly by the chemical.

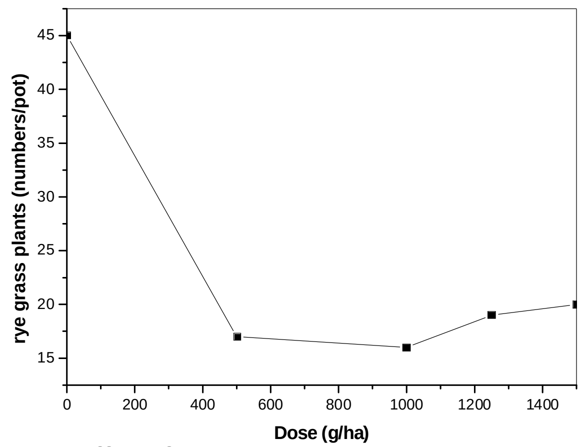

Fig. 3. Effect of isoproturon on annual ryegrass plants (numbers /pot)

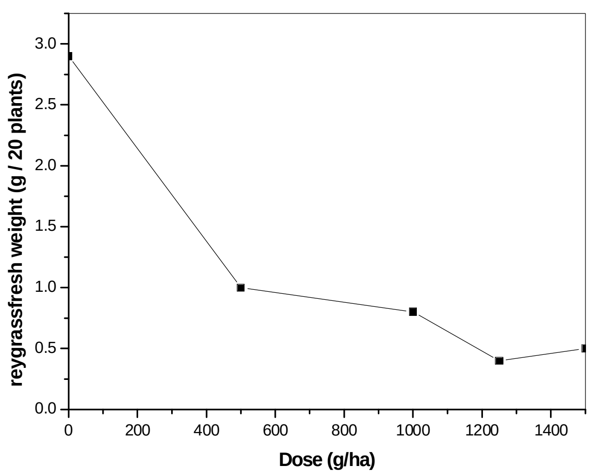

Fig. 4. Effect of isoproturon on annual ryegrass fresh weight (g/20 plants)

Application of the herbicide methabenz-thiazuron as pre-emergence treatment gave some control of *L. multiflorum* but again was less effecteve than the herbicide chlorotoluron. The most effective dose was at 2 kg/ha diallowing about 60% of *L. multiflorum* to emerge. Barley was not affected significantly again by the chemical.

Application of the herbicide diclofop-methyl as a post-emergence herbicide gave effective of *Lolium multiflorum* even at low rates. 0.25 kg/ha of the chemical as plant numbers/pot and plant fresh weight/20 plants were decreased by about 50 % (Fig. 7 and 8). Few plants survived at dose of 1.0 kg/ha and these were very small and damaged. Barley was undamaged by any of the diclofo-methyl treatments.

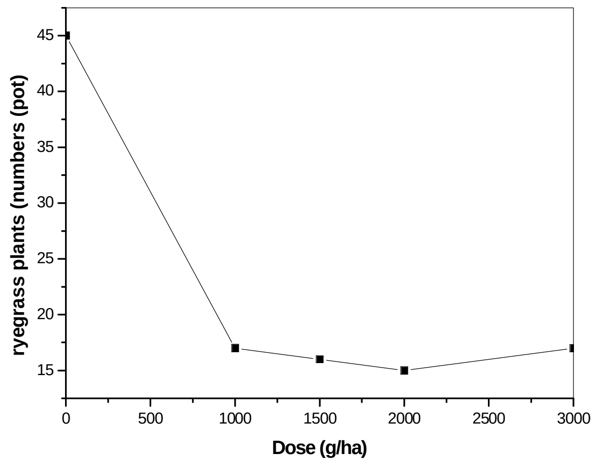

Fig. 5. Effect of methabenzthiazuron on annual ryegrass plants (numbers /pot)

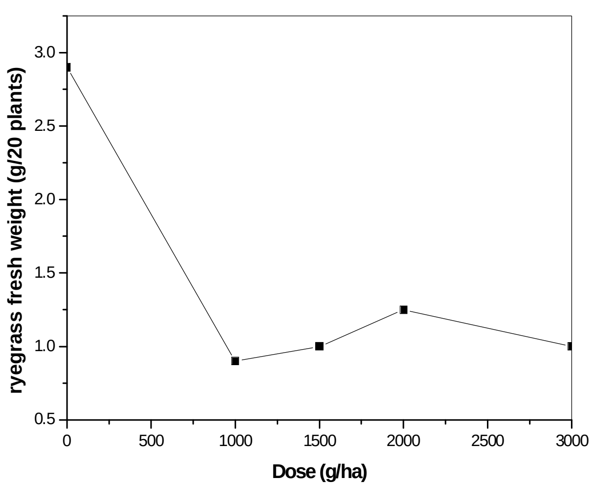

Fig.6. Effect of methabenzthiazuron on annual ryegrass fresh weight (g/20 plants)

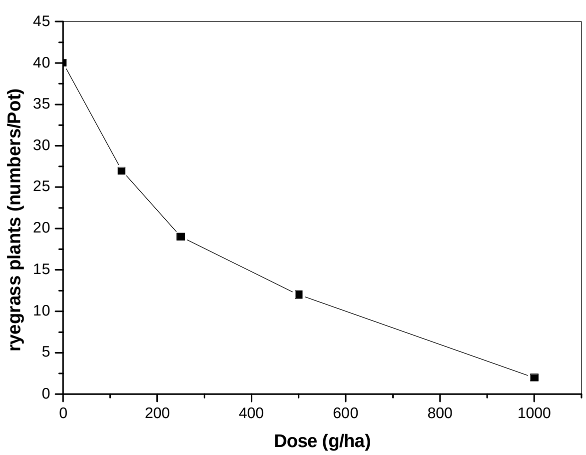

Fig. 7. Effect of diclofop-methyl on ryegrss (numbers)

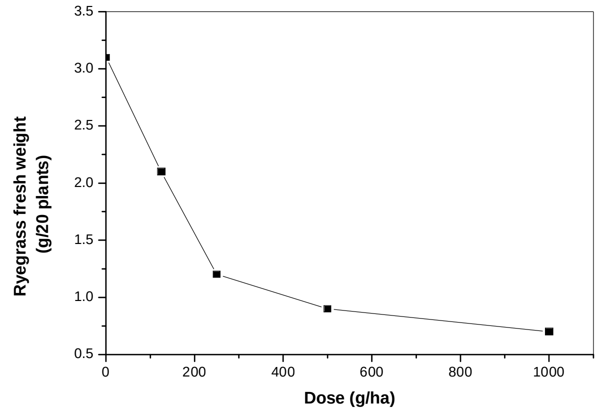

Fig. 8. Effect of diclofop-methyl on ryegrss fresh weight (g/20 plants)

Application of the chemical pendimethalin as post-emergence herbicide at 0.125 and 0.25 kg/ha had little effect on *L. multiflorum* plants numbers or fresh weight. However, at 1.0 kg/ha, there was about 50% reduction in plant numbers and plant fresh weight/20 plants (*i.e.* 75% growth reduction) (Fig. 9 and 10). There was no evidence of damage to barley by the herbicide pendimethalin at any of the tested rates.

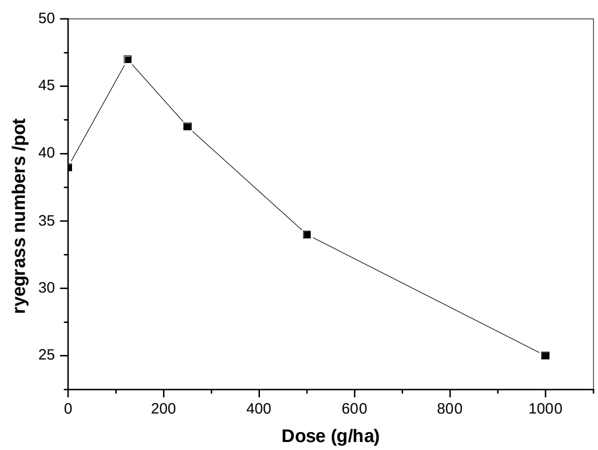

Fig. 9. Effect of pendimethalin on ryegrass numbers

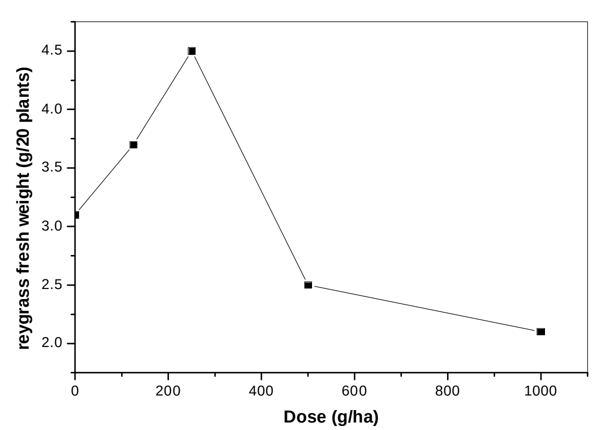

Fig. 10. Effect of pendimethalin on ryegrass fresh weight (g/20 plants)

Italian ryegrass (*Lolium multiflorum*) was controlled significantly ($p<0.01$) by the herbicides; chlorotoluron, isoproturon and methabenzthiazuron.

Application of chlorotoluron as a pre-emergence treatment gave effective control of *Lolium multiflorum* especially at dose of 2.0 kg/ha. This herbicide was also mentioned to be effective in controlling grass weeds in cereals (Saghir 1977). Tag-El-Din *et al.* (1989) reported excellent control of weeds associated with wheat at dose of 2.5 kg/ha of chlorotoluron when applied as post-emergence treatment. However, they reported sever symptoms affected wheat growth and yield. Slight effect of the chemical was seen on barley which suggest the better use of this chemical as pre-emergence treatment. When isoproturon was applied as a pre-emergence herbicide, it gave some control to *L. multiflorum* but was less effective than chlorotoluron as more than 30% of *L. multiflorum* seeds emerged escaping the chemical effect at different doses. Barley was not affected significantly by the chemical. It was reported to control other grass weeds such as sterile oat (*Avena sterllis*) but was less effective in controlling *Lolium* spp. (Ponce and Senas 2006).

Application of the herbicide methabenzthiazuron as pre-emergence treatment gave some control of *L. multiflorum* but again was less effective than the herbicide chlorotoluron. The most effective dose was at 2.0 kg/ha preventing about 60% of *L. multiflorum* to emerge. Barley was not affected significantly again by the chemical. Methabenzthiazuron gave good weed control in potato fields when applied as a pre-emergence treatment at 1-1.5 kg/ha resulting in a higher crop yield (Maliwal and Jain, 1991). Similar result was achieved by the application of methabenzthiazuron as pre-emergence treatment in pea field (Sandhu *et al.* 1980).

The application of the herbicide diclofop-methyl as a post-emergence herbicide gave effective control of *L. multiflorum* even at low rates. At 0.25 kg/ha, plant numbers/pot and plant fresh weight/20 plants were decreased by about 50%. Few plants survived at dose of 1.0 kg/ha. Barley was undamaged by any of the diclofo-methyl treatments. Good control of *Lolium* spp in wheat by diclofo-methyl at rates ranging from 0.375 to 1.5 kg/ha has been reported Khodayari *et al.* 1983, Tag-El-Din *et al.* (1989).

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Use of botanical herbicides in system intensification

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ABSTRACT

Ten field experiments were conducted at Viswavidyalaya farm during 2004 - 14 in system intensification methodology on SRI rice (*Oryza sativa*), groundnut (*Arachis hypogea*), soybean (*Glycine max*), rapeseed (*Brassica campestris*), sesame (*Sesamum indicum*), greengram (*Vigna mungo*) and blackgram (*Vigna aureus*) crops grown in inceptisols following annual planning of weed management to find out the efficacy of botanical extracts. In all experiments varied treatments 5-12 numbers were used in RBD with 3-5 replications in plot size 3-4 x 5 m. The botanical extracts (BE) of different plants with 0.25% Tween 80 surfactants were used at 5, 10 and 100% at pre-emergence (PE) in moist soil along with two mechanical weeding (MW) at 20 and 40 DAP. Weedy check (WC), hand weeding (HW) at 20 and MW at 40 days after planting (DAP), pre-emergence (PE) herbicides at 1-2 DAP pretilachlor at 500 g/ha, alachlor at 1500 g/ha or pendimethalin at 750 g/ha + MW at 30 DAP and post-emergence (POE) herbicides quizalofop-ethyl or fenoxaprop-p-ethyl at 50 g/ha at 20 DAP + MW at 40 DAP were also used in different crops as standard check. The experiments on rapeseed and soybean during 2004-05 showed PE *Eucalyptus* leaf extract attributed 11.2% higher seed yield over WC besides two HW and pendimethalin. During 2010-11 in experiment on SRI rice, the grain yield was 6.35 t/ha in HW, 5.35 t/ha in CC, 5.16 t/ha in *Tectona* methanol extract while 3.44 t/ha in WC. In another experiment during 2010-11 on sesame, green and blackgram, the botanical extract of *Ageratum conyzoides* recorded higher growth and yield in sesame and blackgram while *Ocimum sanctum* extract among the botanicals in greengram exhibited higher harvest index, oil content and also soil nutrient status. In groundnut during 2012, average pod yield of botanical treatments was 32.5% (summer) and 42.5% (*Kharif*) which was higher than WC. Experiment on SRI rice during 2012-13 revealed that maximum WCE was obtained from HW (91%) followed by chemical control CC (84%) and BE (78%) compared to three MW (67%), two MW (53%) over WC. The mean grain yield data showed that HW recorded 88% followed by CC (79%), BE (76%), three MW (67%) and two MW (36%) over control. The maximum WCE was obtained from HW (91%) followed by CC (84%) and BE (78%) compared to 3 MW 67% and 2 MW 53%.

Key words: Botanical herbicides, System intensification, Weed management

The demand for food and processed commodities is increasing due to growing population and rising per capita income. Global food demand is expected to be doubled by 2050 while production environment and natural resources are continuously shrinking and deteriorating. Food crisis has aggravated further because of climate change and diversion of arable lands to urbanization, industrialization and also for producing bio-fuel. About 30% global emissions leading to climate change are attributed to agricultural activities, including land-use changes. Indian agriculture contributes to 8% global agricultural gross domestic product to support 18% of world population on only 9% of world's arable land and 2.3% of geographical area (Vision 2030, ICAR). There are projections that demand for food grains in India would increase to 345 mt in 2030. Hence in the next 15 years, production of food grains needs to be increased at the rate of around 5 mt annually, which is a challenge to agriculturists.

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In such situation 'System of Intensification', using integrated seed, nutrient, water, pest and quality management, is one of the possible alternatives. Biological management for eco safe soil and plant health is the basic concept of this methodology (Uphoff 1999, Ghosh 2014). The production losses due to pests are 33% and the major pest weed plant alone causes 11.5 and 12.5% global and national production losses (Ghosh *et al.* 2013). The climate change effect on biodiversity changes was observed during National Invasive Weed Surveillance (NIWS) Programme (2008-10) launched by Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India through Directorate of Weed Research, Indian Council of Agricultural Research (ICAR). More occurrence of invasive alien weed pest is posturing further threat to pest management and thereby food security (Final Report, NIWS, 2008-10). Because of easy availability and cheaper than hand weeding, the chemical weed management, has been more accepting by the farmers. Recent research under Rastriya Krishi Vikash Yajona (RKVY) Project, Government of West Bengal (Jana *et al.* 2011, Nongmaithem *et al.* 2011, Ghosh *et al.* 2012) indicated that biological management is more eco safe and less costly than chemical herbicides and would be more acceptable in system intensification (Ghosh *et. al.* 2014). The annual planning of weed management is more acceptable in system intensification because of its two basic concepts "reducing seed bank before planting and improve plant health by minimizing weed competition during critical crop weed competition".

MATERIALS AND METHODS

Ten field experiments were conducted at Viswavidyalaya Farm during 2004-2014 on SRI rice (cv.*IET 4786*), groundnut (cv.*JL 24*), soybean (*cv.Bragg*), rapeseed (cv.*B-9*), sesame (*cv.IS-5*), green (cv.*B-1*) and blackgram (cv.*WBU 108*) crops following the annual planning of weed management concept to find out the integrated efficacy of botanical extracts with mechanical weed management besides the pilot trials through UG and PG students practical classes on wasteland during 2002-2015. The following packages of annual planning of weed management were used in these experiments:

Prevention: Use of our own seeds instead of imported seeds to stop invasion of alien weeds and diversification of crops (legume crops in sequence or as intercrop or even as guard crop was used with main crop wherever possible to improve soil health).

Pre-planting care: When more than two months fallow period was available between the two main crops, cover legume crops like *Vigna* in aerobic and *Sesbania* in anaerobic were grown and incorporated at 35-50 DAS before the planting of main crop. Whenever less than one month fallow period in between two crops was available, ready mixture of nonselective 71 SG glyphosate + oxyfluorfen 23.5 EC at 2 g/litre water was used and field crops were sown at least 2-3 weeks after application of these nonselective chemicals. During land preparation *Cyperus* nuts, tubers and other weed residues were removed as far as possible.

During crop growing: At moist soil, PE ecosafe green labeled organic botanical or selective chemical herbicides followed by two mechanical weeding (weeder in anaerobic and wheel hoe in aerobic ecosystem) were used in these experiments. To avoid mixing of weed seeds with crop seeds weed plants were removed as far as possible before harvesting of crop.

The experimental soil was neutral sandy loam with moderate water holding capacity. The average annual rainfall was around 120 cm of which 80% was during June-October months. In all experiments, varied treatments (5-12 numbers) were used using RBD with 3-5 replications and in plot size of 3-4 x 5 m. The crop wise recommended fertilizer (NPK) doses were used along with 2 t/ha neem cake in each experiment. The botanical extracts (BE) of *Tectona grandis* (leaf), *Eucalyptus cameldulensis* (leaf), *Bambusa vulgaris* (root and leaf), *Calotropis procera* (young twigs), *Cucumis sativus* (matured plants) and young plants of *Parthenium hysterophorus*, *Blumea lacera*, *Ageratum conyziodes*, *Ocimum sanctum*, *Physalis minima*, *Cyperus difformis* and *Echinochloa colona* adding 0.25% Tween-80 surfactants were used at 5, 10 and 100% as pre-emergence in moist soil along with two mechanical weeding (MW) at 20 and 40 DAP. Weedy check (WC), hand weeding (HW) at 20 DAP + MW at 40 DAP, PE at 1-2 DAP chemicals (CC) pretilachlor at 500 g/ha, alachlor 1500 g/ha or pendimethalin 30 EC at 750 g/ha + MW at 30 DAP and post-emergence chemicals quizalofop-ethyl or fenoxaprop-p-ethyl at 50 g/ha at 20 DAP + MW at 40 DAP were also used in different crops as standard check. In pilot trials, 2-3 m^2 area in wasteland at Viswavidyalaya garden and farm with young weed plant seedlings were selected in each year from 2002-2015 and UG and PG students group wise sprayed the botanical extracts either as sole or in mixtures in different doses ranged from 10- 200% adding the additives. Effect of CC and BE on seed germination of crops and weeds through á amylase content along with Weed Control Efficacy (WCE), Herbicide Efficiency Index (HEI), Weed Pest Management Index (WPMI) and Net Value Production (NVP) were recorded in various experiments. The micro flora status was also tested at initial, 3 and 21 DAA and at harvest of the crops in most of the pilot and field experiments.

RESULTS AND DISCUSSION

The dominant weed species in the experimental fields were *Cynodon dactylon, Echinochloa colona, Echinochloa formosensis, Digitaria sanguinalis, Eleusine indica, Leersia hexandra, Leptochloa chinensis,Paspalum distichum, Panicum repens, Cyperus arometicus, Cyperus rotundus, Cyperus iria, Cyperus difformis* (monocots) and *Alternanthera philoxeroides, Amaranthus viridis, Chenopodium album, Melilotus alba, Melilotus indica, Digera arvensis, Physalis minima, Cleome viscosa, Stellaria media, Ludwigia octovalvis* (dicots). The pilot trials at laboratory and wasteland indicated the raw and aqueous extracts of different young weed species (*Echinochloa colona, Cyperus difformis, Parthenium hysterophorus, Calotropis procera, Amaranthus viridis, Physalis minima, Bergia capensis, Mikania micrantha, Blumea lacera, Ageratum conyziodes etc*.) and plant parts of *Tectona grandis, Cucumis sativus, Bambusa vulgaris, Ocimum sanctum, Hibiscus subdariffa etc*. when sprayed mixing with additives or surfactants at higher doses 100, 150 and 200 ml/ litre of water in moist soil as PE / POE (weeds were 1-2 leaf stages) showed maximum control of mainly the monocot species. The laboratory testing with same soil and weed seedlings against raw and aqueous extracts of botanicals showed similar inhibition effects.

During 2006-09 in three PG students SRI experiments, one treatment of botanical herbicide (raw extract of *Parthenium hysterophorus* at 50 ml/ litre of water as PE) was added to test the efficacy on rice weeds and to compare with physical (two hand weeding) and chemical (pretilachlor 50 EC at 500 g/ha as PE) weed management. Botanical treatments recorded statistically lower WCE in comparison to physical or chemical treatments.

The experiments on rapeseed and soybean during 2004-05 showed PE *Eucalyptus* leaf extract attributed 11.2% higher seed yield over WC besides two HW and pendimethalin. The amylase content of crop and major weed seeds were reduced by pendimethalin (Table 1).

During 2010-11 (Table 2) experiment on three crops namely sesame, greengram, blackgram among the nine weed management treatments namely, W_1: untreated control, W_2: hand weeding at 20 DAS, W_3: 5% (w/v) *Ageratum conyzoides* aqueous extract, W_4: 5% (w/v) *Blumea lacera* aqueous extract, W_5: 5% (w/v) *Ocimum sanctum* aqueous extract, W_6: 5% (w/ v) *Physalis minima* aqueous extract, W_7: 5% (w/v) *Amaranthus tricolor* aqueous extract, W_8: quizalofop-p-ethyl at 50 g/ha and W_9: fenoxaprop-p-ethyl at 30 g/ ha botanical treatments recorded higher crop growth and yield of sesame in the order $W_3>W_5>W_4>W_6>W_7$. In case of greengram and blackgram the order were $W_5>W_3>W_6>W_4>W_7$ and $W_3>W_5>W_6>W_7>W_4$

Table 1. Effect of pendimethalin on α-amylase activity in rapeseed and soybean crops and weed seeds germination during 2004-05

Plant species		α-amylase activity (μg maltose released per gram fresh tissue per minute)			Reduction (%) of α-amylase activity (μg maltose released per gram fresh tissue per minute) in seeds		
		Hours after treatment			Hours after treatment		
		6	24	48	6	24	48
Brassica campestris	Control	183.3	254.7	360.0	-	-	-
	Pendimethalin	173.3	227.0	313.3	5.45	10.87	12.96
Glycine max	Control	100.7	140.0	218.0	-	-	-
	Pendimethalin	96.7	129.7	184.7	3.97	7.38	15.29
Echinochloa colona	Control	186.3	232.0	361.3	-	-	-
	Pendimethalin	171.3	184.7	236.7	8.05	20.40	34.50
Eleusine indica	Control	178.0	210.0	338.0	-	-	-
	Pendimethalin	172.0	193.3	236.7	3.37	7.94	29.98
Digitaria sanguinalis	Control	140.0	154.7	271.3	-	-	-
	Pendimethalin	124.7	134.0	193.3	10.95	13.36	28.75
Cyperus rotundus	Control	212.7	268.0	413.3	-	-	-
	Pendimethalin	206.0	249.3	363.3	3.14	6.97	12.10
Cleome viscosa	Control	140.0	153.3	256.7	-	-	-
	Pendimethalin	124.7	128.7	216.7	10.95	16.08	15.58
Chenopodium album	Control	163.3	188.0	322.0	-	-	-
	Pendimethalin	148.7	154.7	238.0	8.98	17.73	26.09
Melilotus alba	Control	126.7	150.0	241.3	-	-	-
	Pendimethalin	104.0	121.3	190.0	17.90	19.11	21.27
Alternanthera philoxeroides	Control	145.3	172.7	282.0	-	-	-
	Pendimethalin	134.0	146.0	222.0	7.80	15.45	21.28
Physalis minima	Control	104.7	114.7	162.0	-	-	-
	Pendimethalin	100.7	102.0	116.0	3.82	11.05	28.40
Amaranthus viridis	Control	143.3	176.7	304.7	-	-	-
	Pendimethalin	134.7	147.3	244.7	6.04	16.61	19.69

respectively. *Ageratum conyzoides* extract recorded higher growth and yield in sesame and blackgram while *Ocimum sanctum* extract in greengram exhibited higher harvest index, oil content and also nutrient status among the botanicals. Hand weeding and eco safe chemicals though showed better WCE but considering NVP the eco safe botanicals may be considered as a substitute of traditional weed management practices. All the weed management treatments did not show any phyto-toxic effect on the crops at any date of observation. The botanical treatments recorded slightly lower soil microflora population at 7 DAS in respect to initial, which might be due to the detrimental effect of allelochemicals present in the botanical extracts that suppressed the growth of the micro flora. However, the population increased thereafter and at harvest, the botanical *Ageratum conyzoides* extract showed highest value among the botanicals.

During 2010-11 (Table 3) in experiment on SRI rice, the pooled grain yield data showed 6.35 t/ha (HW), 5.35 t/ha (CC), 5.16 t/ha (*Tectona* methanol extract) while WC recorded 3.44 t/ha. The grain yield of rice was increased 3.6% in the final year over the starting year due to annual planning of weed management. The NVP data showed that the *Tectona* methyl extract (1.39), aqueous extracts of sole *Calotropis* (1.45) and *Parthenium* (1.46) or their mixing as raw extracts (1.45) recorded lesser differences than that of hand weeding (1.59) or eco safe chemical pretilachlor 50 EC (1.67).

Results of experiment on groundnut during 2012 showed that 30 DAS HW recorded the minimum weed biomass and density because at 15 DAS, HW was done and therefore the crop faced lesser competition from weed flora in its critical crop weed competition period and thus the WCE was 100% higher than weedy check, 20.27% higher than CC

Table 2. Effect of weed management treatments on weed control efficiency (WCE) and seed yield of summer three pulse and oilseeds crops during 2010-11 (pooled data 2010 and 2011)

Treatment	WCE at 30 DAS			Seed yield in t/ha		
	Sesame	Greengram	Blackgram	Sesame	Greengram	Blackgram
W_1 Untreated control	-	-	-	0.61	0.93	1.12
W_2 Hand weeding	73.2	66.2	69.7	0.91	1.36	1.67
W_3 *Ageratum conyzoides*	32.8	32.4	32.6	0.77	1.15	1.37
W_4 *Blumea lacera*	23.8	22.7	23.3	0.71	1.05	1.19
W_5 *Ocimum sanctum*	28.8	28.5	28.7	0.73	1.20	1.34
W_6 *Physalis minima*	14.2	16.1	15.1	0.69	1.10	1.28
W_7 *Amaranthus tricolor*	7.3	11.6	9.4	0.66	0.99	1.22
W_8 Quizalofop-p-ethyl	52.5	51.8	52.1	0.83	1.30	1.48
W_9 Fenoxaprop-p-ethyl	58.7	57.0	57.9	0.85	1.33	1.49
Mean	-	-		0.75	1.16	1.35
				C	W	C×W
LSD (P=0.05)				0.031	0.044	0.077

Table 3. Impact of APWM on weed control efficiency (WCE), grain yield and NVP of summer SRI during 2012 and 2013

Treatment	WCE (%) at 25 DAT			Grain yield in t/ha				
	2010	2011	Pooled	2010	2011	Pooled	Percent increase	NVP
T_1 - Unweeded check	-	-	-	3.38	3.51	3.44	3.85	0.81
T_2 - Hand weeding	100.0	100.0	100.0	6.21	6.49	6.35	4.51	1.59
T_3 - *Parthenium* AE	24.7	28.5	26.6	4.68	4.85	4.77	3.63	1.46
T_4 - *Calotropis* AE	21.9	25.7	23.8	4.64	4.82	4.73	3.88	1.45
T_5 - *Tectona* AE	30.2	33.4	31.8	4.86	5.04	4.95	3.70	1.56
T_6 - *Parthenium* ME	27.0	30.4	28.7	4.84	5.02	4.93	3.72	1.28
T_7 - *Calotropis* ME	24.8	28.3	26.5	4.72	4.88	4.80	1.69	1.23
T_8 - *Tectona* ME	40.7	43.0	41.8	5.07	5.26	5.16	3.75	1.39
T_9 - *Parthenium* RLE	12.7	17.6	15.2	4.48	4.64	4.56	3.57	1.37
T_{10} - *Calotropis* RLE	11.7	15.7	14.1	4.40	4.55	4.48	3.41	1.32
T_{11} - *Parthenium* + *Calotropis* RLE	23.9	25.8	25.7	4.70	4.87	4.78	3.62	1.45
T_{12} - Pretilachlor 50 EC	66.5	67.5	67.0	5.25	5.45	5.35	3.81	1.67
LSD (P=0.05)				0.252	0.264	0.258		

AE- aquaous extract, ME – methanol extract, RLE- raw leaf extract, DAA- days after application and 86.59, 88.35, 75.95, 90.98, 80.16 and 76.94%, higher than the botanical treatments T_1, T_2, T_3, T_4, T_5 and T_6, respectively during the Pre-*Kharif* season. The corresponding figures for *Kharif* season were 100, 12.31, 87.41, 89.54, 75.67, 90.34, 77.37 and 76.32%. Chen. (2009) showed similar observations.

The average pod yield of botanical treatments was 32.5 (summer) and 42.5% (*Kharif*), more than WC (Table 4). during summer and *Kharif* season, the mean pod yield of botanical treatments T_3, T_6 and T_5 showed 37 and 47% while T_1, T_2 and T_4 was 28 and 38% more, respectively over the weedy check. Kernel yield data also showed similar variation among the treatments.

Experiment on SRI rice during 2012-13 (Table 5) revealed that maximum pooled WCE at 45 DAT was obtained from HW (90.5%) followed by CC (83.5%) and BE (83%) in comparison to 3 MW (66.5%), 2 MW (52.5%) over WC. The mean grain yield data in HW (88%) followed by CC (79%), BE (76%), 3 MW (67%) and 2 MW (36%) over WC treatment. The pooled WPMI values were 20.0, 11.0 and 7.5 for HW, CC and BE, respectively. The herbicide efficiency index pooled data showed CC 480 while botanical 230. The herbicide treatment BE recorded higher NPV (1.59) followed by HW (1.54) and CC (1.53) corresponding to 3 MW (1.34) and 2 MW (1.03) over WC (0.73). Chemical herbicide pretilachlor reduced the amylase content (µg maltose/ g released fresh tissue/minute) of rice more than that of the botanicals (Table 6) but in case of the dominant three weed seeds *Echinochloa colona*, *Cyperus difformis* and *Ludwigia octovalvis*, the germination inhibition was almost same by both CC and BE. Asthini (2008) also recorded similar observation.

In SRI experiment during 2012-14, the results (Table 7 and Fig. 1) revealed that in comparison to WC, the HW, CC and BE followed by 2 MW yielded 27.97, 29.39 and 23.67% more, respectively. The average yield increase in 2014 than 2012 was 13.5%. The botanicals showed inhibition effect mostly on grass weed only.

Table 4. Effect of treatments on WCE, pod yield, kernel yield and weed index of groundnut in 2012

Treatment	WCE (%)		Pod yield (t/ha)		Kernel yield (t/ha)		Weed index		% increase of pod yield over control	
	Pre-*Kharif*	*Kharif*	Pre-*Kharif*	*Kharif*	Pre-*Kharif*	*Kharif*	Pre-*Kharif*	*Kharif*	Pre-*Kharif*	*Kharif*
T_1	12.1	10.8	1.44	1.33	0.99	0.84	24.2	18.9	32.1	44.6
T_2	10.5	9.0	1.38	1.24	0.87	0.78	27.4	24.4	26.6	34.8
T_3	21.8	20.9	1.53	1.36	1.09	0.93	19.5	17.1	40.4	47.8
T_4	8.2	8.30	1.35	1.23	0.88	0.75	28.9	25.0	23.8	33.7
T_5	17.9	19.4	1.47	1.34	1.01	0.89	22.6	18.3	34.9	45.6
T_6	20.9	20.3	1.48	1.36	1.02	0.87	22.1	17.1	35.8	47.8
T_7	72.1	75.4	1.78	1.55	1.29	1.06	6.3	5.5	63.3	68.5
T_8	90.5	85.9	1.90	1.64	1.39	1.13	-	-	74.3	78.3
T_9	-	-	1.09	0.92	0.65	0.48	42.6	43.9	-	-
LSD (P=0.05)			0.39	0.25	0.36	0.27				

T_1 - 5% aqueous extract *Echinochloa colonum* ; T_2 -5% aqueous extract *Cyperus difformis*; T_3 -5% aqueous extract *Ageratum conyzoides* ; T_4 - 5% aqueous extract *Blumea lacera*; T_5 - 5% aqueous extract *Cucumis sativus* ; T_6 - 5% aqueous extract *Bambusa vulgaris*; T_7 – CC (alachlor 50 EC at 1.5 kg/ha); T_8- Hand weeding (HW) at 15 DAS and T_9- Weedy check (WC)

Table 5. Impact of APWM on WEC, herbicide efficiency index (HEI) and weed pest management index (WPMI) during summer SRI 2012 and 2013

Treatment	WCE (%) at 45 DAT		HEI		WPMI		Grain yield (t/ha)		Percent increase	NVP
	2012	2013	2012	2013	2012	2013	2012	2013		
T_1 - Weedy check	-	-	-	-	-	-	3.10	3.12	0.65	0.73
T_2 - Two MW	54	51	-	-	1	3	4.20	4.27	1.67	1.03
T_3 - Three MW	64	69	-	-	5	6	5.10	5.30	3.92	1.34
T_4- One HW + Two MW	92	89	-	-	23	17	5.80	5.93	2.24	1.54
T_5- CC + two MW	84	83	474	486	11	11	5.45	5.70	4.59	1.53
T_6- BE + two MW	77	89	200	260	7	8	5.33	5.63	5.63	1.59
LSD (0.05)							0.25	0.65	Mean- 3.12	Mean 1.29

MW- Mechanical weeding (rice weeder), HW-Hand weeding, PE- Pre-emergence CC- Chemical control; BE- Botanical control with mixture of *Parthenium, Calotropis* and *Tectona* aqueous extracts

Table 6. Effect of chemical and botanical weed management treatments on the amylase content in seed germination of rice and three dominant weed flora during 2013

Treatment	Amylase content (µg maltose /g released fresh tissue /minute)											
	Control				Botanical mixture				Pretilachlor			
Observations at 4 days after seed germination	24 hour	48 hour	72 hour	96 hour	24 hour	48 hour	72 hour	96 hour	24 hour	48 hour	72 hour	96 hour
Rice	185	225	210	145	153	176	151	143	119	199	83	71
Echinochloa colonum (G)	23	68	25	23	8	17	11	11	4	8	5	4
Cyperus difformis (sedge)	28	31	59	33	13	22	40	20	5	17	31	11
Ludwigia octovalvis (BL)	25	33	108	40	13	20	37	20	8	13	20	11
	Seed	TRT	S x T	S x T x H								
LSD (P=0.05)	0.64	0.56	1.11	2.23								

Table 7. Impact of annual planning and management (APWM) on the grain yield increase of summer SRI rice during 2012-14

Treatment	Grain yield (t/ha) 2012	2013	2014
T_1 - Weedy check	3.10	3.95	4.00
T_2 - Two MW	4.31	5.12	5.17
T_3 - Three MW	5.11	5.72	5.95
T_4- One HW + Two MW	5.82	6.49	7.00
T_5- CC + two MW	6.31	6.27	6.88
T_6- BC + two MW	6.00	6.16	6.46
Average	5.11	5.62	5.91

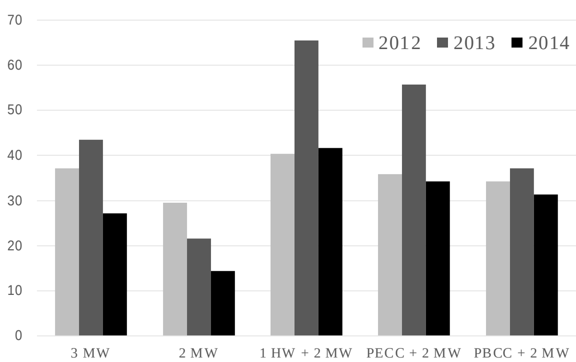

Fig. 1. Effect of annual planning and management (APWM) on% reduction of weed biomass at 45 DAT on SRI rice (2012-13-14)

The SRI experiment conducted at 11 on farm locations of different 9 rice growing districts of West Bengal to test the advantages of annual planning and management (APWM) with a package of practice of the best treatments at on station (SRI) and farmers own practice (TTR) revealed increased average productivity of rice in different locations by 5.6–19.4% in SRI than that of TTR. The results of population of soil microflora status (Table 8) indicated that there an increasing trend of total actinomycetes, fungi and bacteria population at the final year 2014 than that of the initial year 2012. The population of soil total actinomycetes at initial was minimum 94 CFU x 10^5/g soil at Gosaba , South 24 Paraganas while maximum 130 CFU x 10^5/g soil at Raina Burdwan. The corresponding figures at harvest of final year 2014 were 135 (Bangaon North 24 Parganas) and 188 (BCKV, Nadia). Similar results were also observed against total fungi [minimum 08 CFU x 10^4/g soil at Fulkalmi, Nadia and maximum at BCKV 13 CFU x 10^4/g soil at the initial year 2012 and corresponding values at final year 2014 were 23 CFU x 10^4/g soil (Bangaon, North 24 Parganas) and 33 CFU x 10^5/g soil (BCKV, Nadia)] and total bacteria [minimum 80 CFU x 10^6/g soil at Chandamari, Nadia and maximum 98 CFU x 10^6/g soil at Bhobla Paschim Medinipur at the initial year 2012 and the corresponding values at final year 2014 were 108 CFU x 10^6/g soil (Bangaon, North 24 Parganas) and 127 CFU x 10^6/g soil (BCKV, Nadia)]. The lower varied population in some location was mainly due to not continuation of SRI in same land like BCKV (Ghosh *et al.* 2014 A).

The higher yield in botanicals was mainly due to managing weed flora with the help of natural allelochemicals (*Parthenium*- sesquiterpene lactones and phenol; *Calotropis*- calotropin and mudarine; *Ageratum* -coumarin; *Cucumis* -sisymbrifolin; *Bambusa* -rutin and Tricin ; *Echinochloa*- apigenin; *Cyperus*- cyperene and cyperotudone; *Physalis*- imperatorin withanoilides; *Ocimum*- essential oil ; *Blumea* -fenchane, ä- fenchone, monoterpene citral a).

When botanicals extracts are applied in sufficient moist condition a hydrogen ion can break away from the (– OH) group and transfer to a base- the position of equilibrium lies well to the left. Thus losing a hydrogen ion (because the phenoxide ion formed) phenol is stabilized to some extent. The negative charge on the oxygen atom is delocalised around the ring. The more stable the ion is the more likely it is to form. One of the lone pairs on the oxygen atom overlaps with the delocalised electrons on the benzene ring. Therefore, botanical extracts needs

Table 8. Microflora population at different on station and on farm locations in summer SRI 2012 and 2014

Locations	Actinomycetes (CFU x 10^5/g soil)				Fungi (CFU x 10^4/g soil)				Bacteria (CFU x 10^6/g soil)			
	2012		2014		2012		2014		2012		2014	
	Initial	Harvest	Initial	Harvest	Initial	Harvest	Initial	Harvest	Initial	Harvest	Initial	Harvest
BCKV	115	137	143	188	13	17	28	33	87	102	118	127
Shekhampur, Birbhum	*	*	126	143	*	*	23	26	*	*	105	111
Sriniketan, Birbhum	*	*	114	151	*	*	21	28	*	*	102	112
Fulkalmi, Nadia	119	123	147	156	08	14	19	25	85	97	112	120
Chandamari, Nadia	121	129	*	*	10	15	*	*	80	94	*	*
Raina, Burdwan	130	132	154	159	12	15	21	30	94	105	109	118
Gurap, Hooghly	114	135	152	158	12	14	22	28	96	103	112	116
Khanru, Purba Medinipur	*	*	160	167	*	*	25	29	95	101	104	112
Bhobla, Paschim Medinipur	*	*	153	168	*	*	26	31	98	112	116	124
Bangaon, North 24 Parganas	*	*	127	135	*	*	18	23	89	95	102	108
Sankrail, Uluberia, Howrah	119	126	141	157	12	17	23	27	85	97	108	116
Gosaba, South 24 Parganas	94	121	139	161	10	14	24	29	91	101	109	112

*Not done in this year

sufficient moist soil and probably for this reason, these extracts may be more active in rice field when applied at earliest after preparation. However, for confirmation of these results it needs detail studies along with proper formulation and dose of the botanical herbicides (Ghosh *et al.* 2014, Jana *et al.* 2011 and Nongmaithem *et al.* 2011)

In most of the experiments, higher NVP was observed in BE over CC and HW. An initial detrimental effect for two weeks on the soil microflora status was observed in all chemicals including botanicals though in botanicals the population of microflora reduction percentage was lower than that of the chemical synthetic herbicides. Similar results were also obtained by Chen (2009), Ghosh *et al.* (2012), Vaughan and Lehnen (1991) *etc.*

From these experiments, it could be concluded that following the annual planning of weed management (APWM), botanical herbicides integrated with mechanical weeding (more eco-safe and less costlier), are the best alternate option for weed management in system intensification. Annual planning of weed management was also able to increase our productivity by gradual reducing pest losses and increasing soil health status as it is a part of biological management in system intensification. The botanical herbicides are more safer to soil health in comparison to synthetic chemical herbicides. Mixture of botanical extracts with other botanicals or chemical herbicides need to be studied for further exploitation of these natural plant allelochemicals in various ecosystem.

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Forecasting of herbicide consumption using autoregressive integrated moving average model

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ABSTRACT

A study was conducted on modelling and forecasting the time series data of total herbicide consumption in India. Among many time series methodology, Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) model was used for modelling and forecasting purposes using data from 1990 to 2010. Before the modelling, stationarity of the data was checked using Augmented Dicky Fuller test. Best model was chosen using two criterion *viz.* Akaike information criterion and Schwarz's Bayesian criterion. ARIMA (0, 1, 1) model was found to the best among many models from ARIMA family. Forecasting was done using the best model and prediction for total herbicide consumption in India was made for next three year (2011, 2012, 2013) as 6624, 6581 and 6562 tonnes respectively.

Key words: ARIMA, Forecasting, Herbicide consumption, Modelling, Time series

Nowadays, it is very difficult for farmers to employ sufficient hand labour to keep their fields clear of weeds, making herbicides the most logical alternative. According to the Federation of Indian Chambers of Commerce and Industry (FICCI), per capita consumption of agrochemicals in India is still much lower at 0.6 kg/ha compared to 13 kg/ha in China and 7 kg/ha in USA. Herbicides are the largest growing segment and currently account for 16% of the total market (FICCI 2013). Among many agrochemicals, herbicide consumption is increasing day by day with increase in necessity and awareness among farmers in India. Therefore, total consumption of herbicides is very important figure for policy makers and companies to predict the demand and supply of herbicides for the next year. Companies try to forecast demand, plan production, set sales targets and compete to push stocks to distributors based on primary sales, without having an idea of actual demand and consumption by farmers. Use of available technology to track sales, if at all, is ineffective. Further, it is also observed that yearly data on herbicide consumption is not easily available even after 2-3 years, as the main source of the data is only the concerned industry. In this situation, it is difficult for policy makers and industry persons to take appropriate measures in this regard. Therefore, it becomes necessary to predict the consumption of herbicides in advance.

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In many scientific areas, data is observed in the form of time series. Hence to analyze the time series data, many models are fitted either to better understand the data or to predict future points in the series (forecasting). In this context, Autoregressive Integrated Moving Average (ARIMA) models are the most popular and widely used forecasting models for the analysis of uni-variate time series data. Applying ARIMA models, Iqbal *et al.* (2005) forecasted area and production of wheat in Pakistan. In India, Sarika *et al.* (2011) modelled and forecasted the pigeonpea production, Padhan (2012) predicted agricultural productivity and Kumari *et al.* (2014) projected rice yield. In past, no study has been conducted to predict the total herbicide consumption in India. In view of this, an attempt has been made to model and forecast the herbicide consumption in India for consecutive three years based on the past data using ARIMA models.

MATERIALS AND METHODS

India's herbicide consumption data from 1990 to 2010 were collected from www.faostat.fao.org. Data from 1990 to 2008 were used for model building and 2009 and 2010 for model validation. The present study applies Box-Jenkins ARIMA model which is an extrapolation method, and requires past time series data of study variable. The model may be expressed as follows. Let Y_t is a discrete time series variable which takes different values over a period of time. Then ARIMA (p, d, q) model can be given as

$$Y_t = \mu_0 + \mu_1 Y_{t-1} + \mu_2 Y_{t-2} + \cdots + \mu_p Y_{t-p} + \epsilon_t + \delta_1 \epsilon_{t-1} + \cdots + \delta_q \epsilon_{t-q} + \gamma t$$

where $Y_t, Y_{t-1}, \ldots Y_{t-p}$ are the values of response variable at time t, t-1, t-2 and so on, $\mu_0, \mu_1, \ldots \mu_p$ are the coefficients associated with response variable, $\epsilon_t, \epsilon_{t-1}, \ldots, \epsilon_{t-q}$ are the error term, $\delta_1, \ldots, \delta_q$ are the coefficients of the estimated error term and γt is the constant mean of the series, p and q are the parameters of the model and d denote the degree of differencing applied to the data. In order to identify the order of p and q, the ACF (Autocorrelation function) and PACF (Partial autocorrelation function) is applied.

ARIMA modelling and forecasting is performed in four steps: model identification, model estimation, model validation and forecasting. Preliminary, it is very important to check about the stationarity of the data. Since ARIMA modelling is applied only to stationary data (data with constant mean and variance). Therefore, to check the stationarity of the series, Augmented Dickey Fuller (ADF) test was applied. Modelling and forecasting was done using SAS Enterprise Guide 4.3 (SAS Institute Inc., USA). Many models from ARIMA family were used to fit the time series data with different values of p, d and q. Among these, best model was selected using two criterion, *viz.* Akaike information criterion (AIC) and Schwarz's Bayesian criterion (SBC). After identifying the model, parameter estimates were obtained for chosen model. Residual analysis was also done to check the independency of the white noise residuals. If the model is appropriate representation of the time series, then the white noise residuals should be independent of each other. Thus, any significant autocorrelation in the estimated residuals at ACF and PACF indicates model inadequacy and suggests the model modification.

RESULTS AND DISCUSSION

ARIMA modelling starts with the checking for stationarity of the series. Therefore, Augmented Dickey Fuller test (ADF) was applied which revealed the non-stationarity of the data. Hence, first differencing was applied to the data. Later, data series became stationary. Among many models from ARIMA family, ARIMA (0, 1, 1) model was found to be best after taking minimum AIC and SBC criteria for selecting model (Fig. 1). Parameter estimates were obtained using conditional least square method for the selected model and presented (Table 1) along with standard error for the fitted ARIMA (0, 1, 1) model. Selected model is given by: $\hat{Y}_t = \mu_0 + Y_{t-1} - \delta_1\, e_{t-1}$, where μ_0 is the constant, δ_1 is the constant associated with error term. $\hat{Y}_t$ is the estimated value of herbicide consumption at time t and Y_{t-1} is the data point associated with time t-1. Forecast values were obtained for the year 2011, 2012 and 2013 as 6624, 6581 and 6562 tonnes respectively.

Table 1. Parameter estimates along with standard error

Parameter	Estimate	Standard Error	t Value	Pr > |t|
μ_0 (constant)	-24.83	30.81	-0.19	0.85
δ_1	0.51	0.22	2.33	0.03

Thus model is obtained as $Y_t = -24.83 + Y_{t-1} - 0.51\, e_{t-1}$.

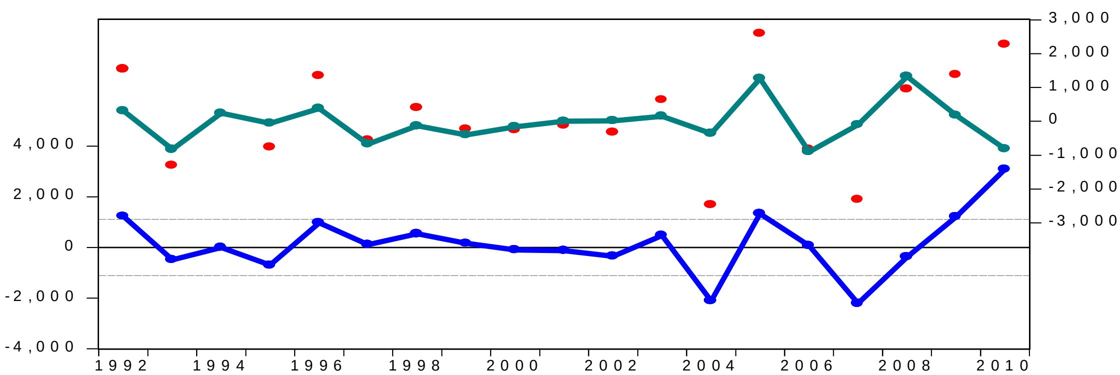

Fig 1. Fitted ARIMA (0, 1, 1) model along with original value* and forecast error

Table 2. Autocorrelation check of residuals

To Lag	Chi-Square	DF	Pr > ChiSq	Autocorrelations					
6	1.68	4	0.7936	-0.078	0.030	-0.054	0.065	0.106	-0.178
12	4.77	10	0.9059	0.113	-0.176	0.062	-0.129	0.006	-0.107
18	11.82	16	0.7560	0.061	0.087	-0.195	-0.050	-0.042	0.104

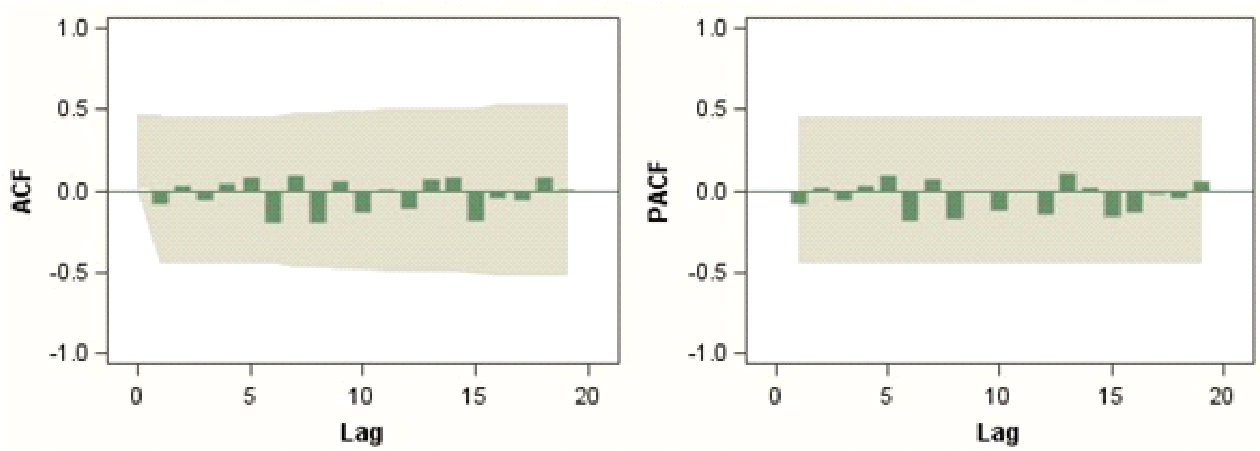

Fig. 2. Residual ACF (autocorrelation function) and PACF (partial autocorrelation function) plots for ARIMA (0, 1, 1) model

Forecast values obtained from the model shows decreasing trend in the herbicide consumption of India. It might be due to the development of low dosage and high potency molecules which require less volume of chemical per unit treated area in comparison to older chemicals.

Residual analysis was done to check the independency of white noise residuals. Non-significant chi-square values led to rejection of hypothesis that residuals are autocorrelated. Hence, it revealed that residuals are independent to each other which was also confirmed by ACF and PACF study as no significant spikes were present in the plots and thus assumption of independence of residuals was not violated (Table 2).

Modelling and forecasting of herbicide consumption data was done using ARIMA modelling. Among the many models from ARIMA family, ARIMA (0, 1, 1) model is found to be best. After an appropriate time series model was decided, its unknown parameters estimated, it was established that the model fitted well. Using the selected model, forecast values for herbicide consumption were obtained for consecutive three years. These are 6624, 6581 and 6562 tonnes for the year 2011, 2012 and 2013, respectively. Forecasting may be done for further many more years but since forecast is associated with standard error, which gradually increase with increase in number of forecast values, therefore, it must be done for short term only.

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Biological activity of red wriggler earthworm on different ratio of weed and dung as mixtures substrate

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ABSTRACT

This study identifies the utilization of common weed *Chenopodium murale* as raw material for vermiculturing. Growth and cocoon production in each mixture was recorded weekly for 18 weeks. Significant variations in food preference were observed in worm when the cattle dung was mixed with weed in different combination. The present study revealed that addition of weed in cow dung not only enhanced the growth of the worm but also increased cocoon production thus providing a possible tool towards proper utilization of weed for production of value added product.

Key words: Biological activity, Earthworm, Vermicompost, Weed utilization

Eradication of weeds has been proved to be impossible in spite of the sincere efforts of the scientists and technologists. However; these materials are actually the reservoir of the nutrients that are required for plant growth. The problem lies that these nutrients are in the form of complex, bound organic chemicals with strong bonds. There is a good evidence that organic matter that pass through the gut of earthworm and deposited on or in the soil in the form of casts possessed higher amounts of nutrients than that of the substrates or soil on which the earthworms feed (Reddy *et al.* 1997). Moreover, the nutrients are changed to assimilable forms in the gut, that are more rapidly taken up by plants (Lee 1985).

Chemical substances present in the food attract and elicit feeding responses in many invertebrates. Flavour potentiators or modifiers in food exert gustatory effect not only in man but also in other animal. The existence of such cues in earthworm can be deduced as they show preference to the nature of organic matter (Kale and Krishnanmoorthy 1981).

Considerable work has been carried out on the use of earthworms to recycle various organic wastes. However, there is not much published report available regarding the vermicomposting of weeds. This work presents the dynamics of *E. foetida* earthworm populations during vermicomposting of weed *Chenopodium murale*.

MATERIALS AND METHODS

Fecundity study of earthworm species *Eisenia foetida* during vermicomposting of selected weed and its different parameters was carried out. 300 gm of feed mixture was taken in plastic containers of 500 gm capacity In different ratio of weed *Chenopodium murale* and cow dung (Table 1). All the treatments were kept in triplicate and same setup without earthworm were also maintained which served as control. All the treatment containers were left for 15 days prior to experimentation for thermal stabilization and softening of wastes for easy ingestion by the earthworm. The water was sprinkled over the feed mixture on alternate day to hold moisture content of about 60 to 80%. After 15 days, 10 healthy non-clitellated red wriggler earthworm weighing 150 to 300 mg were selected from stock culture and introduced in each container. To prevent moisture loss, the containers were covered with wet gunny begs. All containers were placed in dark at room temperature. No additional food was added at any stage during the study period.

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Table 1. Content of weed with cow dung in initial feed mixture

Treatment	Feed composition	
	Weed %	Cow dung %
C_1	0	100
C_2	20	80
C_3	40	60
C_4	60	40
C_5	80	20

Fresh cow dung was procured from village, The main characteristics of Cow dung were: pH: 7.73, organic carbon Cow dung: 362.31g/kg, total kjeldhal nitrogen (TKN): 6.5 g/kg, total phosphorus (TP): 4.2 g/kg, total potassium: 5.11 g/kg, C:N ratio: 55.65, calcium (Ca): 3.2 g/kg, and C:P ratio: 84.65.

Growth and cocoon production in each mixture was recorded weekly for 18 weeks. The feed in the containers was turned out and earthworms and cocoons were separated from the feed by hand sorting, after which they were counted and weighed after washing with water and drying them by paper towels. The worms were weighed without first voiding them, since it has been reported that the gut content would lie around 10% of live weight, where as larger differences are expected in relation to feed (Neuhauser *et al.* 1980). Corrections for gut content were not applied to any of the data in the study. Then all measured earthworm and feed (but not cocoons) were returned to the containers.

At the end of vermicomposting period the earthworms and cocoons were separated and final compost from each reactor was air dried at room temperature. Homogenized samples of final compost were ground in a stainless steel blend, stored in airtight plastic vials for further chemical analysis.

RESULTS AND DISCUSSION

No mortality was observed in any of the feed mixture. Gunadi and Edwards (2003) have reported the death of *Eisenia foetida* after 2 weeks in fresh cattle solids, although physiochemical properties were suitable for the growth of the earthworms. They attributed the deaths of earthworms to the anaerobic conditions which developed after 2 weeks in fresh cattle solids. In our experiments, all the weed feed mixture were pre composted for 2 weeks and during this period all the toxic gases produced might have been eliminated. It is established that pre-composting is essential to avoid the deaths of the worms.

The change in biomass and cocoon production differed depending on the substrates. at deferent all the feed mixtures (Table 2). The maximum biomass (1049 ± 4.15 mg) after 120 days was observed in 20:80 ratio (20:80 ratio) treatment and minimum biomass (993 ± 5.19 mg) in 100% cow dung. All the compositions showed increase in biomass with respect to control. The increase was linear up to 12 months but after that it showed a decline trend.

The maximum weight by earthworm was attained in 11th - 14th week in all the treatments. The fastest growth rate was observed in 40:60 ratio treatment (11 ± 0.10 mg/worm/day) whereas 60:40 ratio treatment supported the least growth (8 ± 0.05 mg/worm/day). The maximum growth rate of *Eisenia foetida* was registered between the range of 8 ± 0.05/earthworm/day (in 60:40 ratio treatment) to 11 ± 0.10/earthworm/day (in 40:60 ratio treatment). The net weight gain by worm was highest in 60:40 ratio treatment (834 ± 6.29 mg/worm) and lowest in 0:100 ratio treatment (777 ± 7.21 mg/worm) (fig. 1). Increasing proportion of weed in the feed mixture promoted a decrease in biomass of *Eisenia foetida.* The loss in worm biomass can be attributed to the exhaustion of food. When *Eisenia foetida* received food below a maintained level it lost weight at a rate which depended upon quantity and nature of

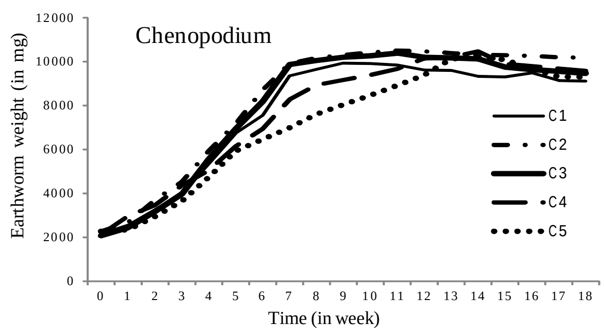

Fig. 1. Growth pattern of earthworm in different feed mixtures

Table 2. Earthworm growth in different feed mixtures of cow dung with *Chenopodium murale* weed

Feed no.	Mean initial wt./worm (mg)	Maximum wt. achieved/worm (mg)	Maximum wt. achieved in	Net wt. gain/worm (mg)	Growth rate/worm/day (mg)
C_1	216 ± 3.96	993 ± 5.19	12th Week	777 ± 7.21	9 ± 0.08
C_2	226 ± 3.96	1049 ± 4.15	11th Week	823 ± 7.67	10 ± 0.09
C_3	207 ± 3.46	1038 ± 5.27	11th Week	831 ±8.60	11 ± 0.10
C_4	212 ± 3.22	1046 ± 3.10	14th Week	834 ± 6.29	8 ± 0.05
C_5	227 ± 2.94	1021 ± 4.38	14th Week	794 ± 7.22	8 ± 0.06

Table 3. Cocoon production in different feed mixtures of *Chenopodium murale*

Feed no.	Cocoon production started in	Total nos. of cocoons after 11 weeks	Nos. of cocoons produced/earthworm	Nos. of cocoons produced/earthworm/day
C_1	6th Week	143 ± 1.40	14.3 ± 0.13	0.34 ± 0.004
C_2	5th Week	137 ± 0.94	13.7 ± 0.09	3.91 ± 0.02
C_3	5th Week	170 ± 0.46	17.0 ± 0.05	4.86 ± 0.005
C_4	5th Week	159 ± 0.46	15.9 ± 0.05	4.54 ± 0.002
C_5	6th Week	120 ± 1.40	12.0 ± 0.13	2.85 ± 0.02

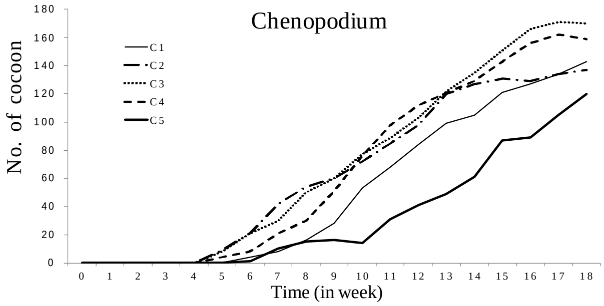

Fig. 2 Cocoon production in feed mixture of *Chenopodium murale* with cow dung

ingestible substrates Neuhauser *et al.* (1980). However, Dominguez *et al.* (1997) reported a decrease in worm biomass even when additional food was added to the experiment every week.

Cocoon production started in 6th week in 100% cow dung; in 7th week in other feed mixtures except 80:20 ratio treatment (6th week). After 120 days maximum cocoons (170 ± 0.46) were counted in 40:60 ratio treatment and minimum (120 ± 1.40) in 80:20 ratio treatment (Fig. 2). The mean number of cocoon production was between 12.0 ± 0.13 (in C_5 treatment) and 17.0 ± 0.05 (in C_3 treatment) cocoons earthworm^{-1} for different feed mixtures tested as shown in (Table 3).

Cocoon production fluctuated with time. Initially cocoon production rate was high. The range of mean number of cocoons produced per worm per day was 0.34 ± 0.004 in cow dung to 4.86 ± 0.005 in 40:60 ratio treatment. The difference between the rates of cocoon production could be related to the biochemical quality of the feeds,which is an important factor in determining the time taken to reach sex maturity and onset of maturity (Edwards *et al*. 1998). Feeds which provide earthworms with sufficient amount of easily metabolizable organic matter and non assimilated carbohydrates favour growth and reproduction. Parthasarathi (2007) examined the growth and reproduction of indigenous *Lampito mauritii* in comparison with exotic *Eudrilus eugeniae* cultured on three feed substrates-clay loam soil, cowdung and press mud (filter cake) over a period of 360 days under laboratory conditions. The decrease of worm length and biomass observed slightly on 63-70th days in *Lampito mauritii* and 42-49th days in *Eudrilus eugeniae*. After 270 days both worms in all these fed substrates showed decreasing trends of length and biomass which were due to continued reproduction and aging. It was observed that both weight gain and cocoon production was more when *Chenopodium murale* weed was mixed with pure cowdung. It indicated that *Chenopodium murale* weed is a good biomass and reproduction supporting medium which can be used effectively for culturing *Eisenia foetida* as well as recycling of weed material for production of vermicompost when mixed with pure cowdung. Weed strongly influenced the biology of *Eisenia foetida*. Net biomass gain by earthworm in different feed mixture was in order of $C_4 > C_3 > {}_2 > C_5 > C_1$ and that of cocoon production of $C_3 > C_4 > C_2 > C_1 > C_5$. Therefore, there is a need to divert research activities to expore the potential of different weeds as a raw material for vermicomposting their utilization and to design a national level policy for their proper utilization.

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Short communication

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Herbicide combinations for control of complex weed flora in transplanted rice

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Rice (*Oryza sativa* L.) is the staple food of more than 60% of the world population. In India, rice occupies an area of 43.95 mha with production and productivity of 106.65 mt and 2.4 t/ha, respectively (Ministry of Agriculture 2015). Because of growing population, the demand of rice is expected to increase in the coming decades. India should add 1.7 million tonnes of additional rice every year to ensure national food security (Das and Chandra 2013). Though, India has the largest area under rice in the world but its productivity is very low. This might be due to several constraints. Among them weeds pose a major threat. Weeds compete with the crop for light, nutrients, moisture, etc. Weeds also harbor insect pests that cause decrease in yield and quality of produce. Rice grain production in our country is reported to suffer a loss of 15 mt annually due to weed competition. Uncontrolled weed growth causes 33-45% reduction in grain yield of transplanted rice (Singh *et al.* 2007, Manhas *et al.* 2012).

At present, use of a single herbicide is not convenient and effective in eliminating the weed menace in transplanted rice. Studies have shown that combination of herbicides may be a better option rather than alone application because it offers even broader spectrum of weed control, saves time and reduces the cost of cultivation. This situation warrants for initiating research efforts to evaluate and identify suitable herbicide combinations to widen the weed control spectrum. Therefore, keeping the above facts in mind, the present investigation was carried out to study the herbicide combinations for control of complex weed flora in transplanted rice (*Oryza sativa* L.).

A field experiment was conducted at G.B. Pant University of Agriculture and Technology, Pantnagar during *Kharif*, 2014. The soil of the experimental site was silty loam having pH of 7.38, containing high organic carbon (0.89%), low available nitrogen (244.6 kg/ha), medium available phosphorus (22.4 kg/ha) and potassium (215.6 kg/ha), respectively. The experiment was laid out in randomized block design and replicated thrice with twelve treatments, *viz.* post-emergence application of bispyribac-sodium 25 g/ha, penoxsulam 24% SC 22.5 g/ha, bispyribac-sodium 25 g/ha + ethoxysulfuron 18.75 g/ha, bispyribac-sodium 25 g/ha + readymix of chlorimuron-ethyl and metsulfuron-methyl 4 g/ha, pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of ethoxysulfuron 18.75 g/ha, pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of readymix of chlorimuron-ethyl and metsulfuron-methyl 4 g/ha, pre-emergence application of pyrazosulfuron 20 g/ha *fb* post-emergence application of readymix of chlorimuron-ethyl and metsulfuron-methyl 4 g/ha, post-emergence application of readymix of penoxsulam + cyahalofop-butyl 6% OD 135 g/ha, post-emergence application of readymix of triafamone + ethoxysulfuron 60 g/ha, pre-emergence application of pendimethalin 750 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha, hand weeding at 25 and 45 DAT and weedy check. Rice variety '*Narendra 359*' was transplanted on 27th June 2014 at spacing of 20 x 10 cm. All the plots (5 x 3 m) were fertilized with 120 kg N, 60 kg P, 40 kg K/ha through NPK mixture, urea, murate of potash and 20 kg $ZnSO_4$/ha. Full dose of P and K and half dose of N were applied uniformly as basal at the time of transplanting. Remaining half dose of N was top dressed in two equal splits *i.e.* one-fourth at active tillering stage [30-35 days after transplanting(DAT)] and one-fourth at panicle initiation (60-65 DAT) stage of the crop. After treatment execution, the water application was uniform for all the treatments to keep the soil near saturation. Rice crop was harvested on 17th October 2014.

Species-wise weed density and biomass were recorded at 30, 60, 90 DAT and at harvest by placing a quadrate of 50 x 50 cm from the marked sampling area in each plot. The cost of cultivation was calculated by taking into account the prevailing market price of inputs and operational cost from the farmer's field. The returns were calculated by using minimum support price of rice (Rs. 1360/100 kg) for 2014-15. The significant differences between treatments were compared by critical difference at 5% level of probability. The data on weed density and biomass were subjected to square root transformation for comparison.

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Weed flora

The dominant weed flora of the experimental field consisted of *Echinochloa colona*, *Echinochloa crusgalli*, *Panicum maximum*, *Leptochloa chinensis* and *Ischaemum rugosum* among grasses, *Caesulia axillaris*, *Ammania baccifera* and *Alternanthera sessilis* among broad-leaved weeds and *Cyperus iria* and *Cyprus difformis* among sedges.

Effect on weeds

All the weed control treatments significantly reduced the density of weeds (Table 1) but their efficiency in controlling different types of weeds varied significantly. Grassy and broad-leaf weeds were found predominanted at 60 DAT. Pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of ethoxysulfuron 18.75 g/ha resulted in the lowest total weed density. Similar results were also reported by Hossain *et al.* (2014). The better performance of this treatment might be attributed to the effective control of grasses and broad-leaf weeds by pretilachlor and control of broad leaf weeds and sedges by ethoxysulfuron. This was statistically similar to post-emergence application of readymix of penoxsulam + cyhalofop-butyl 135 g/ha, pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of readymix of chlorimuron-ethyl + metsulfuron-methyl 4 g/ha and post-emergence application of bispyribac-sodium 25 g/ha + ethoxysulfuron 18.75 g/ha.

Different weed control treatments significantly reduced the biomass of different weed species over the weedy check (Table 1). Post-emergence application of readymix of penoxsulam + cyhalofop-butyl 135 g/ha recorded complete reduction in biomass of grassy weeds. The effective control of grasses in this treatment might be attributed to the combined broad spectrum activity of penoxsulam and cyhalofop-butyl which controls grasses effectively. Besides this treatment, pre-emergence application of pendimethalin 1000 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha also recorded low dry matter of grassy weeds. The lowest dry matter of broad-leaf weeds was recorded with post-emergence application of bispyribac-sodium 25 g/ha + ethoxysulfuron 18.75 g/ha, post-emergence application of readymix of penoxsulam + cyhalofop-butyl 135g/ha and post-emergence application of readymix mixture of triafamone + ethoxysulfuron 60 g/ha. The broad spectrum effect of bispyribac-sodium, penoxsulam and triafamone and effective control of broad-leaf weeds by ethoxysulfuron might be the reason for reduced weed biomass in these treatments. These were at par with pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of ethoxysulfuron 18.75 g/ha, pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of readymix of chlorimuron-ethyl + metsulfuron methyl 4 g/ha and pre-emergence application of pendimethalin 1000 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha. The sedges were not much problem and the dry matter of sedges was completely reduced in most of the treatments where combinations of herbicides were used. The total weed dry matter at 60 DAT however, was found to be lowest with pre-emergence application of pendimethalin 1000 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha, owing to the control of weeds in early stages by pendimethalin and in later stages by bispyribac-sodium. This treatment, therefore, recorded the highest weed control efficiency (97.7%) (Table 1). These results were in conformity with the findings of Walia *et al.* (2012) for direct seeded rice. Significant reduction in total dry matter over weedy check with bispyribac–sodium at 60 DAT was also reported by Kumar *et al.* (2013). The low weed dry matter and high weed control efficiency of the above treatment was at par with pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of ethoxysulfuron 18.75 g/ha, post-emergence application of readymix of penoxsulam + cyhalofop-butyl 135 g/ha and twice hand weeding at 25 and 45 DAT. Among the herbicidal treatments, the lowest weed control effieiency was recorded with alone post-emergence application of bispyribac-sodium 25 g/ha. The better performance of treatments with herbicide combinations indicates their superiority over alone application. The highest weed density and dry matter were recorded in weedy check. This suggests that without proper management of weeds in transplanted rice, the weed growth will be at its peak and hamper crop growth.

The highest grain yield (6.42 t/ha) was recorded with pre-emergence application of pendimethalin 1000 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha (Table 1). Similar results have been also reported by Walia *et al.* (2012) for direct-seeded rice. This was at par with post-emergence application of readymix of penoxsulam + cyhalofop-butyl 135 g/ha (6.32 t/ha) and twice hand weeding at 25 and 45 DAT (6.28 t/ha). The higher grain yield may be attributed to the reduced weed competition and thereby increased crop growth due to control of weeds at initial stage by pre-emergence application of pendimethalin which controls grasses and broad leaved weeds effectively and subsequent control by bispyribac-sodium, which offers broad spectrum weed control (Parthipan *et al.* 2013), thus offering broad spectrum control of weed for the

Table 1. Effect of weed management practices on weed density, weed dry weight at 60 DAT and grain yield of transplanted rice

Treatment	Dose (g/ha)	Weed density (no./m²)				Weed dry matter (g/m²)				Grain yield (t/ha)
		Grasses	Broad-leaf weeds	Sedges	Total weed density	Grasses	Broad-leaf weeds	Sedges	Total weed dry matter	
Bispyribac-sodium	25	3.4 (10.7)	6.9 (47.3)	3.2 (9.3)	8.3 (67.3)	2.9 (7.67)	2.7 (6.3)	3.2 (9.0)	4.9 (23.0)	4.42
Penoxsulam	22.5	3.8 (13.3)	6.3 (38.7)	1.9 (2.7)	7.5 (54.6)	2.6 (5.9)	2.23 (4.0)	1.7 (2.0)	3.6 (11.9)	5.42
Bispyribac-sodium + ethoxysulfuron	25 + 18.75	3.9 (14.0)	2.2 (4.0)	1.0 (0.0)	4.4 (18.0)	3.4 (10.2)	1.2 (0.4)	1.0 (0.0)	3.4 (10.6)	5.56
Bispyribac-sodium + chlorimuron-ethyl + metsulfuron-methyl	20 + 4	4.0 (14.7)	4.8 (22.0)	1.0 (0.0)	6.1 (36.7)	4.0 (15.3)	1.7 (1.8)	1.0 (0.0)	4.2 (17.1)	5.05
Pretilachlor *fb* ethoxysulfuron	750 *fb* 18.75	2.8 (7.3)	2.7 (6.7)	1.0 (0.0)	3.8 (14.0)	2.7 (7.9)	1.3 (0.7)	1.0 (0.0)	2.9 (8.0)	5.90
Pretilachlor *fb* chlorimuron-ethyl + Metsulfuron methyl	750 *fb* 4	3.6 (12.0)	2.8 (7.3)	1.0 (0.0)	4.5 (19.3)	4.2 (16.5)	1.4 (0.9)	1.0 (0.0)	4.3 (17.5)	5.46
Pyrazosulfuron *fb* chlorimuron-ethyl + metsulfuron-methyl	20 *fb* 4	4.9 (22.7)	5.4 (28.0)	1.0 (0.0)	7.2 (50.7)	4.2 (16.9)	1.5 (1.2)	1.0 (0.0)	4.3 (18.1)	4.85
Penoxsulam + cyhalofop-butyl (RM)	135	1.0 (0.0)	3.5 (11.3)	2.5 (5.3)	4.2 (16.7	1.0 (0.0)	1.2 (0.5)	2.6 (5.7)	2.7 (6.2)	6.32
Triafamone + ethoxysulfuron (RM)	60	3.5 (11.3)	4.8 (22.0)	1.0 (0.0)	5.9 (33.3)	3.4 (10.9)	1.2 (0.5)	1.0 (0.0)	3.5 (11.3)	5.97
Pendimethalin *fb* bispyribac-sodium	1000 *fb* 25	3.0 (8.0)	3.8 (13.3)	2.0 (3.3)	5.0 (24.7)	1.8 (2.2)	1.4 (0.9)	1.7 (2.1)	2.5 (5.2)	6.42
Hand weeding at 25 and 45 DAT	-	3.2 (9.3)	7.1 (49.3)	1.5 (1.3)	7.8 (60.0)	2.0 (3.2)	2.1 (3.6)	1.6 (1.7)	3.1 (8.5)	6.28
Weedy check	-	9.1 (81.3)	12.2 (150)	5.8 (33.3)	16.3 (265)	14.2 (201)	3.4 (10.8)	3.7 (13.0)	15.0 (225)	3.60
LSD (P= 0.05)		0.7	1.0	0.6	1.0	0.7	0.2	0.4	0.7	0.21

Original values are given in parenthesis; RM= Readymix; DAT= Days after transplanting

whole crop period. The lowest grain yield was recorded in weedy check. Lower grain yield in weedy check might be due to severe crop weed competition, as evident from higher weed density and dry matter (Table 1). Similar results were also reported by Prakash *et al.* (2011), Bhat *et al.* (2013).

SUMMARY

Among the weed control treatments, herbicidal combinations of pre-emergence application of pendimethalin 1000 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha and post-emergence application of readymix of penoxsulam + cyhalofop-butyl 135 g/ha were found most effective in controlling weed infestation with the highest weed control efficiency and grain yield.

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Short communication

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Floristic composition and weed diversity in rice fields

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Rice (*Oryza sativa* L.), the staple food of more than 60% population of the World, plays a crucial role in the economic and social stability of the world. In India, about 33% of rice yield losses caused by weeds (Mukherjee 2004), while in Sri Lanka, weeds accounted for 30 – 40% of yield losses (Abeysekera 2001). In world rice production, about 10% of the total yield is reduced by weeds (Oerke and Dehne 2004). Rice is growing in about 45 million hectares with production of 96 million tonnes contributing 45% to the total food grain production of India. The weeds that flourish along with the rice crops further affect the low agriculture production because of limited area for cultivation. Therefore the present study was undertaken to identify and enlist the weed species in rice fields, The vegetative analysis of weeds in fields, the density and species richness of the weeds, the dominance of weed species / type.

The field experiment was conducted during winter season (November 2010 to April 2011) in the agricultural fields at five different villages *i.e.* Kiliyanur, Konthamur, Thensiruvallur, Thailapuram and Aadhanapattu Village around Vanur taluk – Villupuram district, Tamilnadu. The average annual rainfall is 1119.8 mm with a minimum and maximum average annual temperature of 32.78 °C in May and 24.08 °C in January, respectively. (IMD: India meteorological department). The work was carried out in five different villages in and around Vanur taluk. The soil was silty clay in texture and high in fertility with 7.0-8.2 pH. The rice was broadcasted in early June with the arrival of pre-monsoon at upland site. At lowland site 29 days old seedlings were transplanted in early December on 5 × 5 m sized plots in randomized block design. The observation of weeds in rice field was carried out at 15th and 30 days after transplanting. From the date of rice cultivation to harvest time, weed species were observed for floristic study. For the vegetation analysis of weeds, ten quadrants of 1 × 1 m were placed for density and abundance, per method of Misra (1968). The weeds with higher density and species richness were considered as dominant weeds.

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Vegetation survey

A systematic sampling method was carried out to study the weed species in rice fields. Total 10 quadrants from each village were taluk. Hundred number of local people were interviewed for knowing medicinal value of the weeds encountered during survey in rice fields.

After rice harvest, 1 kg soil sample (0 - 30 cm depth) was collected from each plot and were used to find out the soil pH, organic matter content, nitrogen (N), phosphorus (P) and potassium (K). The soil pH was determined by using Fischor's Digital meter as well as pH paper. Organic matter content was determined by Walkey and Black's method (1934). Nitrogen in soil was determined by micro- Kjeldahl method and Olsen's method (1954) was used to determine phosphorus. Potassium was determined by atomic absorption spectrophotometer (Gupta 2000). The experiment for soil texture analysis was conducted based on the procedure given by Piper (1944) (Table 3).

A total of 7609 individual of weeds representing 56 species 45 genera and 23 families were recorded. At site 3 (Thensiruvallur) there was high number of species diversity containing 44 species belonging to 24 families with a total density of 1277 individuals followed by site 2 (Konthamur) comprising 38 species belonging to 21 family with 1479 individuals. At site 1 (Kiliyanur), were 37 species belonging to 18 family with 1930 individuals while at site 5 (Aadhanapattu), 32 species belonging to 17 families and 1753 individuals were recorded. Thailapuram had 30 species, 16 families and 1242 individuals.

Survey recorded maximum 45 species in Thensiruvallur followed by Konthamur (38 species), Kiliyanur (37 species), Aadhanapattu (32 species) and Thailapuram (30 species) villages with a total of 56 species belonging to 23 families distributed in different life forms *i.e.* herbs (40), grasses (8), sedges (4) and ferns (1). Dicot species were more prominent than monocot. Weeds appeared fifteen days after transplantation. *Echinochloa colona* was an abundant weed in the five different rice fields. The differences in weed species numbers and its composition between the study sites probably indicated how much the crops get affected in the field. The supremacy of monocots over dicots at upland site in present investigation was similar to the findings of Thapa and Jha (2002). The domination of grasses and sedges in the present study was at par with the findings of Thapa and Jha (2002) and Dangol *et al.* (2002). Assessment of the losses due to weed is a difficult work because the extent of damage vary from year to year depending on the crop, weed species, soil condition and the climate (Moody 1982) (Table 1).

Species diversity was unevenly distributed along with the taxonomic groups. The following family of Amaranthaceae (8 species), Poaceae (8 species), Cyperaceae (5 species), Asteraceae (4 species), Malvaceae (4 species), Solanaceae (3 species) were found as leading in the flora out of 23 families. Other families were comparatively less diverse. The present study was at par with the findings of purple nutsedge (*Cyperus rotundus* L.) which is one of the most dominant weeds in many field and vegetable crops due to its unique biological and physiological properties (Rao 1968). (Table 2).

Soil texture

The soil texture of all the study sites has showed clayey loam and sandy loam which represented by varying proportion of different particles such as clay, coarse sand, fine sand. The proportion of clay particles is more in all the fields.

Soil N P K

The pH of all the soil samples ranged from 7–8.2. It was neutral non acidic or alkaline in condition. The EC was good in all the soil samples, ranged from 0.5 to 1.5. Having estimated the soil nitrogen, it was recorded as low in all the five fields (Table 3). It ranged from 59-63. Nitrogen content was lower because the weed growth changed soil chemistry and reduced soil nutrient content. Weeds can utilize plant nutrients more efficiently than crop plant due to their rapidly spreading and deeply penetrating root system (Jordan and Shanter 1980).

Phosphorus content in the soil was medium in range *i.e.* 8–24%. Soil potassium content was medium in the range from 105 -113. During the *Kharif* season, broad-leaved weeds such as *Monochoria hastata, Ludwigia parviflora, Nymphoides indicum* and *Echinochloa crusgalli* became aggressive in transplanted rice (Mukherjee *et al.* 2008). In transplanted rice, *Echinochloa* spp., *Ischaemum rugosum, Caesulia axillaris, Commelina* spp., *Cyperus* spp., and *Fimbristylis miliaceae* are dominant weeds (Singh *et al.* 2009).

Species diversity was unevenly spread among taxonomic groups. The 23 families recorded, Amaranthaceae (8 species) Poaceae (8 species), Cyperaceae (5 species) Asteraceae (4 species) Euphorbiaceae (4 species) Malvaceae (4 species) Solanaceae (3 species), Portulacaceae, Convolvulaceae and Commelinaceae (each 2 species) domined the family and they constituted together 71% of the total plant species. Other families were comparatively less diverse and 12 families had a single species. But the top four Poaceae had 37.8% of total density followed by Cyperaceae (17.34%), Asteraceae (13.6%), and Marsileaceae (10.46%) contribued nearly 80% of total density at all the five studied sites. Similar results have been reported by Dangol *et al.* (1986) from the rice fields of Rampur, Chitwan, Nepal.

Species diversity

In consideration of diversity indices, Simpson index provided better comparison among different study sites as compared to Shannon–Weiner Index. As far as Simpson Index Diversity Index is concerned the plant communities were most diversed at site 1 - Kiliyanur (8.66) had higher value followed by site 4 -Thailapuram (7.28), site 3 -Thensiruvallur (6.82), site 5- Aadhanapattu (6.56), and site 2 - Konthamur, (6.19). On the part of Simpson diversity index, Kiliyanur (2.46) was more diverse followed by Thensiruvallur, Thailapuram was parallel in weed diversity (2.36), followed by Aadhanapattu (2.25) and Konthamur (2.11) (Table 3).

Medicinal values of weeds

The medicinal data of five sites were analyzed and from those medicinal weed species, 51% were commonly used by the inhabitants for curing various diseases such as cold, cough, fever, liver complaints, kidney stones, wound healing, diabetes, toothache and other miscellaneous purposes (Table 4).

Out of 56 weed species (Table 1), 29 species (Table 4) were commonly used by the inhabitants in that 48.2% of species were used as a whole plant as a medicinal value followed by 24% of species have the combination root and leaves, 10% of species have the combination of root, bark and seed, 6.8% of species have the combination of leaves and fruits, 3.5% of species have the combination of roots, seeds, bulbous and tubers, respectively.

Table 1. Distribution of weed species in five different rice field in different villages around Vanur taluk – Villupuram district

Species	Family	Village					Total density
		Kiliya.	Kont.	Then.	Thai.	Aadh.	
Abutilon indicum	Malvaceae	1	1	2	0	3	7
Acalypha indica	Euphorbiaceae	4	1	3	2	1	11
Acanthospermum hispidum	Asteraceae	0	0	2	0	0	2
Achyranthes aspera	Amaranthaceae	4	3	0	10	9	26
Aerva lananta	Amaranthaceae	8		8	0	0	16
Alternanthera echinata	Amaranthaceae	0	0	2	0	0	2
Alternanthera sessilis	Amaranthaceae	112	0	0	0	38	150
Amaranthus spinosus	Amaranthaceae	1	1	2	1		5
Amaranthus viridis	Amaranthaceae	0	0	0	3	1	4
Ammania baccifera	Lythraceae	88	116	113	33	82	432
Asteracantha longifolia	Acanthaceae	17	10	12	4	14	57
Bergia capensis	Elatinaceae	146	4	23	102	94	369
Brachiaria reptens	Poaceae	0	1	1	0	0	2
Celosia argentea	Amaranthaceae	0	1	2	0	0	3
Centella asiatica	Apiaceae	1		1		1	3
Chloris barbata	Poaceae	22	9	10	11	10	62
Cleoma viscosa	Capparidaceae	1	1	1			3
Coccinia indica	Cucurbitaceae			1			1
Commelina benghalensis	Commelinacea	9	4	4	5	5	27
Commelina diffusa	Commelinaceae	1	1	1		1	4
Convolvulus arvensis	Convolvulaceae		1	1			2
Croton bonplandianum	Euphorbiaceae				2		2
Cynodon dactylon	Poaceae	220	180	124	125	108	757
Cyperus difformis	Cyperaceae	251	215	147	230	299	1142
Cyperus iria	Cyperaceae	3	3	14	26	4	50
Cyperus rotundus	Cyperaceae	17	4	11	49	43	124
Dactyloctenium aegyptium	Poaceae	18	4	9	8	6	45
Digera arvensis	Amaranthaceae	5	2	1	2		10
Digitaria sanguinalis	Poaceae		2			1	3
Echinochloa colonum	Poaceae	392	394	375	325	484	1970
Echinochloa crusgalli	Poaceae	23	7	14	12	7	63
Eclipta alba	Asteraceae	259	289	175	72	234	1029
Eichhornia crassipes	Pontederiaceae		1	1	2		4
Eleocharis atropurpurea	Cyperaceae				1		1
Eragrostis pilosa	Poaceae		2	1			5
Euphorbia hirta	Euphorbiaceae	22	13	8	15	19	77
Fimbristylis miliacea	Cyperaceae	3	1	7	2	2	15
Ipomoea carnea	Convolvulaceae		1	2			3
Ischaemum rugosum	Poaceae		1			1	2
Leucas aspera	Lamiaceae	9	3	2	4		18
Lippia nodiflora	Verbenaceae	26	42	47	59	34	208
Ludwigia parviflora	Onagraceae	13	8	5	5	11	42
Marsilea quadrifoliata	Marsileaceae	233	147	124	122	178	804
Ocimum canum	Labiatae	8		2			10
Phyllanthus niruri	Euphorbiaceae	4	3	7		9	23
Physalis minima	Solanaceae	1	1		1	1	4
Physalis peruviana	Solanaceae			2			2
Portulaca meridiana	Portulacaceae		1				1
Portulaca oleracea	Portulacaceae				6		6
Sida acuta	Malvaceae			1			1
Sida cordifolia	Malvaceae		1				1
Sida rhombifolia	Malvaceae					1	2
Solanum nigrum	Solanaceae	1		1			2
Sphenoclea zeylanica	Sphenocleaceae					48	48
Tridax procumbens	Asteraceae	1		7	3		11
Vernonia cinerea	Asteraceae	3		1		3	7

Kiliya- Kiliyanur, Kont – Konthamur, Then- Thensiruvallur, Thai –Thailapuram, Aadh- Aadhanapattu P- species present; A- species absent

Table 2. Consolidated details of weed diversity in five different sites in vanur taluk

Variables	Site 1	Site 2	Site 3	Site 4	Site 5
Species Richness	37	38	44	30	32
Family	18	20	22	16	16
Density	1930	1479	1277	1242	1753
Diversity Index					
Simpson Mean	8.66	6.19	6.82	7.28	6.56
Shannon Mean	2.46	2.11	2.36	2.36	2.25
Fisher's Alpha	6.49	7.11	8.58	5.54	5.17

Table 3. Analysis of soil characteristics in five different soil samples

	Site 1 (Kiliya)	Site 2 (Kont)	Site 3 (Then)	Site 4 (Thai)	Site 5 (Aadh)
Soil characteristics					
pH	7.2	7	7.1	7.2	8.2
EC	0.1	0.17	0.26	0.14	0.22
Physio-chemical properties in soil(kg/acr)					
N	60	63	55	59	59
P	24	18	20	8	9
K	105	113	110	113	113

Kiliya-Kiliyanur, Kont–Konthamur, Then-Thensiruvallur, Thai–Thailapuram, Aadh-Aadhanapattu; EC – Electrical conductivity (m.mhos/cm), N–nitrogen, P- phosphorus, K- potassium

The Floristic composition of weeds in five different rice field around Vanur taluk was studied from November 2010 to April 2011. From the six month observations, it was found that weed growth occured within 41 days after rice sowing and they may propagate by seeds and propagules or by both. A total of 56 weed species belonging to 23 families were identified. Out of this, 37 species in Kiliyanur, 38 species in Konthamur, 45 species in Thensiruvallur, 30 species in Thailapuram and 32 species in Aadhanapattu were identified. An important value index for each weed species was calculated to its dominance. Herbaceous species were dominant in rice field. The weeds of *Bergia capensis, Cynodon dactylon, Cyperus difformis, Eclipta alba, Echinochloa colona, Marsilea quadrifolia* were dominant species. In view of weed species diversity, the rice field at Thensiruvallur village was exceedingly diverse when compared to other fields. The perennial weeds caused the most serious problem in rice fields. Major weeds produce a large number of seeds, which may remain in soil and serve as soil seed bank for the

Table 4. Medicinal value of weed species present in paddy field

Species	Family	Part	Uses
Abutilon indicum (Linn.)	Malvaceae	Seed, root, bark,	Hypothermic, analgesic and aphrodisiac
Acalypha indica Linn.	Euphorbiaceae	Roots, leaves,	Anthelmintic, expectorant, emetic and anodyne
Achyranthes aspera Linn	Amaranthaceae	Whole plant	Cardiac, stimulant, diuretic, astringent.
Aerva lanata	Amaranthaceae	stalks, flower	Anthelmintic, diuretic, anti-inflammatory and anti-bacteria
Amaranthus spinosus	Amaranthaceae	Roots, leaves,	Diuretic, emollient and febrifuge
Amaranthus viridis	Amaranthaceae	Whole plant	Diuretic and emollient
Centella asiatica	Apiaceae	Whole plant	It is a tonic, blood
Celosia argentea	Amaranthaceae	Roots, leaves,	Antibacterial, anti-inflammatory. Aantibacterial, wound and healing.
Commelina benghalensis	Commelinaceae	Roots, leaves,	It is used for the children for digestion.
Coccinia grandis	Cucurbitaceae	Bulbous tuber	Hypoglycaemic, antiprotozoa.
Cyperus rotundus	Cyperaceae	Whole plant	Shoots and tubers are useful as stimulant, vemifuge and stimulates milk secretion.
Cynodon dactylon	Poaceae	Whole plant	Dysentry
Eclipta alba	Asteraceae	Leaves, fruit	Useful to cure asthma and other diseases.
Euphorbia hirta	Euphorbiaceae	Roots, leaves	Diuretic and aphrodisiac
Ipomoea carnea	Convolvulaceae	Roots, leaves	Aphrodisiac and galactogenic
Ipomoea reptans	Convolvulaceae	Roots, leaves	Hypoglycemic, diuretic.
Lippia nodiflora	Verbenaceae	Whole plant	Cold and suppurations
Marsilea quadrifoliata	Marsileaceae	Whole plant	It is used to treat Snakebites.
Ocimum canum	Lamiaceae	Whole plant	Diaphoretic and stimulant
Ocimum sanctum	Lamiaceae	Whole plant	Antidysenteric and stimulant.
Phyllanthus niruri	Euphorbiaceae	Whole plant	Antibacterial
Physalis minima	Solanaceae	Leaves, fruit	Diuretic and purgative.
Portulaca oleracea	Portulacaceae	Whole plant	Anti-inflammatory, Anti-bacteria and Anti-fungal effects
Sida cordifolia	Malvaceae	Seed, root, bark	Antiparalytic and aphrodisiac
Solanum nigrum	Solanaceae	Seed, root, bark	Spasmolytic
Sida acuta	Malvaceae	roots , seeds	Astringent, febrifuge and stomachic
Sida rhombifolia Linn.	Malvaceae	Whole plant	Anabolic and emollient
Tridax procumbens	Asteraceae	Whole plant	Anti-inflammatory and Anti-bacterial and Anti-fungal effects
Vernonia cinerea	Asteraceae	Whole plant	Astringent, diaphoretic, antirheumatic

next cropping season. The major weeds should be controlled at proper time to check reduction in rice yield, and they must be removed before flowering and fruiting to reduce the production of seeds that remain as soil seed bank.

SUMMARY

The Floristic composition of weeds in five different rice field around Vanur taluk of Villupuram district, Tamil Nadu, India was studied from November 2010 to April 2011. A total of 56 weed species belonging to 23 families was identified. Out of this 37 species in Kiliyanur, 38 species in Konthamur, 45 species in Thensiruvallur, 30 species in Thailapuram, and 32 species in Aadhanapattu were identified. An important value index for each weeds species was calculated to find dominance. *Bergia capensis, Cynodon dactylon, Cyperus difformis, Eclipta alba, Echinochloa colona, Marsilea quadrifolia* were dominant weeds species. Considering species diversity, Thensiruvallur village rice field was highly diverse of weed species compared to other fields. From the six month observations, it was found that weed growth occurs within forty one days after rice sowing. The perennial weeds created the most serious problem in rice fields.

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Short communication

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Bioefficacy of clodinafop-propargyl + metsulfuron-methyl against complex weed flora in wheat

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Wheat (*Triticum aestivum L.*) is a staple food of the world and falls under Poaceae family. It is the single most important cereal crop that has been considered as integral component of the food security system of the several nations. In India, total area under wheat is 29.90 million ha with the production and productivity of 93.90 million tonnes and 3.14 t/ha, respectively. Wheat is an important *Rabi* season crop of Uttar Pradesh, contributing towards food security of the country to a large extent. Heavy weed infestation is one of the major factor declining productivity of wheat. In wheat, acute problem of both grassy and broad leaved weeds is becoming very common in north India. The crop is infested with heavy population of *Phalaris minor, Cyperus rotundus, Cynodon dactylon, Chenopodium album, Anagallis arvensis, Avena fatua, Convolvulus arvensis* and *Lathyrus aphaca etc.* Hence, there is a need to find out some suitable herbicides to tackle this problem of mixed weed flora. A few herbicides such as sulfosulfuron and clodinafop-propargyl have sown their high efficacy against weeds in wheat. At present, some herbicides molecules (ready mixed combination) having its very high potency at lower doses to kill grassy along with broad-leaved weeds have been developed. These molecules may be more effective to control various weed species as well as relatively safer for environmental pollution point of view. Keeping all these facts in view, the present investigation was carried out to find out effective herbicide to control the weeds in wheat crop.

The field experiment was conducted during *Rabi* season of 2012-13 at Agronomy Research Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (UP). The soil of the experimental field was silt loam, having pH 8.6, organic carbon 0.31, available N, P and K 178, 14.5 and 231.5 kg/ha, respectively. The trial was laid out in randomized block design with three replications, having ten number of treatments, *viz*. clodinafop-propargyl 15% + metsulfuron-methyl 1% at 300, 400, 500 and 800 g/ha, metsulfuron-methyl + iodosulfuron at 400 g/ha, sulfosulfuron + metsulfuron-methyl at 32 g/ha, fenoxaprop 7.77% + metribuzin 13.6% at 1250 g/ha, clodinafop + 2,4-D at 60 + 500 g/ha along with weed free and weedy check. Wheat variety *'NW-1014'* was sown 20 cm apart by ferti-seed drill on 18 December 2012. Species-wise and total weeds (no./m^2) were recorded from three places selected at random in each plot at various stages. A quadrate of 50 × 50 cm size was used for recording the weed density and weed dry weight. The weeds within the quadrate were identified and counted and expressed in (no./m^2). Weed dry matter was recorded from three places selected randomly. After sun drying, weeds were dried in hot air oven at 70 ± 1 ^{0}C for 48 hours to obtain a constant weight. The oven dried and thoroughly ground weed samples were digested and nitrogen was determined by micro Kjeldahl method. The number of effective shoots which bear the spike were counted from the one meter row length and marked (marked with sticks) in each plot for the different growth studies and averaged out. The grain yield was recorded in kg/plot and finally the values were converted into kg/ha.

The weed density of the different weed species and total weeds was affected significantly due to weed control treatments. clodinafop + MSM (120 + 8 g/ha) 800 g, mesosulfuron + iodosulfuron (12 + 2.4 g/ha) 400 g and fenoxaprop + metribuzin (100 +175 g/ha)1250 g/ha being at par controlled *P. minor* population completely while other weeds were also controlled very effectively over rest of the treatments. Similar type of trend was observed in case of broad-leaved also. Total weed density at 60th day stage, clodinafop + MSM (120 + 8 g/ha) 800 g/ha alone recorded significantly low over rest of the treatments. (Table 1) However, moderate total weed

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density was recorded with fenoxaprop + metribuzin (100 +175 g/ha) 1250 g, mesosulfuron + iodosulfuron (12 + 2.4 g/ha) 400 g and clodinafop + MSM (60 + 4 g/ha) 400 g/ha. While in case of clodinafop + MSM (45 + 3 g/ha) 300 g/ha, higher number of total weeds were recorded might be due to under dose of herbicides (Katara *et al.* 2012). Dry matter accumulation at 60th day stage, clodinafop + MSM (120 + 8 g/ha) 800 g and clodinafop + MSM (75 + 5 g/ha) 500 g/ha (4.5 and 5.4 g/m^2) being at par recorded significantly low *fb* mesosulfuron + iodosulfuron (12 + 2.4 g/ha) 400 g/ha (14.2 g/m^2) and fenoxaprop + metribuzin (100 +175 g/ha) (12.0 g/m^2) each and other herbicide treatments (Table 1) Fenoxaprop + metribuzin (100 +175 g/ha) showed moderate control of weeds which showed in term of weed dry weight (Singh *et al.* 2012). The highest weed control efficiency was recorded with clodinafop + MSM (120 + 8 g/ha) 800 g/ha (97%) followed by clodinafop + MSM (75 + 5 g/ha) 500 g/ha (95.8%), which was very much comparable with the weed free treatment (100%). However, fenoxaprop + metribuzin (100 +175 g/ha) (93.8%), clodinafop + MSM (60 + 4 g/ha) 400 g/ha (93.0%) and sulfosulfuron + MSM (32 g/ha) (91.7%) also recorded the WCE quite fare. While lowest value of WCE was recorded with clodinafop + MSM (45 + 3 g/ha) 300 g/ha (48.99%). Number of effective shoots/m^2 was recorded significantly higher in weed free check (348.80) over clodinafop + MSM (45 + 3 g/ha) 300 g/ha and weedy cheek. All the herbicidal treatments showed non-significant differences to each other. But higher values of effective shoots were recorded in clodinafop + MSM (60 + 4 g/ha) 400 g/ha (325.2) followed by sulfosulfuron + MSM (32 g/ha) (324.2/m2). However, the lowest number of effective shoots was recorded in weedy check (232.0/m^2). The grain yield was affected significantly due to different weed control treatments (Table 1). Among these, weed free check being at par to other herbicide treatments recorded significantly higher grain yield over weed check and clodinafop + MSM (45 + 3 g/ ha) 300 g/ha treatments. It might be due to the effective weed control of grassy and non grassy weeds due to various herbicide treatments. Malik *et al.* 2013 also reported the higher weed control efficiency of fenoxaprop + metribuzin (100 +175 g/ ha) in wheat. The treatment in which highest value of WCE was recorded gave lowest value of weed index (Table 1). Among the weed control treatments, lower value of weed index was calculated in clodinafop + MSM (60 + 4 g/ha) 400 g/ha (1.45 %) followed by clodinafop + MSM (75 + 5 g/ha) 500 g/ha (2.19%).

Table 1. Effect of various treatments on density and dry weight at 60 DAS, effective shoot, grain yield; weed index and nitrogen uptake by weeds

Treatment	Weed density (no./m^2)				Weed dry weight (g/m^2)	Effective shoots (m^2)	Grain yield (t/ha)	WI (%)	N uptake by weeds (kg/ha)
	P. minor	BLWs	Others	Total weeds					
Clodinafop + MSM (45 + 3g/ha) 300 g/ha	4.1 (16.0)	3.7 (13.0)	2.3 (5.0)	6.0 (35.0)	8.1 (65.0)	286.8	3.30	17.7	18.24
Clodinafop + MSM (60 + 4 g/ha) 400 g/ha	1.9 (3.0)	3.0 (8.5)	1.9 (3.0)	3.9 (14.5)	4.1 (16.3)	325.2	3.95	1.45	2.50
Clodinafop + MSM (75 + 5 g/ha) 500 g/ha	1.2 (1.0)	1.9 (3.0)	1.6 (2.0)	2.6 (6.0)	2.4 (5.4)	311.4	3.92	2.44	1.50
Clodinafop + MSM (120 + 8 g/ha) 800 g/ha	0.7 (0.0)	1.9 (3.0)	0.7 (0.0)	1.9 (3.0)	2.2 (4.5)	308.7	3.85	3.94	1.08
Mesosulfuron + iodosulfuron (12 + 2.4 g/ha) 400 g/ha	0.7 (0.0)	3.2 (9.5)	1.9 (3.0)	3.6 (12.5)	3.3 (10.3)	304.0	3.50	12.66	3.55
Sulfosulfuron + MSM (30 + 2 g/ha) 40 g/ha	1.7 (2.5)	3.5 (11.8)	1.2 (1.0)	4.0 (15.3)	4.5 (19.6)	324.2	3.91	2.18	2.98
Fenoxaprop + metribuzin (100 +175 g/ha) 1250 g/ha	0.7 (0.0)	2.2 (4.3)	2.1 (4.0)	3.0 (8.3)	3.6 (12.7)	307.5	3.46	13.66	1.99
Clodinofop + 2,4-D (60 + 500 g/ha)	2.1 (4.0)	4.5 (19.5)	2.5 (5.6)	4.8 (22.6)	4.8 (22.3)	321.4	3.62	9.68	4.18
Weed free	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	348.8	4.01	0.00	0.00
Weedy check	6.2 (38.0)	10.8 (116.3)	4.3 (18.0)	13.1 (172.4)	10.4 (108.6)	232.0	3.04	24.14	35.76
LSD (P=0.05)	0.29	0.5	0.18	0.44	0.54	42.2	0.49	-	0.44

DAS = Days after sowing, WCE=Weed control efficiency, BLWs =Broad leaves weeds, WI= Weed index. MSM: Metsulfuron-methyl; Note: Values in parentheses are original value and transformed to $\sqrt{x + 0.5}$.

Table 2. Phytotoxicity of herbicide treatments at corresponding stages on visual observation (Score 0-10)

Treatment	Crop discoloration (DAHA)			Chlorosis (DAHA)			Stunting (DAHA)			Wilting (DAHA)		
	15	30	60	15	30	60	15	30	60	15	30	60
Clodinafop + MSM (45 + 3g/ha) 300 g/ha	0	0	0	0	0	0	0	0	0	0	0	0
Clodinafop + MSM (60 + 4 g/ha) 400 g/ha	0	0	0	0	0	0	0	0	0	0	0	0
Clodinafop + MSM (75 + 5 g/ha) 500 g/ha	1	0	0	1	0	0	0	0	0	0	0	0
Clodinafop + MSM (120 + 8 g/ha) 800 g/ha	2	1	0	2	1	0	0	0	0	0	0	0
Mesosulfuron + iodosulfuron (12 + 2.4 g/ha) 400 g/ha	2	1	1	2	1	1	1	1	1	0	0	0
Sulfosulfuron + MSM (3 + 2 g/ha) 40 g/ha	0	0	0	0	0	0	0	0	0	0	0	0
Fenoxaprop + metribuzin (100 +175 g/ha) 1250 g/ha	2	2	1	2	1	1	1	2	1	0	0	0
Clodinofop + 2,4-D (60 + 500 g/ha)	0	0	0	0	0	0	0	0	0	0	0	0
Weed free	0	0	0	0	0	0	0	0	0	0	0	0
Weedy check	0	0	0	0	0	0	0	0	0	0	0	0

MSM: Metsulfuron-methyl, DAHA= Days after herbicide application

While, higher value of weed index was calculated in clodinafop + MSM (45 + 3 g/ha) 300 g/ha (17.66%). It might due to the insufficient dose of clodinafop-propargyl + metsulfuron-methyl (45 + 3 g/ha) 300 g/ha resulted to which caused the lower control of different type of weeds. Nitrogen uptake by weeds was influenced significantly due to different treatments. Among all the weed control treatments, clodinafop + MSM (120 + 8 g/ha) 800 g/ha (1.2 kg/ha), clodinafop + MSM (75 + 5 g/ha) 500 g/ha (1.4 kg/ha) being at par recorded significantly lower nitrogen uptake over rest of the treatments followed by fenoxaprop + metribuzin (100 +175 g/ha) (1.6 kg/ha) and clodinafop + MSM (60 + 4 g/ha) 400 g/ha (1.7 kg/ha). Whereas, higher and lower nitrogen uptake was recorded with weedy and weed free check treatments, respectively (Tanveer *et al.* 2007). As far as Phyto-toxicity of different herbicide treatment was concerned clodinafop + MSM (45 + 3 g/ha) 300 g/ha, clodinafop + MSM (60 + 4 g/ha) 400 g/ha and clodinafop + MSM (75 + 5 g/ha) 500 g/ha did not show any injury on wheat crop as it was evident from the parameters recorded on leaf chlorosis, stunting and necrosis. However, higher dose of at (clodinafop + MSM (120 + 8 g/ha) 800 g/ha caused the chlorosis and but it was only upto 15 DAHA and later on it was disappeared. But fenoxaprop + metribuzin (100 +175 g/ha) and Atlantis showed the toxicity systems even up to 60 days stage of herbicide application which might be responsible for declining the yield attributes and grain yield of wheat over lower doses of clodinafop-propargyl + metsulfuron-methyl (400 to 500 g/ha. However, the higher doses of clodinafop-propargyl + metsulfuron-methyl (500 and 800 g/ha) as well as fenoxaprop + metribuzin (100 +175 g/ha) and Atlantis controlled grassy and BLWs very effectively as it was expressed in term of WCE of all these treatment individually.

SUMMARY

The field experiment was conducted during *Rabi* season of 2012-13 at Faizabad to study the bio-efficacy of clodinafop-propargyl + metsulfuron-methyl and some other new herbicide molecules against complex weed flora in wheat. Significant reduction density was recorded at different stages of crop growth due to effect of different treatments. As far as the narrow leaved (*P. minor*) and BLWs were concerned, both type of weeds were effectively controlled by application of clodinafop-propargyl + metsulfuron-methyl 400 g/ha at 32 DAS which was proved superior with respect to number of effective shoots/m^2 (0.32) and grain yield (3.95 t/ha) of wheat over rest of the other herbicidal treatments. Lower value of weed index was calculated in clodinafop-propargyl + metsulfuron-methyl 400 g/ha (1.45%) followed by other herbicidal treatments.

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Short communication

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Indian hemp : An emerging weed of wheat fields in Punjab

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Key words: *Cannabis sativa*, Punjab, Survey, Weed, Wheat

Wheat (*Triticum aestivum* L.) is the predominant *Rabi* crop of North-Western Plain Zone and Central Zone of India. It occupied about 35.12 lac hectare area with a production of 165.91 lac tonnes during 2013-14 in Punjab (Anonymous 2014). A number of factors influence wheat production including weed infestation. Yield losses of wheat due to weeds are estimated around 25-50% and in very severe cases the losses may go upto 80% (Malik *et al.* 1995). The present study was conducted to identify emerging weeds in wheat crop in various districts of Punjab so as to devise effective weed control strategies in time.

Weed survey was conducted in wheat during the month of March in 2014 and 2015 in ten districts of Punjab belonging to three zones. Stoppage was made at 10 km for each survey and survey spot was selected more than 100 m deep in the field. The observations were recorded with quadrate of 50 x 50 cm placed randomly at four spots in one acre or a large field. Frequency and absolute density were worked out from the weed count data using following equations:

a. Frequency (%) = (Number of quadrates in which species occurs/ Total number of quadrates) x100

b. Absolute density (m^2) = (Total no of individuals of a species in all quadrates/ Total number of quadrates)

Interpretation of weed frequency was calculated as per McIntosh (1962), Ahmad *et al.* (2009)

The major weeds of wheat included four broad-leaf weeds (*Cannabis sativa*, *Chenopodium album*, *Malva neglecta* and *Rumex dentatus*) and four grasses (*Avena ludoviciana*, *Phalaris minor*, *Poa annua* and *Sorghum halepense*) (Table 1). During 2014, six weed species belonging to four families were recorded in wheat crop. However, infestation of *M. neglecta* and *S. halepense* in wheat fields widened the weed spectrum during 2015 with eight weed species belonging to five families.

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Table 1. Weeds flora of wheat in various districts of Punjab

Weed species	Common name	Local name	Family
A.ludoviciana	Wild oats	Jaundhar	Poaceae
C.sativa	Indian hemp	Bhang	Malvaceae
C.album	Lambs quarter	Bathu	Chenopodiaceae
M. neglecta	Button weed	-	Malvaceae
P. minor	Littleseed canary grass	Gulli danda	Poaceae
P. annua	Annual blue grass	Ghuien	Poaceae
R. dentatus	-	Jangli palak	Polygonaceae
S. halepense	Johnson grass	Baru	Poaceae

Submontane zone: In district Roopnagar, three and four weed species were recorded during 2014 and 2015, respectively (Tables 2 and 3). *P. minor* was the most densely populated weed during both the years. *C. sativa* was not recorded in 2014, and in 2015, it turned out to be the fourth major weed of wheat in this district after *P. minor*, *P. annua* and *R. dentatus* based on the frequency and absolute density data. In district Hoshiarpur, five weed species were observed during both the years. During 2014, *R. dentatus* and *P. minor* were the most frequent and most densely populated weeds, respectively. The most noteworthy change was that although *C.sativa* was an occasional weed during 2014 (54.6%), but it became a common weed of wheat fields of district Hoshiarpur by attaining very high frequency of 83.6% during 2015. Absolute density of this weed also increased in this district by more than three times from 1.2 to 3.7 plants m^2 within one year.

During 2014, five weed species, *viz. P. minor*, *R. dentatus*, *C. sativa*, *C. album* and *P.annua* were recorded in wheat fields of districts Jalandhar and Kapurthala of central zone. *C. album* was not recorded in district SBSN but other four weed species as observed in Jalandhar and Kapurthala were recorded in this district along with *A. ludoviciana* as the additional weed. During 2015, *M. neglecta* was also observed in wheat fields of Kapurthala and Jalandhar districts and *S. halepense* in SBSN district only. In Ludhiana and Moga districts, six weed spp. *viz.*, *P. minor*, *R. dentatus*, *C. sativa*, *A. ludoviciana*, *P. annua* and *C. album* infested wheat fields. Weed flora of wheat fields of Ludhaiana and Moga districts was same during both the years.

Table 2. Frequency (%) and density (m²) of weeds infesting wheat fields in three zones of Punjab during March in 2014

Agro-climatic	*P. minor*		*R.dentatus*		*C. sativa*		*A. ludoviciana*		*C.album*		*S. halepense*		*M. neglecta*		*P. annua*	
zone	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D
Submontane																
Roop Nagar	50.7	1.2	17.8	0.5	0	0	0	0	0	0	0	0	0	0	15.8	0.9
Hoshiarpur	56.8	2.2	60.1	0.6	54.6	1.2	34.8	0.5	0	0	0	0	0	0	10.7	0.2
Central																
Kapurthala	72.8	8.7	60.8	0.6	40.8	0.9	0	0	15.9	0.5	0	0	0	0	25.8	0.5
Jalandhar	75.8	3.9	65.6	0.4	45.6	0.7	0	0	15.3	0.3	0	0	0	0	18.7	0.7
SBSN	78.7	2.1	20.7	0.2	5.8	0.1	10.8	0.2	0	0	0	0	0	0	13.7	0.4
Ludhiana	89.8	6.1	45.8	0.5	30.8	0.2	18.6	0.2	12.6	0.2	0	0	0	0	17.6	0.4
Moga	70.6	4.1	30.6	0.6	10.6	0.1	15.8	0.2	15.8	0.3	0	0	0	0	20.7	0.4
Arid Irrigated																
Bathinda	10.8	0.7	17.8	0.6	0	0	14.8	0.5	54.8	2.1	0	0	0	0	13.8	0.4
Muktsar	54.8	1.5	13.7	0.4	0	0	18.7	0.4	64.7	2.2	0	0	0	0	10.9	0.7
Faridkot	30.8	1.4	12.8	0.6	0	0	12.8	0.3	37.8	2.0	0	0	0	0	8.7	0.2

Table 3. Frequency (%) and density (m²) of weeds infesting wheat fields in three zones of Punjab during March in 2015

Agro-climatic	*P.minor*		*R.dentatus*		*C.sativa*		*A.ludoviciana*		*C.album*		*S. halepense*		*M. neglecta*		*P. annua*	
zone	F	D	F	D	F	D	F	D	F	D	F	D	F	D	F	D
Submontane																
Roop Nagar	75.8	1.8	25.8	0.7	11.9	0.2	0	0	0	0	0	0	0	0	22.7	1.2
Hoshiarpur	72.6	2.7	75.6	0.8	83.6	3.7	55.6	0.7	0	0	0	0	0	0	15.7	0.3
Central																
Kapurthala	74.5	7.7	72.5	0.7	65.7	1.2	0	0	23.5	0.6	0	0	8.5	0.2	32.5	0.7
Jalandhar	78.5	4.9	74.5	0.5	64.7	0.9	0	0	18.6	0.4	0	0	6.7	0.3	21.5	0.9
SBSN	82.5	2.7	22.7	0.4	12.7	0.1	20.6	0.3	0	0	32.5	0.8	0	0	16.7	0.5
Ludhiana	87.5	5.8	58.6	0.7	45.6	0.3	24.5	0.2	15.6	0.3	0	0	0	0	20.8	0.5
Moga	72.8	3.6	39.8	0.8	19.8	0.3	16.8	0.4	20.8	0.6	0	0	0	0	25.7	0.6
Arid Irrigated																
Bathinda	14.5	0.9	23.5	0.7	0	0	12.5	0.3	65.7	1.3	0	0	0	0	10.7	0.2
Muktsar	68.9	1.9	11.6	0.3	7.6	0.1	14.6	0.2	75.6	2.7	0	0	0	0	8.9	0.4
Faridkot	34.6	1.6	10.8	0.4	0	0	9.8	0.2	39.8	1.9	0	0	0	0	7.9	0.3

P. minor was the most frequent and densely populated weed of Jalandhar, Kapurthala, SBSN, Ludhiana and Moga districts of Punjab. *C. sativa* was an occasional weed (40.8-45.6%) of districts Kapurthala and Jalandhar during 2014, but it became a frequent weed (64.7-65.7%) in wheat fields of these districts during 2015 (Tables 2 and 3)..

In Bathinda, Muktsar and Faridkot districts (arid irrigated zone), five weed species *viz.*, *P. minor*, *R. dentatus*, *A. ludoviciana*, *C. album* and *P. annua* were observed during 2014. During 2015, six weed species were observed in Muktsar district with the addition of *C. sativa* in the weed spectrum. As compared to other zones, *P. minor* infestation was comparatively less in this zone of Punjab. *C. album* was the most frequent and most densely populated weed of arid irrigated zone. There was no infestation of *C. sativa* in wheat fields of arid irrigated zone in 2014. Although at a very low frequency, it has started to emerge even in Muktsar district of this zone in 2015 (Table 2 and 3).

This survey clearly shows that *P. minor* is still the dominant weed of wheat fields but *C. sativa*, which was earlier a weed of non-cropped areas has also started infesting wheat fields. The survey indicated alarming increase in frequencies and densities of *C. sativa* in different areas of Punjab particularly in districts Hoshiarpur, Kapurthala, Jalandhar and Ludhiana in Submontane and central zones. In these districts, the frequency of *C. sativa* increased from 30.8-54.6% to 45.6-83.6% in one year. This level of increase in infestation indicated that this weed is likely to become a major weed of wheat in near future in these districts. Khan *et al*. (2014) ranked *C. sativa* as second most dense and frequent weed after *Parthenium hysterophorus* in Peshawar valley of Pakistan.

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SUMMARY

Wheat fields of three agro-climatic zones, *viz.* submontane zone (districts Roopnagar and Hoshiarpur), central zone (Jalandhar, Kapurthala, Shaheed Bhagat Singh Nagar, Ludhiana and Moga) and arid irrigated zone (districts Bathinda, Muktsar and Faridkot) were surveyed for recording weed flora during the month of March in 2014 and 2015. The major weed flora included four broad-leaf weeds *Cannabis sativa*, The most noteworthy change was increase in the frequency of *C. sativa* over two years. *C. sativa* which was earlier a weed of non-cropped areas has started infesting wheat fields also. The frequency of C. *sativa* in districts Ludhiana, Kapurthala, Jalandhar and Hoshiarpur increased from 30.8-54.6% in 2014 to 45.6-83.6% in 2015. In districts Roopnagar, Shaheed Bhagat Singh Nagar and Moga, the frequency of this weed increased from 0-10.6% in 2014 to 11.9-19.8% in 2015. The survey indicated that *C. sativa* is likely to become a major weed of wheat in near future in four districts *viz*., Ludhiana, Kapurthala, Jalandhar and Hoshiarpur.

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Weed control in sesamum with pre-emergence herbicides

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Sesamum is regarded as "Queen of Oilseeds" by users because of quality (fatty acid composition) of its oil and its resistance to oxidation and acidity even when stored at ambient air temperature (Rathore 2005). The area under sesamum in India was 13.74 lakh ha with production of 5.22 lakh tonnes having productivity of 380 kg/ha during 2012-13, however, in Maharashtra state sesamum area is 0.31 lakh ha with production of 0.8 lakh tonnes and productivity of 260 kg/ha during 2012-13. The area under Marathawada region was 0.10 lakh ha with production of 0.02 lakh tonnes and productivity of 217 kg/ha during 2012-13 (Anonymus 2013).

In sesamum the weed competition is one of the most important causes of yield loss, which is estimated around 30-60 per cent. (Mukhtar and Elamin 2012). Application of herbicide is one of the best options and adequate information regarding the use of herbicide is available but in *Kharif* farmers have to synchronous the sowing time and pre-emergence herbicide application. Hence a field experiment was conducted at weed science Research Center, Parbhani during 2013 to find out the most effective pre emergence herbicide for Sesamum crop.

The experiment was conducted at Weed Science Research Center, VNMKV, Parbhani (M.S.) on black cotton soil with low nitrogen, medium phosphorus and high potassium content. The experiment was laid out in randomized block design with seven treatments [pendimethalin 0.75 kg/ha as pre-mergence, butachlor 1.50 kg/ha as pre-emergence, oxyfluorfen 0.10 kg/ha as pre-mergence, alachlor 1.00 kg/ha as pre-emergence, Weed free (four hand weeding at 15 days interval), weedy check, and two hand weeding (20 and 40 DAS) and one hoeing (30 DAS) and replicated thrice. The gross plot size was 5.4 x 4.5 m and net plot size 4.5 x 4.2 m. The sesamum cv. '*Phule Til- 1*' was sown by drilling on 16^{th} June 2013 at 45 x 15 cm. Basal dose of fertilizer at 30:60 kg/ha N and P was applied. The total annual rainfall received was 658 mm in 40 rainy days. The weed count and dry weed weight was measured at 15 days interval. The weed count was measured with a quadrent.

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Weed count

Thirty three weed species associated with sesamum crop were recorded. Among which dicot contributed more than grassy species. Dominating dicots weeds were *Ipomoea* spp., *Phylanthus medrapatensis, Convolvulus arvensis, Euphorbia hitra, Parthenium hyseterophorus, Digera arvensis* and *Acalypha indica*. In grassy species *Cynodon dactylon* and *Bracheria eruciformis,* and in sedges *Cyperus rotundus* was recorded during the period of investigation.

As regards to herbicidal treatments, at all stages lower weed count of monocots was observed with (PE- butachlor at 1.5 kg/ha) followed by (PE-alachlor at 1.0 kg/ha). Whereas lowest weed count of dicots was observed in herbicidal treatment of (PE-butachlor 1.5 kg/ha) .

Dry weed weight

At all dates of observations, lowest dry weed weight of monocots and dicots was recorded in treatment (weed free) (Table 1). As regards to herbicidal treatments, at all crop growth stages lower dry weight of monocot weeds was observed with treatment (butachlor 1.5 kg/ha) followed by treatment (alachlor 1.0 kg/ha). Whereas lowest dry weed weight of dicots was observed in herbicidal treatment (PE- butachlor at 1.5 kg/ha) followed by treatment (PE- oxyfluorfen at 0.10 kg/ha.

Weed control efficiency

Highest weed control efficiency was recorded in weed free followed by two hand weedings + one hoeing. Among herbicidal treatments, PE - butachlor at 1.5 kg/ha recorded higher weed control efficiency because of restricted growth of weeds.

Yield and net returns

Highest sesamum seed yield (0.48 t/ha) and stalk yield (1.40 t/ha) were harvested from weed free, which was statistically similar with two hand weedings + one hoeing *i.e.* (seed yield 0.45 t/ha and

Table 1. Mean weed count/m² as influenced by different treatments at various crop growth stages

Treatment	30 DAS		45 DAS		60 DAS	
	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot
T_1 – Pendimethalin 0.75 kg/ha	4.50 (19.8)	11.53 (132.5)	4.74 (22.0)	11.80 (138.9)	4.88 (23.4)	11.87 (140.4)
T_2 – Butachlor 1.50 kg/ha	3.98 (15.4)	10.98 (120.1)	4.31 (18.1)	11.40 (129.6)	4.44 (19.3)	11.59 (133.8)
T_3 – Oxyfluorfen 0.10 kg/ha	6.60 (43.2)	11.13 (123.6)	7.02 (48.9)	11.54 (132.8)	7.32 (53.2)	11.71 (136.8)
T_4 – Alachlor 1.00 kg/ha	4.24 (17.5)	11.26 (126.5)	4.49 (19.7)	11.63 (134.9)	4.59 (20.6)	11.73 (137.1)
T_5 – Weed free	3.12 (9.3)	4.98 (24.3)	3.40 (11.1)	5.31 (27.7)	3.61 (12.6)	5.58 (30.7)
T_6 – Weedy check	11.14 (123.6)	18.97 (359.9)	11.94 (142.1)	19.72 (388.7)	12.70 (156.3)	19.81 (392.0)
T_7 – 2 hand weedings + 1 hoeing	3.31 (10.5)	5.13 (25.9)	3.52 (12.0)	5.44 (29.1)	3.67 (13.0)	5.70 (32.1)
LSD (P=0.05)	2.66	6.10	2.82	6.31	2.98	6.37

Table 2. Mean dry weed weight (g/m²) as influenced by different treatments at various crop growth stages

Treatment	30 DAS		45 DAS		60 DAS	
	Monocot	Dicot	Monocot	Dicot	Monocot	Dicot
T_1 – Pendimethalin 0.75 kg/ha	3.20 (10.2)	9.17 (83.6)	4.74 (22.0)	9.41 (88.0)	4.92 (23.7)	9.86 (96.7)
T_2 – Butachlor 1.50 kg/ha	2.60 (6.3)	8.31 (68.5)	2.96 (8.3)	8.71 (75.4)	3.05 (8.8)	8.90 (78.7)
T_3 – Oxyfluorfen 0.10 kg/ha	4.10 (16.3)	9.14 (83.0)	4.89 (23.4)	9.36 (87.1)	5.01 (24.6)	9.74 (94.4)
T_4 – Alachlor 1.00 kg/ha	2.86 (7.7)	9.02 (80.9)	3.11 (9.2)	9.29 (85.8)	3.43 (11.3)	9.56 (90.9)
T_5 – Weed free	1.54 (1.9)	2.01 (3.5)	1.80 (2.7)	2.18 (4.2)	1.96 (3.3)	2.26 (4.6)
T_6 – Weedy check	8.61 (73.6)	19.70 (387.6)	10.12 (101.9)	20.54 (421.4)	12.15 (147.1)	21.79 (474.3)
T_7 – 2 hand weedings + 1 hoeing	1.96 (3.3)	2.05 (3.7)	2.37 (5.1)	2.27 (4.6)	2.59 (6.2)	2.56 (6.1)
LSD (P=0.05)	1.86	4.88	2.49	5.04	2.69	5.28

The data were subjected to $\sqrt{x + 0.5}$ transformation and values in parentheses are original.

Table 3. Mean seed yield, stalk yield, gross / net monetary return and B:C ratio as influenced by different treatments at harvest

Treatment	Seed yield (t/ha)	Stalk yield (t/ha)	Gross monetary return (x10³ `/ha)	Net monetary return (x10³ `/ha)	B:C ratio	Mean WCE (%)
T_1 – Pendimethalin 0.75 kg/ha	0.39	1.20	48.00	32.95	3.18	56.3
T_2 – Butachlor 1.50 kg/ha	0.42	1.25	51.62	37.21	3.58	65.0
T_3 – Oxyfluorfen 0.10 kg/ha	0.36	0.96	44.28	29.58	3.01	54.3
T_4 – Alachlor 1.00 kg/ha	0.40	1.20	49.20	34.63	3.37	62.1
T_5 – Weed free	0.48	1.40	58.95	39.10	2.96	86.2
T_6 – Weedy check	0.27	1.02	32.90	19.05	2.37	-
T_7 – 2 hand weedings + 1 hoeing	0.45	1.30	55.25	36.80	2.99	83.2
LSD (P=0.05)	0.09	0.15	4.93	4.00	-	-

straw yield 1.30 t/ha), PE - application of butachlor at 1.5 kg/ha and found significantly superior over rest of the treatments. Weedy check recorded lowest seed yield/ha (Table 2). Similar results were reported earlier by Mondal *et al.* (2008) and Sukhadia *et al.* (2004).

Highest net return was achieved with weed free. However, it was statistically at par PE - butachlor at 1.5 kg/ha and found significant over rest of all treatments. Similar results were also reported by Mondal *et al.* (2008). Similarly, highest benefit : cost ratio of 3.58 was observed in herbicidal treatment T_2 (PE- butachlor at 1.5 kg/ha) followed treatment T_4 (PE - alachlor at 1.0 kg/ha).

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Short communication

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Potassium salt based glyphosate effect on cotton yield and quality

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Key words: Cotton, fibre quality, glyphosate, seed cotton yield

Cotton, being a fibre crop, it plays a predominant role in the national and international economy. Cotton, being a long duration, wide spaced and relatively slow growing crop during early growth stages is subjected to severe weed problem. About 30% of the cotton crop losses were due to weeds.

Number of sympodial branches are significantly reduced due to weed infestation. Velayutham *et al.* (2002) reported that unweeded check reduced the boll number/plant and boll weight of cotton. Khan and Khan (2003) reported that grassy weeds cause 15 to 40% and broad-leaf weeds 15 to 30% yield losses in cotton crop. The weeds adversely affected the quality characters of cotton like fibre length, seed weight, fibre uniformity, Micronnaire and Pressely indices. With these references, the present study was undertaken to evaluate the performance of potassium salt based glyphosate in cotton weed control.

The present study was carried out during winter season of 2011-12 at Eastern Block farm, Tamil Nadu Agricultural University. The soil was sandy clay loam in texture with low in available nitrogen (187.3 kg/ha), medium in available phosphorus (12.8 kg/ha) and high in available potassium (559.0 kg/ha) with pH of 8.44. The experiment was laid out in randomized block design with ten treatments and replicated thrice (Table 1). Good viable delinted seeds of '*MRC 7347 BG-II*' were dibbled on one side of the ridges with a spacing of 90 × 60 cm. The seed rate adopted was 2.5 kg of delinted seeds/ha. The experimental plots were applied with recommended dose of fertilizers (150:75:75 kg NPK /ha). Nitrogen, phosphorus and potassium were applied in the form of urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) respectively. Full dose of P and 50% of N and K were applied as basal before sowing and the balance of 50% of N and K were applied as top dressing at 45 and 60 DAS in two equal splits.

The pre-emergence herbicide was applied with pendimethalin (30 EC) at 750 g/ha at 3 DAS followed by earthing up at 45 and 55 DAS. Calculated quantity of herbicide with a spray fluid of 500 l/ha was sprayed uniformly over the plots using hand operated sprayer fitted with fan type nozzle. Calculated quantity of potassium salt based glyphosate at three different doses, *viz.* 1350, 1800, 2250 g/ha to the respective treatment plots was sprayed at 35 and 70 DAS using hand operated sprayer fitted with fan type and mist type nozzle, respectively under controlled application by using hood. The treatments which having hand weeding, hand weeder weeding and power weeding were done at the respective days. The seed cotton (Kapas) was harvested in three pickings commencing on 125 DAS in all the treatment plots. Observations on weed characters like weed flora, weed density, weed dry weight were recorded on regular intervals.

Yield attributes significantly improved in various weed management methods over unweeded control and resulted in higher seed cotton yield as earlier reported by Bhoi *et al.* (2010). More number of sympodial branches with higher number of bolls and boll weight (Table 1) were obtained with the post-emergence application of glyphosate at 1800 g/ha at 35 and 70 DAS + IC at 45 and 55 DAS due to better control of late emerging weeds and creating favourable environment through intercultural operations which was comparable with PE pendimethalin at 750 g/ha + IC at 45 and 55 DAS. These results are also in conformity with Stewart *et al.* (2005) who reported that, total number of bolls and boll weight are important components of overall yield and also, number of bolls, boll weight and seed cotton yield were higher with glyphosate applied treatments compared to non-treated control.

Better growing conditions with lesser weed competition with POE glyphosate at 1800 g/ha at 35 and 70 DAS + IC at 45 and 55 DAS resulted in higher number of sympodial branches (19.6), bolls (58.4) and boll weight (6.6 g) with higher boll setting per cent of 53 (Table 1). These results are in line with the earlier findings of Ali *et al.* (2005) who had stated that, application of PE pendimethalin at 1.0 kg/ha in combination with interculturing plus hand weeding

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Table 1. Effect of weed management methods on yield attributes and yield of cotton

Treatment	Sympodial branches/ plant	Bolls/ plant	Boll setting percentage (%)	Boll weight (g/boll)	Yield (t/ha)
Glyphosate at 1350 g/ha+ IC at 35 and 70 DAS	16.2	44.7	50.8	5.0	1.94
Glyphosate at 1800 g/ha + IC at 35 and 70 DAS	17.7	49.2	49.8	5.6	2.18
Glyphosate at 2250 g/ha + IC at 35 and 70 DAS	18.2	54.8	51.3	5.7	2.25
Glyphosate at 1800 g/haat 35 and 70 DAS+ IC at 45 and 55 DAS	19.6	58.4	53.0	6.6	2.93
Pendimethalin at 750 g/ha+ ICat 45 and 55 DAS	18.4	55.4	53.0	6.5	2.71
HW at 35 and 70 DAS + IC at 45and 55 DAS	18.2	55.8	51.8	5.8	2.42
HWW at 35 and 70 DAS + IC at 45 and 55 DAS	16.3	51.3	50.8	5.1	2.00
PWW at 35 and 70 DAS + IC at 45 and 55 DAS	16.5	51.7	50.6	5.2	2.24
HW at 25 and 45 DAS	17.5	50.4	52.8	5.5	2.29
Unweeded control	15.1	22.5	33.1	4.9	0.91
LSD (P=0.05)	0.95	3.31	10.9	0.52	0.46

gave 199.4% increase in seed cotton yield over untreated check. Nalini *et al*. (2011) also reported higher number of bolls and seed cotton yield from PE pendimethalin + hand weeding treatment. Followed by this treatment, HW at 35 and 70 DAS + IC at 45 and 55 DAS recorded higher yield attributes.

Highest seed cotton yield was obtained with post-emergence application of glyphosate at 1800 g/ha applied at 35 and 70 DAS with intercultural operation of earthing up at 45 and 55 DAS which was comparable with pre-emergence application of pendimethalin at 750 g/ha + intercultural operation at 45 and 55 DAS. The treatments with intercultural operation performed better in yield attributes and higher yield compared to treatments without intercultural operation.

Cotton fibre quality in glyphosate applied plots was showed similarity with hand weeding, hand weeder weeding and power weeder weeding. This shows that, POE glyphosate application did not affect the quality parameters. Cotton fibre quality characteristics are dependent upon the inherent genetics of the individual variety (Bradow and Davidonis 2000).

SUMMARY

A field investigation was carried out at Eastern Block farm, Tamil Nadu Agricultural University, during winter season of 2011-12 to evaluate the new formulation of potassium salt based glyphosate (Roundup Crop Shield 460 SL) on seed cotton yield and quality parameters in winter irrigated cotton. Experimental results revealed that higher seed cotton yield was obtained with POE glyphosate at 1800 g/ha at 35 and 70 DAS with + IC at 45 and 55 DAS which was comparable with PE pendimethalin at 750 g/ha + IC at 45 and 55 DAS. While comparing, intercultural operation carried out treatments performed better and recorded more seed cotton yield than the treatments without intercultural operation, Cotton fibre quality in glyphosate applied plots was showed similarity with hand weeding, hand weeder weeding and power weeder weeding, shows that POE glyphosate application did not affect the quality parameters.

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Short communication

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Weed management with new generation herbicides in maize

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Key words: Atrazine, Cowpea, Intercropping, Maize, Tembotrione, Topramezone, Weed management

Maize is one of the important rainy season crop of Telangana, which has brought about a perceptible change in the economy of the farmers. Being rainy season crop, it suffers from severe infestation of weeds, which often inflicts huge losses ranging from 28 to 100 % (Patel *et al.* 2006). Few herbicides like atrazine, oxyfluorfen, 2,4-D and pendimethalin are available for weed control in maize. At present farmers are applying only 2,4-D at 1.0 kg/ha or atrazine at 1.0 kg/ha as post-emergence herbicides in maize, but these herbicides control only broad leaf weeds. Control of grasses and sedges remain a problem for the farmers, especially when the too high or too low soil moisture hinders the intercultural operation and scarcity of labour during critical stages of weeding. Hence, present study was undertaken to evaluate the tank mix efficacy of new herbicides topramezone and tembotrione with atrazine.

A field experiment was conducted during *Kharif*, 2014 at College Farm, College of Agriculture, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The soil of the experimental site was sandy loam in texture low in available N medium in available P and K. The experiment was laid out in randomized block design with ten treatments replicated thrice. The recommended dose of fertilizer was 180-60-60 kg of N, P_2o_5 and K_2o. Maize hybrid '*DHM-117*' was sown with a spacing of 60 x 20 cm. Observations on weed density and weed drymatter were recorded by using quadrate of 0.5 x 0.5 m^2.

The experimental field was infested with *Cynodon dactylon*, *Digitaria sanguinalis*, *Dactyloctenium aegyptium*, *Echinocloa* spp and *Rottboellia exaltata* among grasses; *Parthenium hysterophorus*, *Commelina benghalensis*, *Amaranthus viridis*, *Euphorbia geniculata*, *Digera arvensis* and *Trianthema portulacastrum* among the broad-leaved weeds and sedge *Cyperus rotundus*.

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Weed control through various means significantly reduced the weed density over weedy check at 20 DAS. (Table 1). Topramezone + atrazine at 25.2 + 250 g/ha + MSO as (post-emergence) recorded lower density of grasses (4.50/m^2) which was at par with tembotrione + atrazine at 105 + 250 g/ha + stefes mero adjuvant as post-emergence (6.0/m^2). Lower density of sedges (19.72/m^2) was recorded in intercropping with cowpea and application of pendimethalin at 1.0 kg/ha as pre-emergence, which was at par with topramezone + atrazine at 25.2 + 250 g/ha + MSO as post-emergence (23.5/m^2). Topramezone + atrazine at 25.2 + 250 g/ha + MSO as post-emergence recorded lower density (3.56 /m^2) of broad-leaved weeds (BLW), which was at par with tembotrione + atrazine 105 + 250 g/ha + stefes mero as post-emergence (4.38/m^2) and atrazine as pre-emergence at 1.0 kg/ha followed by intercultivation at 30 DAS (5.30 /m^2) and all these were significantly superior to other treatments. Total number of weeds was significantly lower with topramezone + atrazine at 25.2 + 250 g/ha + MSO as post-emergence (31.56/m^2) and at par with tembotrione + atrazine at 105 + 250 g/ha + stefes mero (36.03/m^2), intercropping with cowpea and application of pendimethalin at 1.0 kg/ha as pre-emergence (37.38 /m^2) and atrazine as pre-emergence followed by intercultivation at 30 DAS (41.37/m^2).

Topramezone + atrazine at 25.2 + 250 g/ha + MSO as post-emergence recorded significantly lower weed dry matter (16.73 g/m^2) which was at par with tembotrione + atrazine at 105 + 250 g/ha + stefes mero as post-emergence (18.23 g/m^2), intercropping with cowpea and pendimethalin at 1.0 kg/ha as pre-emergence (18.93 g/m^2) and atrazine at 1.0 kg/ha as pre-emergence followed by IC at 30 DAS (20.34 g/m^2). These results are in accordance with Bollman *et al.* (2008) and Roy *et al.* (2008).

Maximum grain yield (6.58 t/ha was recorded) in hand weeding at 20 and 40 DAS which was 60.5% over the unweeded control and on par with

Table 1. Effect of different weed control treatments on weed density (no./m^2) and dry matter production (g/m^2) of weeds

Treatment	Weed density (20 DAS)			Total	Weed dry weight (20 DAS)
	Grasses	Sedges	BLW		
Atrazine (1.0 kg/ha) as PE *fb* inter- cultivation at 30 DAS	(9.6) 3.25	(26.4) 5.23	(5.3) 2.50	(41.4) 6.51	(20.3) 4.61
Topramezone (25.2 g/ ha) + MSO (adjuvant) as PoE	(13.7) 3.83	(28.6) 5.44	(7.6) 2.93	(49.9) 7.13	(27.1) 5.31
Tembotrione (105 g /ha) + adjuvant as PoE	(12.7) 3.70	(29.5) 5.52	(8.9) 3.15	(51.1) 7.22	(28.3) 5.41
Topramezone + atrazine (25.2 +250 g/ ha) + adjuvant as PoE	(4.5) 2.34	(23.5) 4.94	(3.6) 2.13	(31.6) 5.71	(16.7) 4.21
Tembotrione + atrazine (105+250 g /ha) + adjuvant as PoE.	(6.0) 2.64	(25.6) 5.16	(4.4) 2.31	(36.0) 6.08	(18.2) 4.38
Tembotrione (105 g/ha) as PoE	(13.2) 3.76	(34.0) 5.91	(9.3) 3.21	(56.5) 7.58	(30.6) 5.61
Intercropping of maize with cowpea and PE application of pendimethalin (1.0 kg/ha).	(10.8) 3.43	(19.7) 4.55	(6.8) 2.79	(37.4) 6.19	(18.9) 4.46
Hand weeding at 20 and 40 DAS.	(46.3) 6.87	(37.3) 6.18	(54.7) 7.46	(138.3) 11.80	(73.3) 8.62
Intercultivation at 20 and 40 DAS	(47.9) 6.99	(36.5) 6.12	(56.6) 7.58	(141.0) 11.91	(74.6) 8.69
Unweeded control	(53.2) 7.35	(38.6) 6.29	(57.7) 7.66	(149.4) 12.26	(79.3) 8.96
LSD (P=0.05)	0.52	0.54	0.65	0.84	0.4

Table 2. Effect of different weed control treatments on grain yield, stover yield and economics of maize

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Net returns (x10^3 `/ha)	B:C ratio
Atrazine (1.0 kg/ha) as PE *fb* inter- cultivation at 30 DAS	5.72	7.02	55.34	3.11
Topramezone (25.2 g/ ha) + MSO (adjuvant) as PoE	4.99	6.84	43.13	2.50
Tembotrione (105 g /ha) + adjuvant as PoE	4.83	6.74	40.97	2.43
Topramezone + atrazine (25.2 + 250 g/ ha) + adjuvant as PoE	6.44	7.60	62.61	3.17
Tembotrione + atrazine (105+250 g /ha) + adjuvant as PoE	6.28	7.50	60.18	3.10
Tembotrione (105 g/ha) as PoE	4.53	6.58	37.03	2.30
Intercropping of maize with cowpea and PE application of pendimethalin (1.0 kg/ha)	(4.71) (MEY)	6.37	41.17	2.55
Hand weeding at 20 and 40 DAS	6.58	8.04	59.37	2.72
Intercultivation at 20 and 40 DAS	5.49	7.00	52.35	3.01
Unweeded control	2.59	5.36	14.73	1.60
LSD (P=0.05)	0.36	0.43	4.77	

PoE - post-emergence PE - pre-emergence

topramezone + atrazine at 25.2 + 250 g/ha + MSO as PoE (6.44 t/ha) with 59.6% increase over the unweeded control and tembotrione + atrazine at 105 + 250 g/ha + stefes mero as PoE (6.28 t/ha) with 58.7% increase over the control (Table 2). These findings were substantiating with the results of Hatti *et al.* (2014).

Higher benefit: cost ratio was recorded in tank mix of topramezone + atrazine at 25.2 + 250 g/ha + MSO as PoE (3.17) followed by atrazine as PE followed by intercultivation at 30 DAS (3.11).

Tank mix application of topramezone (25.2 g/ ha) or tembotrione (105 g/ha) with lower doses of atrazine at 250 g/ha along with adjuvants is effective in controlling the weeds and recording higher yield in *Kharif* maize.

SUMMARY

Topramezone + atrazine at 25.2 + 250 g/ha + methylated seed oil MSO (adjuvant) or tembotrione + atrazine at 105 + 250 g/ha + stefes mero (adjuvant) as post-emergence, atrazine at 1.0 kg/ha followed by intercultivation at 30 DAS and intercropping of maize with cowpea and pendimethalin at 1.0 kg/ha as pre-emergence reduced the weed density and weed biomass significantly at 20 DAS.

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Short communication

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Use of post-emergence herbicides to control weeds in ramie plantation

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Key words: *Boehmeria nivea,* Ramie, Fiber yield, *Imperata cylindrica,* Quizalofop-ethyl, Weed

Ramie (*Boehmeria nivea* (L.) Gaud. is a semi-perennial herbaceous bast fibre crop which produces longest (120 mm) and strongest (40-65 g/tex) textile fibre of plant origin (Mitra *et al.* 2014). The cultivated area of ramie in the world is about 0.088 million ha with a production of 0.163 million tonnes fibre per annum, 85% of which comes from China (Mitra *et al.* 2013). In India, ramie is naturally distributed in the North-Eastern states like Asam, Arunachal Pradesh, Manipur, Mizoram, Nagaland and northern part of West Bengal but the area under the crop is meagre. The crop faces stiff competition from both annual and perennial weeds in the field as the growth rate of ramie is much slower than that of the existing weeds during the initial establishment phase or after each cutting. Traditionally manual weeding is being practiced in ramie crop but it accounts for almost 25% of total cost of cultivation (Kumar *et al.* 2015) and is very difficult also during rainy season. Sarma *et al.* (1980) reported that combined application of atrazine and paraquat at 1 kg + 2 l/ha sprayed carefully between the rows after each cutting could control the grassy weeds in ramie plantation. However, this application was unable to control the second flush of weeds and also some perennial weeds like *Imperata cylindrica* and *Cynodon dactylon* which showed significant vegetative growth afterwards. Hence, the present experiment was conducted with an aim to identify suitable herbicides for effective control of wide spectrum of weeds present in ramie crop particularly during the rainy season when the weed growth is very high.

The field experiment was conducted in a three year old ramie plantation in two successive cuttings during 2013 at ICAR-CRIJAF Barrackpore West Bengal. The soil was clay loam in texture, with medium organic carbon (0.65%), available N (295 kg/ha) and K (180 kg/ha), while the avilable P content in soil was high (35 kg/ha). The crop was grown with recommended package and practices (Mitra *et al.* 2013). After the harvesting of existing ramie on 15-06. 2013, seven weed control treatments *viz.* weed free, ethoxysulfuron 15% WDG at 20 g/ha, quizalofop-ethyl 10% EC at 40 g/ha, quizalofop-ethyl 5% EC at 60 g/ha, fenoxaprop-p-ethyl 10% EC at 100 g/ha, protected spray (only in inter row space) of glyphosate 41% SL at 1.25 kg/ha and weedy check were imposed in randomized block design with three replications. All the herbicide treatments were followed by one hand weeding (HW) at 10 days after spraying of the herbicide (DAS). Herbicides were sprayed 20 days after each cutting/harvesting of ramie when the sprouted canes attained the height of about 25 cm and almost all weeds emerged from soil. Weed population was recorded in each plot from two randomly selected quadrats (0.5 x 0.5 m) at 30 days growth stages/days after cutting.

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Weed control efficiency (WCE) and weed control index (WCI) were calculated on the basis of weed population and of weed dry weight, respectively (Das 2008). Crop was harvested at 60 day age when the lower part of the canes turned light brown or coppery in colour and lower leaves became yellowish and begin to shed. The experimental data of both the cuttings were analyzed by applying the technique of 'analysis of variance' and significance was tested by variance ratio, *i.e.* F value at 5% level. Analysis of variance for weed density and dry weight was carried out after square root $\sqrt{(x+0.5)}$ transformation to normalise the data. Regression model was developed to study the relationship of fibre yield and weed dry matter to estimate the loss in fibre yield due to weed infestation.

Weed flora

A total of nine weed species were recorded in weedy plot (Fig. 1) which comprised of four grass weeds, *viz. Imperata cylindrica* L. (relative density-42-46%), *Dichanthium annulatum* (Forsk) Stapf, (10.6-13.9%), *Cynodon dactylon* (L.) Pers, (10.7%) and *Paspalum disticum* L.,(4.6-5.9 %); four broad-leaved weeds, *viz. Ageratum conyzoides* L.(6.4-8.2%), *Blumea laciniata* (Burmf) D (4.7 %)., *Amaranthus viridis* L.(1.7-5.9 %) and *Tridex procumbens L.* (1.6-3.5%) and only one sedge, *i.e. Cyperus rotundus* (8.2-12.7%) (Fig. 1).

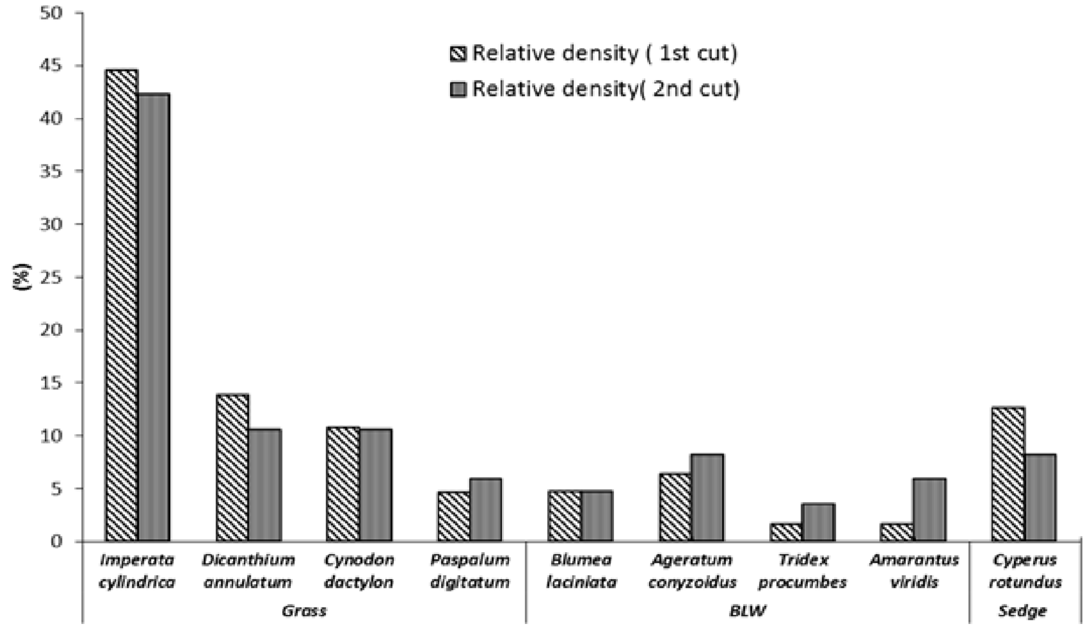

Fig. 1. Relative density of weed species in weedy plot at 30 DAS

Table 1. Effect of weed control treatment on weed density at 30 days after cutting

Treatment	Weed density (no./m^2) First cut				Second cut			
	Grass	BLW	*Cyperus*	Total	Grass	BLW	*Cyperus*	Total
Ethoxysulfuron at 20g/ha + HW at 10 DASp	3.83 (15.0)	2.12 (4.0)	1.91 (3.3)	4.81 (23.0)	3.98 (16.0)	2.34 (6.3)	2.86 (8.0)	5.50 (30.3)
Quizalofop-ethyl at 40 g/ha+ HW at 10 DASp	2.86 (8.0)	2.12 (5.3)	2.12 (4.7)	4.47 (20.0)	3.33 (10.7)	3.68 (13.3)	2.39 (5.3)	5.49 (30.7)
Quizalofop-ethyl at 60 g/ha + HW at 10 DASp	3.03 (9.3)	3.12 (9.3)	2.39 (6.7)	4.84 (24.0)	3.89 (14.7)	4.00 (17.3)	2.39 (6.7)	6.17 (37.3)
Fenoxaprop-p-ethyl at 100g/ha + HW at 10 DASp	4.18 (17.3)	2.59 (6.7)	3.12 (9.3)	5.80 (33.3)	4.72 (22.7)	3.12 (9.3)	2.39 (6.7)	6.17 (38.7)
Glyphosate at 1.25 kg/ha (protected) + HW at 10 DASp	4.37 (18.7)	2.59 (6.7)	2.39 (6.7)	5.55 (30.7)	3.28 (10.7)	2.45 (8.0)	2.65 (6.7)	4.88 (25.3)
Weedy check	8.0 (64.0)	3.24 (10.7)	3.30 (12.0)	9.25 (85.3)	8.72 (76)	5.08 (25.3)	3.12 (9.3)	10.53 (110.7)
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)
LSD (P=0.05)	1.36	1.38	NS	1.04	1.31	2.16	1.61	1.93

DASp- Days after herbicide spray; Original values in parentheses were transformed by square root transformation $\sqrt{x+0.5}$ before analysis

Effect on weeds

All the herbicides significantly influenced the density and dry weight of weeds, though, the efficacy of the herbicides varied with type of weeds *i.e.* grasses, broad-leaved weeds (BLW) and sedge (Table 1 and 2). Weed density and dry weight was found to be the highest (85.3 plants/m^2 and 41.9 g/m^2) in weedy plot, while, the values were lowest in weed free plot at 30 DAS. Herbicide application significantly reduced both the density and dry weight of almost all types of weeds in ramie compared to the unweeded plots in both the cuttings. In the first cut, lowest weed density (24/m^2) and weed dry weight (10 g/m^2) were recorded with quizalofop-ethyl at 40 g/ha closely followed by quizalofop-ethyl at 60 g/ha treatment while in second cutting, glyphosate at at 1.25 kg/ha (protected spray) treatment was found to be most effective in reducing the density and dry weight of weeds (Table 1). Effective control of grassy weeds in ramie by spraying of quizalofop-ethyl at 60 g/ha and quizalofop-ethyl at 40 g/ha in jute had also been reported by Ghorai *et al.* (2013).

The variation in density and dry weight of broad-leaved weeds were non-significant among all the herbicides treatments during first cutting while in

Table 2. Effect of weed control treatment on weed dry weight at 30 days after cutting

Treatment	Weed dry weight (g/m^2)							
	First cut				Second cut			
	Grass	BLW	*Cyperus*	Total	Grass	BLW	*Cyperus*	Total
Ethoxysulfuron at 20g/ha + HW at 10 DASp	2.93 (8.9)	1.81 (2.8)	1.47 (2.0)	3.68 (13.2)	2.80 (7.7)	1.85 (3.6)	2.05 (4.6)	3.91 (15.1)
Quizalofop-ethyl at 40 g/ha+ HW at 10 DASp	2.05 (3.8)	1.69 (3.04)	1.59 (2.6)	3.20 (10.0)	2.36 (5.1)	3.06 (9.9)	1.79 (3.0)	4.03 (16.3)
Quizalofop-ethyl at 60 g/ha + HW at 10 DASp	2.17 (4.5)	2.38 (5.2)	1.76 (3.2)	3.50 (12.2)	2.74 (7.0)	2.82 (7.6)	1.84 (3.8)	4.46 (19.7)
Fenoxaprop-p-ethyl at 100g/ha + HW at 10 DASp	2.94 (8.32)	2.10 (4.1)	2.22 (4.9)	4.16 (16.9)	3.12 (9.4)	2.40 (5.3)	1.76 (3.4)	4.26 (17.9)
Glyphosate at 1.25 kg/ha (protected) + HW at 10 DASp	3.07 (8.9)	2.04 (3.9)	1.74 (2.6)	3.97 (15.5)	2.33 (5.1)	1.94 (4.6)	1.91 (2.3)	3.51 (12.9)
Weedy check	5.57 (30.7)	2.49 (6.0)	2.34 (5.1)	6.50 (41.9)	6.09 (36.7)	3.48 (11.7)	2.22 (7.1)	7.31 (52.9)
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)
LSD (P=0.05)	0.88	1.01	1.09	0.69	0.80	1.57	1.06	1.38

DASp- Days after herbicide spray; Original value in parentheses was transformed by square root transformation $\sqrt{x+0.5}$ before analysis

Table 3. Effect of weed control treatment on yield attributes and fibre yield of ramie

Treatment	First cut				Second cut			
	Plant height (cm)	Basal diameter (cm)	Fibre yield (kg/ha)	Weed Index (%)	Plant height (cm)	Basal diameter (cm)	Fibre yield (kg/ha)	Weed Index (%)
Ethoxysulfuron at 20g/ha + HW at 10 DASp	92.0	0.92	395.8	21.5	77.0	0.82	379.2	19.5
Quizalofop-ethyl at 40 g/ha+ HW at 10 DASp	118.3	1.17	447.5	11.2	103.0	1.10	416.0	11.0
Quizalofop-ethyl at 60 g/ha + HW at 10 DASp	114.0	1.17	437.5	13.2	99.0	1.03	400.7	15.0
Fenoxaprop-p-ethyl at 100g/ha + HW at 10 DASp	110.7	1.10	379.2	24.8	95.7	1.00	341.7	27.4
Glyphosate at 1.25 kg/ha (protected) + HW at 10 DASp	110.0	1.13	404.2	19.8	95.0	1.03	379.2	19.5
Weedy check	79.3	0.73	258.3	48.8	69.3	0.70	229.2	51.3
Weed free	130.0	1.33	504.2	0.0	115.3	1.23	470.8	0.0
LSD (P=0.05)	15.0	0.24	77.2		15.6	0.21	90.6	

DASp- Days after herbicide spray

second cutting, the value of said parameters were found to be significantly lower in ethoxysulfuron and glyphosate treatments compared to weedy check. The same trend was observed for the density of *Cyperus rotundus* during first cut. Weed control efficiency (WCE) was the highest (76.6%) with quizalofop-ethyl treatment followed by ethoxysulfuron (73.0%) and quizalofop-ethyl (71.9%) treatments during first cutting. In the second cutting, protected spray of glyphosate 1.25 l/ha recorded highest WCE (77.1%) followed by application of ethoxysulfuron 20 g/ha (72.0%). Weed control index (WCI) was also the highest (76.0%) with quizalofop-ethyl 40 g/ha followed by quizalofop-ethyl 60 g/ha (70.9%) and ethoxysulfuron at 20 g/ha (68.4%), while in second cutting the highest WCI was recorded with protected spray of glyphosate (75.7%) followed by ethoxysulfuron (71.4%). Ethoxysulfuron had been reported to control broad spectrum weeds *i.e.* grass, BLW and *Cyperus* sp. in rice (Pal *et al.* 2008).

Lower efficacy of glyphosate during first cutting may be attributed to the fact that it was sprayed only in inter row space and hence it could not control the weeds present in the intra row space. In second cutting, regrowth of *Imperata cylindrica* and *Cyperus* was lower in inter row space (42% relative density) which resulted into comparatively higher efficacy of glyphosate during second cutting. Effective control of weeds in jute by protected spray of glyphosate was reported earlier by Ghorai *et al.* (2013)

Effect on crop

Application of all the herbicides significantly influenced the yield attributes and fibre yield of ramie.

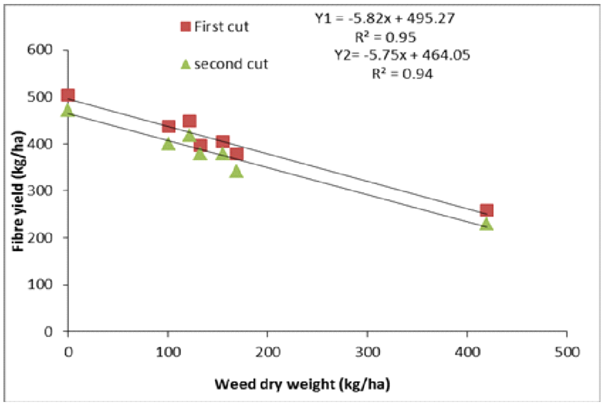

Fig. 2. Regression analysis of weed dry weight fibre yield of ramie

Maximum plant height, basal diameter and fibre yield of ramie were recorded in weed free treatment (Table 3). All the herbicide treatments, recorded significantly higher plant height and basal diameter of the crop over weedy check and maximum value of both parameters were observed in quizalofop-ethyl 40 g/ha followed by quizalofop-ethyl 60 g/ha treatment. Fibre yield of ramie was highest with weed free treatment which was statistically at par with both the quizalofop-ethyl treatments. This was possibly due to the fact that quizalofop-ethyl alike weed free treatment effectively suppressed the growth of the dominant grassy weeds (42-46%) for a longer period and provided a less competitive environment for crop growth, which finally resulted in taller plants and higher fibre yield of ramie. Weed index was found to be maximum in unweeded plot in both the cutting (48.8 and 51.3%). A significant reduction in plant height was recorded was recorded in ethoxysulfuron 15% WDG at 20 g/ha treatment though similar trend was not observed in fibre yield of ramie both the cuttings. The results indicated a probable phytotoxic effect of ethoxysulfuron on ramie at the early stage which the crop could overcome at latter part of growth. A negative correlation was observed between weed dry weight and fibre yield of ramie (Fig. 2). The regression equation clearly showed that an increase of 1.0 kg/ha in weed dry weight resulted in decrease of fibre yield by 5.82 and 5.75 kg/ha in first and second cuts, respectively.

The results of the present study indicated that application of quizalofop-ethyl 10% EC 40 g/ha or quizalofop-ethyl 5% EC at 60 g/ha or protected spray of glyphosate at 1.25 kg/ha with one hand weeding could effectively suppress both grassy and perennial weeds in ramie and increased the fibre yield of the crop.

SUMMARY

Imperata cylindrica was the dominant grass weed (42-46%) followed by *Cynodon dactylon* (10%) and *Cyperus rotundus* (8-12%). Weed infestation throughout growing season of ramie reduced the fibre yield up to 51%. Significant reduction in weed density and dry weight was recorded in both quizalofop-ethyl at 40 g/ha and quizalofop-ethyl at 60 g/ha with weed control efficiency of 72-77% and weed index of 11-15%. The highest fibre yield was recorded in weed free treatment (470-504 kg/ha/cut) which was statistically at par with that of quizalofop-ethyl at 40 g/ha and quizalofop-ethyl at 60 ml/ha treatments (400-447 kg/ha/cut), respectively. Significant reduction of plant height of ramie was observed in ethoxysulfuron at 20 g/ha at initial growth stage. Quizalofop-ethyl at 40 g/ha or quizalofop-ethyl at 60 g/ha followed by one hand weeding may be applied for effective weed control in ramie.

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Short communication

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Phytotoxic evaluation of wasteland weed species

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Key words: Inhibition potential, Leachates, *Parthenium hysterophorus*, Phytotoxicity

Weeds are widely recognized among one of the greatest threats to plant biodiversity. They cause loss of native floral diversity and huge yield losses in agricultural system. they also possesses strong capability to replace neighbouring flora by producing phytotoxic effects, that directly affects the growth through inhibition, suppression or mortality of the plants in a community. These phytotoxic effects attributed to natural phenomenon known as allelopathy/allelopathic interactions. Allelopathy plays a significant role under both natural and managed ecosystems (Rice 1984). Allelochemicals are plant secondary metabolites normally released into the environment through volatilization, leaching, root exudation and decomposition of plant residues in the soil (Khalaj *et al.* 2013) and have positive and negative influences on the plant growth (Jalali *et al.* 2013). These chemicals play a vital role in plant-plant interactions. To link between allelochemicals and allelopathy Makoi and Ndakidemi (2012) noted in their study that most of the allelopathic effects in plants are known to result from allelochemicals released from plants.

Bhadoria (2011) produced an extended list of readily visible effects of allelochemicals on the growth and development of other plants, includes inhibition or retardation of germination rate; reduction of root and shoot length; reduced dry weight accumulation etc.

Parthenium hysterophorus, *Croton bonplandianum*, *Cassia occidentalis*, *Cassia obtusifolia*, *Calotropis procera*, and *Tephrosia purpurea* are weeds that commonly seen growing along railway tracks, roadsides, open lands, wastelands and competes with some crops. Some of these weeds replace or displace natural vegetation and cause severe loss of natural biodiversity at national and international levels and decrease crop yields as well.

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The experiments were conducted during 2014 at St. John's College, Agra, Uttar Pradesh. Fresh leaves and roots of selected wasteland weeds, *viz*. *P. hysterophorus* (W1), *C. bonplandianum* (W2), *C. occidentalis* (W3), *C. obtusifolia* (W4), *C. procera* (W5) and *T. purpurea* (W6) were collected from the nearby wasteland fields. For germination test, the seeds of wheat and barley were procured from the commercial suppliers.

Leaves and root were collected from selected test plants; 100 g leaf and root were soaked in 500 mL double distilled water separately under aseptic conditions for 9 days and placed in conical flasks in a refrigerator at 8 °C. The aqueous leachates were filtered through three layers of muslin cloth/cheese cloth to remove debris. The filtrate was then re-filtered through Whatman No.1 filter paper. Two concentrations, 50% (C_1) and 100% (C_2) were prepared and directly used for bioassay.

Seeds of wheat and barley were thoroughly washed with tap water to remove dirt and dust and then rinsed with mild detergent solution for 5-7 min. Seeds were surface sterilized with 0.1% $HgCl_2$ for 10 min and again washed with sterilized distilled water 4-7 times. Seeds were divided into 5 replicates of 10 seeds each in Petri Dishes and were placed on filter paper in Petri Dishes and moistened with leaf and root leachates of different weed species, whereas control received distilled water. All the seed lots were allowed to germinate and germination was recorded for 10 days. Seedlings growth (radicle length, plumule length and biomass) was also recorded after 10 days of germination.

Data obtained were analyzed using the three way analysis of variance (ANOVA) technique and least significant difference (LSD=0.05) tested by the Fisher LSD method with the help of Sigma plot software.

Seed germination

Maximum inhibition on seed germination of wheat was noticed in 100% concentration of leaf leachates of *P. hysterophorus* (79.3%). High concentration of leaf leachates of other plants also showed remarkable reduction in seed germination percentage of wheat. The inhibition order was observed as *C. occidentalis* (77.5%) > *C. obtusifolia* (75.6%) > *C. bonplandianum* (50.5%) > *T. purpurea* (49.7%) > *C. procera* (44.3%) as compared to control (99.7%). High concentration of root leachates (100%) showed more inhibition as compared to 50% leaf leachates, while least inhibition was observed in 50% root leachates (Table 1).

Table 1. Effect of leaf and root leachates of different weed species on seed germination of wheat

Plant	Treatment	Germination percentage (%)	
		Leaf leachates	Root leachates
W_1	50%	42.21 ± 0.88 aA	49.17 ± 1.87 aB
	100%	20.40 ± 1.20 bB	31.41 ± 1.20 bA
	Control	99.68 ± 0.18 c	99.68 ± 0.22 c
W_2	50%	56.11 ± 1.50 aA	65.21 ± 1.51 aB
	100%	49.21 ± 1.91 bB	58.04 ± 2.83 bA
	Control	99.68 ± 0.18 c	99.68 ± 0.22 c
W_3	50%	44.01 ± 1.70 aA	51.40 ± 0.89 aB
	100%	22.12 ± 0.37 bB	35.21 ± 0.18 bA
	Control	99.68 ± 0.18 c	99.68 ± 0.22 c
W_4	50%	45.45 ± 0.34 aA	54.20 ± 1.00 aB
	100%	24.12 ± 1.01 bB	35.05 ± 0.15 bA
	Control	99.68 ± 0.18 c	99.68 ± 0.22 c
W_5	50%	65.11 ± 1.80 aA	72.58 ± 2.38 aB
	100%	55.41 ± 1.71 bB	69.27 ± 1.56 bA
	Control	99.68 ± 0.18 c	99.68 ± 0.22 c
W_6	50%	58.21 ± 1.11 aA	64.17 ± 0.47 aB
	100%	50.01 ± 1.18 bB	61.31 ± 0.71 bA
	Control	99.68 ± 0.18 c	99.68 ± 0.22 c
LSD (P=0.05)	50%	0.98	1.04
	100%	1.02	0.88

Same trend of inhibition on seed germination of barley, where maximum inhibition was observed in 100% concentration of leaf leachates of *P. hysterophorus* (78.9%) and minimum in 50% root leachates of *C. procera* (26.9%). *C. occidentalis* and *C. obtusifolia* showed remarkable inhibition after *P. hysterophorus* in both cases *i.e.* > 75.0% at higher concentration of leaf leachates and > 70.0% at root leachates whereas control showed 100% germination. Three Way ANOVA indicated that there was a statistically significant interaction ($P < 0.001$) between leachates, concentrations and plants on mean germination percentage of wheat and barley, individually. It is clear from the results that all the selected weed species caused remarkable inhibition on seed germination as well as seedling growth of wheat and barley. Leaf leachates of most of the weed species especially *P. hysterophorus*, *C. bonplandianum*, *C. occidentalis*, *C. obtusifolia* and *T. purpurea* were found highly phytotoxic against both parameters in wheat and barley as compared to root leachates. As the concentration increased their effects were also escalated. A number of previous studies support the findings of this experiment that the degree of inhibition increases with increasing extract concentration (Laosinwattana *et al.* 2007, Knox *et al.* 2011).

The degree of inhibition was higher in leaves therefore leads to more phytotoxicity damage to seed germination than roots and this is in agreement with Sarkar *et al.* (2012) findings that allelochemicals concentrations may differs between plant parts.

Seedling growth

Maximum reduction in radical length, plumule length and biomass of wheat was noticed in 100% concentration of leaf leachates of *P. hysterophorus* (2.7 cm, 3.7 cm and 0.018 g) followed by *C. occidentalis* (2.9 cm, 4.5 cm and 0.021 g) > *C. obtusifolia* (2.9 cm, 4.7 cm and 0.023 g) as compared to control (7.2 cm, 6.8 cm and 0.28 g).

Table 2. Effect of leaf and root leachates of different weed species on seed germination of barley

Plant	Treatment	Germination percentage (%)	
		Leaf leachates	Root leachates
W_1	50%	43.14 ± 0.74 aA	54.41 ± 2.00 aB
	100%	21.1 ± 0.60 bB	34.51 ± 1.30 bA
	Control	100 ± 0.00 c	100 ± 0.00 c
W_2	50%	56.75 ± 3.04 aA	69.47 ± 2.26 aB
	100%	51.74 ± 1.44 bB	62.17 ± 0.56 bA
	Control	100 ± 0.00 c	100 ± 0.00 c
W_3	50%	46.20 ± 0.89 aA	56.24 ± 0.05 aB
	100%	23.22 ± 0.51 bB	39.21 ± 0.49 bA
	Control	100 ± 0.00 c	100 ± 0.00 c
W_4	50%	48.20 ± 1.90 aA	56.2 ± 0.90 aB
	100%	25.22 ± 1.01 bB	39.80 ± 1.59 bA
	Control	100 ± 0.00 c	100 ± 0.00 c
W_5	50%	67.08 ± 1.88 aA	73.14 ± 0.73 aB
	100%	61.14 ± 3.83 bB	70.80 ± 3.60 bA
	Control	100 ± 0.00 c	100 ± 0.00 c
W6	50%	59.62 ± 1.22 aA	66.24 ± 2.04 aB
	100%	50.21 ± 0.70 bB	64.74 ± 1.53 bA
	Control	100 ± 0.00 c	100 ± 0.00 c
LSD (P=0.05)	50%	1.06	0.92
	100%	0.93	1

W1, W2, W3, W4 and W5 indicate *P. hysterophorus*, *C. bonplandianum*, *C. occidentalis*, *C. obtusifolia*, *C. procera*, and *T. purpurea*.

Each value is the average of five replicates (n=5); ± Standard deviation; CD Critical difference (Table 2)

Different letters in lower case within a column for each plant indicate a statistically significant difference in mean values of germination % of wheat ($P < 0.001$)

Different letters in upper case within same row for each plant indicate a statistically significant difference in mean values of germination % of wheat ($P < 0.001$)

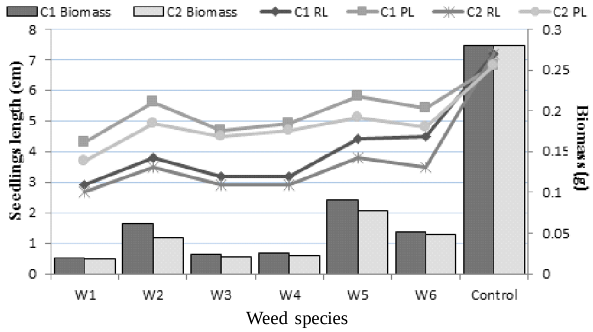
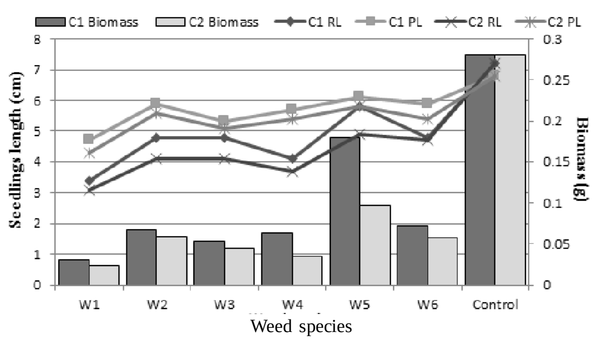


Fig. 1. Effect of leaf leachates of different weed species on seedling growth of wheat

Least inhibition on seedling growth was observed in 50% concentration of *C. procera* (4.4 cm, 5.8 cm and 0.091 g). High concentration (100%) of root leachates suppressed the growth of radicle and plumule growth, consequently reduced biomass of wheat as compared to 50% concentration (Fig. 2). Root leachates of *P. hysterophorus* showed maximum reduction in seedlings length and biomass (3.1 cm, 4.3 cm and 0.023 g) at 100% concentration, followed by *C. obtusifolia* (3.7 cm, 5.4 cm and 0.035 g). Least effect was observed in 50% concentration of *C. procera i.e.* 5.8 cm, 6.1 cm and 0.18 g.



C1 and C2= 50% and 100% concentrations; RL= radicle length; PL = plumule length

Fig. 2. Effect of root leachates of different weed species on seedling growth of wheat

Inhibitory effects of 100% concentration of leaf leachates on radical length, plumule length and biomass of barley plant. Maximum reduction in seedlings length and biomass (2.2 cm, 3.4 cm and 0.023 g) was observed in *P. hysterophorus* leaf leachates at 100% concentration closely followed by *C. occidentalis* (3.1 cm, 3.5 cm and 0.025 g), when compared with control (8.7 cm, 9.2 cm and 0.34 g). half concentration of leaf leachates of all weed species caused 50% reduction in seedlings length except *C. procera* (Fig. 3), 100% root leachates of *P. hysterophorus* and *C. occidentalis* caused maximum reduction in seedlings lengths and biomass *i.e.* 3.8 cm, 4.2 cm and 0.031 g in *P. hysterophorus* leachates and 3.8 cm, 4.8 cm and 0.034 g in *C. occidentalis* leachates, respectively. half concentration (50%) of root leachates showed minimum effects on seedlings growth as compared to 100% concentration. Leachates of *C. procera* and *T. purpurea* showed least inhibitory effects on seedlings growth at 50% concentrations.

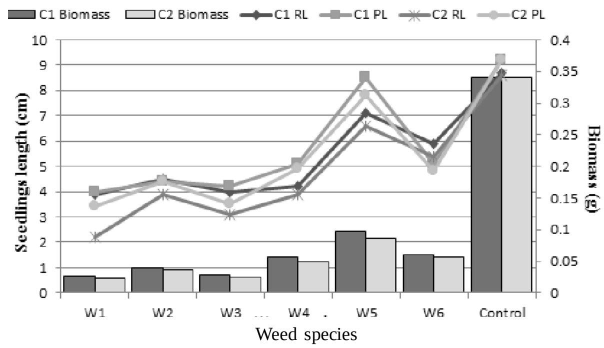


Fig. 3. Effect of leaf leachates of different weed species on seedling growth of barley

Aqueous leaf leachates of all the selected weed species retarded the seedling growth and reduced dry matter production (Fig. 4). It is in the line with the findings of Belz *et al.* 2007, Msafiri *et al.* 2013, reported adverse effects of foliar leachates of *P. hysterophorus* induces to retardation or complete inhibition of growth. It is also confirmed with the Zhang *et al.* (2009) findings that different plants have different inhibitory potential therefore they exhibit differential allelopathic potential against different species.

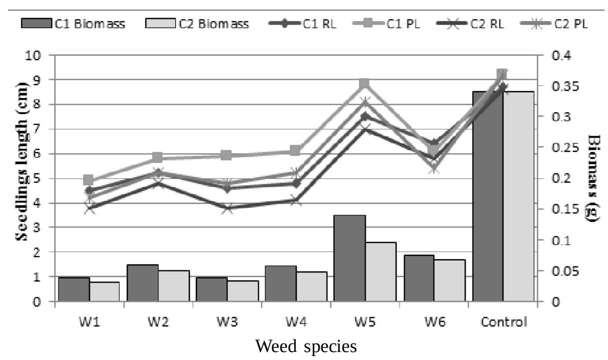


Fig. 4. Effect of root leachates of different weed species on seedling growth of barley

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SUMMARY

To characterize the phytotoxic potential, a laboratory experiment was conducted by considering some prominent wasteland weeds like *Parthenium hysterophorus*, *Croton bonplandianum*, *Cassia occidentalis, Cassia obtusifolia, Calotropis procera,* and *Tephrosia purpurea*. Aqueous leachates of leaf and root of different concentrations (50 and 100%) were tested against seed germination and seedlings growth of wheat and barley, as test plants. High concentration (100%) of leaf leachates showed remarkable inhibition on seed germination, radicle and plumule length and decreased biomass respectively, closely followed by the 50% concentration of leaf leachates. Maximum inhibition (> 70.00%) was recorded in 100% concentration of *P. hysterophorus*, *C. occidentalis* and *C. obtusifolia* leaf leachates as compared to root leachates (< 65.00%) except *P. hysterophorus* and similar trend of inhibition in radicle, plumule length and biomass was recorded. Root leachates showed least inhibitory effects at 50% concentration whereas 100% root leachates were comparatively more effective than 50% leaf leachates. A statistically significant interaction between leachates, concentrations and plants ($P < 0.001$) was observed; hence a significant inhibition was seen at higher concentration of leaf leachates. Inhibition potential of considered weeds clearly indicates the presence of phytotoxic chemicals in their tissues that supports them in establishment, competing and replacement of surrounding flora.

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Short communication

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Response of Isachne to herbicides using bioassay techniques

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Isachne miliacea Roth. locally known as 'Chovverippullu, Naringa, Njammal, and Changalipullu' is one of the dominant weed in the low land rice ecosystems of Kerala. The weed belongs to the family Poaceae. It is seen both in *Kharif* (KAU 1988), and *Rabi* seasons (KAU 1990). Varghese (1996) has reported that *I. miliacea* alone can contribute to 61% reduction in the production of rice in Onattukara region. Presently, the weed is reported to be spreading to other rice growing regions of the state. Currently weed shift has become a common phenomenon in the rice ecosystems of Kerala. This can be attributed to the opportunistic germination, habit, fecundity and competitive ability of the weeds together with the natural resistance of some species to newer herbicides which are more specific in action.

The prostrate nature of *I. miliacea* and its ability to germinate from both seed and stem cuttings contribute to the fast spread of the weed in the rice ecosystems. The weed escapes attention in a mature rice field due to its prostrate nature, information on the sensitivity of the weed to new herbicides is also meagre. Hence a study was conducted to evaluate the sensitivity of *I. miliacea* to pre- and post-emergence herbicides using seed and whole plant bioassay techniques, respectively., According to Blacklow and Pheloung (1991), bioassay tests give practical information on the response of a species to specific herbicides. Zhang *et al.* (2012) used whole plant bioassay techniques with weed species for herbicide dose-response and resistance diagnosis.

The study was conducted during 2014-2015 in College of Horticulture, Vellanikkara, Thrissur to understand the response of *I. miliacea* to common herbicides. The sensitivity of *I. miliacea* to pre-emergence, post-emergence and non-traditional rice herbicides was tested using bioassay technique.

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Seed bioassay technique was adopted to test the sensitivity of the weed to pre-emergence herbicides. Three sets of experiments were conducted in Petridishes of area 63.5 cm^2, using Top of paper method (TP) and Between paper method (BP) as described by ISTA (1996). In the first set, herbicide soaked filter paper was placed at the bottom of Petri plates and seeds were placed on it (TP method). In the second set, the herbicide soaked filter paper was placed on top of the seeds and another water soaked filter paper was placed at the bottom (BP method I). In the third set, seeds were placed in between two filter paper soaked with herbicides (BP method II).

TP method gives the effect of the herbicide on the germinating radicle of the weed, BP method I gives the effect of the herbicides on the germinating plumule. In BP method II effect on both plumule and radicle is obtained.

To test the efficacy of pre- and post-emergence herbicides to *I. miliacea,* the weed was grown in mud pots of diameter 0.18 m. Four pots were arranged to test in an area of 0.16 sq.m and the water required for covering this area was caliberated using a hand sprayer. The quantity of herbicides required to cover 0.16 sq. m area was calculated (Table 1, 2 and 3). The weeds were allowed to spread in the pots afer 15 days of spraying. The herbicides were sprayed when the weeds were in the vegetative phase using a hand sprayer. The herbicides were classified as susceptible, moderately resistant and resistant to *I. miliacea* based on phytotoxicity symptoms such as leaf scorching, leaf curling, tip burn, yellowing, dead plants and regrowth.

All the herbicides tested gave excellent control in BP method II where the seeds were placed between two herbicide soaked filter papers. The seed of *I. miliacea* showed zero germination for all the four pre-emergence herbicides tested by this method (Table 4). Pendimethalin was the only herbicide which gave better control in TP method as compared

Table 1. The recommended dose and quantity of pre-emergence herbicides used

Herbicide	Recommended dose (kg/ha)	Quantity used in petriplate (ml)
Butachlor	1.25	0.008
Pretilachlor	0.50-0.75	0.004
Oxyfluorfen	0.15	0.0009
Pendimethalin	1- 1.50	0.008

Table 2. The recommended dose and quantity of post-emergence herbicides used

Herbicide	Recommended dose (g/ha)	Quantity used in 0.16 sq.m area (g)
Bispyribac sodium	25	0.0004
Pyrazosulfuron-ethyl	35	0.0005
Azimsulfuron	35	0.0005
Penoxsulam	25	0.0004
Fenoxaprop p-ethyl	60	0.0001

Table 3. The recommended dose and quantity of non-traditional rice herbicides used

Herbicide	Recommended dose (kg/ha)	Quantity used in 0.16 sq.m (ml)
Glyphosate	2	0.03
Diuron	3	0.04
Paraquat	3	0.04
Glufosinate ammonium	2	0.03

Table 4. Seed bioassay using pre-emergence herbicides

Herbicide	Seed germination percentage		
	Top paper TP I	Between paper BP I	Between paper BP II
Control	47.5^{e}	42.5^{d}	50.0^{b}
Pretilachlor	7.5^{b}	5.0^{b}	0.0^{a}
Oxyfluorfen	10.0^{c}	0.0^{a}	0.0^{a}
Pendimethalin	22.5^{d}	32.5^{c}	0.0^{a}
Butachlor	0.0^{a}	0.0^{a}	0.0^{a}

Statistical analysis done using Friedman test, The alphabets denote the effectiveness of the herbicide within the column

to BP methods I and II. This may be because pendimethalin affects cell division of the root and is a root inhibitor and it is not translocated by xylem. Oxyfluorfen inhibited seed germination in both BP methods I and II, this may be because the chemical is more sensitive to the plumule than the radicle. The action of pretilachlor was similar to oxyfluorfen but less effective. Butachlor gave the best result in all the three methods indicating that both the germinating radicle and plumule were affected by the herbicide.

In the whole plant bioassay technique for post-emergence herbicides, best control was obtained for azimsulfuron followed by cyhalofop-butyl and fenoxaprop p- ethyl. Hence they were classified as susceptible herbicides for *I. miliacea* (Table 5).

Bispyribac-sodium and penoxsulam showed initial control but regrowth was seen after two weeks the weed showed moderate resistance to these herbicides. This may be due to faster metabolism of the weed or the insensitivity of the target enzyme to the ALS inhibitor as suggested Nady *et al.* (2012) in the case of *Echinochloa colona*

The weed was resistant to pyrazosulfuron. Similar effect of the herbicide has also been observed by Margo *et al.* (2010) on *Cyperus difformis.* This indicates variation in the target enzymes of the ALS inhibitors of pyrazosulfuron-ethyl.

All the four non-traditional rice herbicides tested, *viz.* glyphosate, diuron, paraquat, glufosinate ammonium gave excellent control of *I. miliacea* and no regrowth was observed after two weeks (Table 6). These herbicides can be recommended for control of the in paddy fields before land preparation.

The study clearly indicates that the pre-emergence herbicides butachlor and oxyfluorfen and the post-emergence herbicides azimsulfuron,

Table 5. Whole plant bioassay using pre-emergence herbicides (DAS – Days After Spraying)

Herbicide	Mode of action	2 DAS	4 DAS	8 DAS	15 DAS
Bispyribac-sodium	Inhibition of ALS	No discolouration	Leaf discolouration	Reddish colour at the tip of leaves, wilting started	Wilted, regrowth
Pyrazosulfuron-ethyl	Inhibition of ALS	No discolouration	No discolouration	Leaf discolouration	Not wilted
Azimsulfuron	Inhibition of ALS	No discolouration	Leaf discolouration	Reddish colour at the tip of leaves, wilting started	Wilted
Penoxsulam	Inhibition of ALS	No discolouration	Leaf scorching	Reddish colour at the tip of leaves, wilting started	Regrowth observed
Cyhalofop-butyl	Inhibition of ACCase	No discolouration	Leaf discolouration	Reddish colour at the tip of leaves, wilting started	Wilted
Fenoxaprop -p-ethyl	Inhibition of ACCase	No discolouration	Leaf discolouration	Reddish colour at the tip of leaves, wilting started	Wilted

[ALS - Aceto Lactate synthase, ACCase - Acetyl CoA Carboxylase]

Table 6. Whole plant bioassay using non-traditional herbicides

Herbicide	Mode of action	2 DAS	4 DAS	8 DAS	15 DAS
Glyphosate	Inhibition of amino acids	Leaf discolouration	Leaf tip and shoot tip burned	Wilting started	Permanently wilted
Diuron	Inhibition of photosystem- I	Leaf discolouration	Leaf scorching	Wilting started	Permanently wilted
Paraquat	Inhibition of photosystem- I	Wilting Started	Permanently wilted	Permanently wilted	Permanently wilted
Glufosinate ammonium	Inhibition of glutamine synthetase	Leaf scorching	Leaf chlorosis	Leaf necrosis, wilting started	Permanently wilted

(DAS – Days After Spraying)

cyhalofop-butyl, and fenoxaprop-p-ethyl can be recommended in rice fields prone to the infestation of *I. miliacea*.

SUMMARY

A study was conducted during 2014-2015 in College of Horticulture, Vellanikkara, Thrissur to understand response of the *Isachne miliacea* to common herbicides. Sensitivity of the weed to pre- and post-emergence herbicides were tested using seed and whole plant bioassay techniques, respectively. The pre-emergence herbicides butachlor and oxyfluorfen gave the best results. Among post-emergence herbicides, effective control was observed for azimsulfuron, cyhalofop-butyl and fenoxaprop-p-ethyl. The weed was found to be resistant to pyrazosulfuron. Regrowth was observed after two weeks for bispyribac sodium and penoxsulam. All the non-traditional rice herbicides tested, *viz*. glyphosate, diuron, paraquat, glufosinate ammonium gave excellent control of the weed.

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