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Weed management in rice as influenced by nitrogen application and herbicide use

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ABSTRACT

A field experiment was conducted for two consecutive rainy seasons of 2010 and 2011 at Varanasi (U.P.) to evaluate the effect of nitrogen application and weed management on transplanted rice and associated weeds. Puddled transplanting recorded significantly reduced weed density and heigher weed control efficiency at 60 days after transplanting (DAT) as compared to unpuddled transplanting. Butachlor 1.5 kg/ha followed by cono-weeding at 20 and 40 DAT recorded significantly higher plant height, no. of tillers/hill, dry matter accumulation, leaf area index, 1000-grain weight, no. of panicles/hill, grains/panicle and grain yield as compared to pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 DAT, and butachlor 1.5 kg/ha followed by azimsulfuron 35 g /ha at 15 DAT. Significantly higher yield components and rice grain yield were recorded with the application of 1/4 at 10 DAT, 1/2 at tillering and 1/4 N at panicle initiation as compared to conventional scheduling of nitrogen application.

Key words: Azimsulfuron, Butachlor, Cono-weeding, Nitrogen timing, Transplanted rice

In India, rice is the staple food for millions of people and plays a vital role in the economy. It is generally grown by transplanting in puddled soils. Weeds are regarded as one of the major limiting factors of the crop production (Rao and Nagamani 2010). Weeds share light, nutrients and water with the crop and thus interfere with rice growth and production in many ways. The effective control of weeds at initial stages (0-40 DAT) can help in improving productivity of the crop. Aminpanah *et al.* (2013) observed that the highest grain yield were observed with pretilachlor. Suganthi *et al.* (2010) reported that pre-emergence application of pretilachlor 1.0 kg/ha and pretilachlor 0.75 kg/ha with a hand weeding at 45 DAT offered better weed control and resulted in increased yield and economics of transplanted rice compared to the recommended weed control methods of butachlor 1.25 kg/ha, anilofos 0.4 kg/ha and pretilachlor 0.75 kg/ha, and hand weeding twice. Application of azimsulfuron 27.5 g/ha + metsulfuron-methyl 2 g/ha + 0.2% surfactant was more effective in controlling weeds and recorded higher mean grain and straw yields (Jayadeva *et al.* 2010). Naresh *et al.* (2013) reported that yields of rice in conventional puddled transplanting were higher as compared to unpuddled transplanting, reduced-till transplanting, and direct-seeding systems.

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Nitrogen plays an important role in realising higher rice yield and maintaining the photosynthetic activity during grain filling stage of the crop. It is important to increase nitrogen utilization efficiency in rice production system through scheduling of nitrogen application as per the demand of crop plants. Singh and Thakur (2007) recorded that application of nitrogen up to 90 kg/ha in four splits (1/4 basal + 1/4 at active tillering + 1/4 at panicle initiation + 1/4 at boot stage) and 3 splits (1/4 at basal + 1/4 at active tillering and 1/4 at panicle initiation). The present study was undertaken to study the influence of nitrogen application and weed management on rice and weed growth, and yield of transplanted rice.

MATERIALS AND METHODS

A field experiment was conducted for consecutive two rainy seasons of 2010 and 2011 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The geographical location of the farm lies at $25^0$18'N latitude and $88^0$36'E latitude at an altitude of 129 m from the mean sea level in the Northern Indo-Gangetic alluvial plains. The soil of experimental site was sandy-clay-loam in texture with slightly basic reaction (pH-7.37). It was low in organic C (0.49%) and available N (197.5 kg/ha), medium in available P (24.0 kg/ha) and K (230.9 kg/ha). The total rainfall of 715.8 mm and 1137.7 mm was received during rice crop seasons of 2010 and 2011, respectively. The field experiment was conducted in split-plot design which was replicated thrice. Treatment combinations of two methods of rice transplanting (puddled and unpuddled) and five weed management methods (butachlor 1.5 kg/ha followed by azimsulfuron 35 g/ ha + non-ionic surfactant (0.25%) at 25 DAT, pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha+NIS (0.25%) at 25 DAT, butachlor 1.5 kg/ha followed by cono-weeder at 20 DAT and two hand weedings at 20 and 40 DAT and weedy) were kept in main plots, and the sub-plot treatments were nitrogen (120 kg/ha) application timing as conventional scheduling of nitrogen application (1/2 at basal dressing, 1/4 at tillering and 1/4 at panicle initiation), and initial reduced dose and delayed nitrogen application (1/4 at 10 DAT, 1/2 at tillering and 1/4 at panicle initiation) with the cultivar *'BPT-5204'*.

Rice was transplanted in July and harvested in November. The land was prepared by giving two ploughings each followed by planking with the help of a tractor-drawn cultivator. The puddling was done at the time of transplanting only in puddled transplanting treatments, while in unpuddled transplanting the water was given after ploughing the field twice followed by planking after receipt of monsoonal rainfall. A uniform fertilizer dose of 120, 60, 60 kg N, P_2O_5 and K_2O/ha in the form of urea, single super phosphate and muriate of potash was applied to each experimental unit. All P and K were applied at sowing while N was applied according to treatments. Two rice seedlings per hill were transplanted at 20 cm x 15 cm spacing in experimental field. Rice was harvested at full physiological maturity, sun-dried for a week and threshed manually. Weed and crop samples were collected from each individual plot for studying various crop and weed characters. Weed samples were collected by placing a quadrat (0.5 m x 0.5 m) randomly at two places in each plot. Treatment-wise pre- and post-emergence herbicides were applied by knapsack sprayer fitted with flat fan nozzle using water volume of 300 L/ha. The data on weed density were subjected to square root $(\sqrt{x+1})$ transformation before statistical analysis to obtain homogeneity of variances.

RESULTS AND DISCUSSION

Effect on weeds

The experimental field was infested with grassy weeds, *viz. Echinochloa colona*, *Echinochloa crusgalli*, *Cynodon dactylon*, *Panicum repens* and *Paspalum distichum;* broad-leaved weeds, *viz. Ammania baccifera*, *Eclipta alba*, *Caesulia axillaris*, *Commelina benghalensis*, *Euphorbia hirta* and *Ludwigia parviflora;* and sedges, *viz. Cyperus iria*, *Cyperus difformis* and *Fimbristylis miliaceae*.

Method of rice transplanting significantly influenced the weed density at 60 DAT (Table 1). The lower weed density was recorded under puddled transplanting, which was significantly superior to unpuddled transplanting. This might be due to effective control of all categories of weeds during intensive puddling, which was started two weeks before transplanting and sufficient time allowed for germination of weed seeds present in the soil.

Amongst weed management methods, lower density of grasses, broad-leaved weeds and sedges at 60 DAT and higher weed control efficiency (Table 1, 3) was recorded with butachlor 1.5 kg/ha followed by cono-weeding at 20 DAT. Pretilachlor 0.75 kg/ha followed by azimsulfuron 35 g/ha at 15 DAT had significantly lower broad-leaved weeds and sedges and higher weed control efficiency as compared to the butachlor 1.50 kg/ha followed by azimsulfuron 35 g/ha at 15 DAT at 60 DAT. This was due to integration of chemical and mechanical method of weed control resulting in broad-spectrum control of weeds.

Initial reduced dose and delayed N application (1/4 at 10 DAT, 1/2 at tillering and 1/4 at panicle initiation) recorded significantly reduced weed density and significantly higher weed control efficiency as compared to conventional scheduling of nitrogen application. It might be due to the dynamics of N supply synchronized to meet the demand by the rice crop as reported by Mukherjee and Maity (2011).

Effect on rice

In case of rice transplanting methods, puddled transplanting recorded significantly higher plant height, number of tillers/hill, dry matter accumulation and leaf area index as compared to unpuddled transplanting (Table 2). It might be due to low crop-weed competition on growth attributes in puddled transplanting as compared to unpuddled transplanting.

Amongst weed control methods, butachlor 1.5 kg/ha followed by cono-weeding at 20 DAT recorded significantly higher plant height, no. of tillers/hill, dry matter accumulation and leaf area index. This might be due to comparatively less weed competition for nutrients, and better weed control as reported by Rajendran *et al.* (2003).

Table 1. Effect of methods of rice transplanting, nitrogen application and weed management on weed density rice at 60 DAT

Treatment	Weed density (no./m^2)						Total weed density (no./m^2)	
	Grasses		Broad-leaved weeds		Sedges			
	2010	2011	2010	2011	2010	2011	2010	2011
Rice transplanting								
Puddled transplanting	2.91* (9.5)	2.85 (9.1)	2.60 (7.8)	2.55 (7.5)	2.24 (6.0)	2.19 (5.79)	4.39 (20.2)	4.29 (19.4)
Unpuddled transplanting	3.33 (12.0)	3.25 (11.6)	3.07 (10.4)	3.00 (10.0)	2.56 (7.5)	2.51 (7.3)	5.16 (27.6)	5.04 (26.4)
LSD (P=0.05)	0.26	0.24	0.21	0.20	0.18	0.17	0.27	0.25
Weed management								
Butachlor 1.5 kg/ha(PE) *fb* azimsulfuron 35 g/ha at 15 DAT	2.81 (8.9)	2.75 (8.6)	3.47 (13.0)	3.39 (12.5)	3.34 (12.1)	3.26 (11.6)	5.60 (32.3)	5.46 (30.8)
Pretilachlor 0.75 kg/ha (PE) *fb* azimsulfuron 35 g/ha at 15 DAT	2.49 (7.2)	2.44 (6.9)	2.91 (8.5)	2.85 (9.1)	1.51 (3.28)	1.49 (3.2)	4.03 (17.2)	3.93 (16.4)
Butachlor 1.5 kg/ha *fb* cono-weeding at 20 DAT	1.70 (3.9)	1.67 (3.8)	2.21 (5.9)	2.17 (5.7)	1.26 (2.6)	1.25 (2.6)	2.82 (8.9)	2.76 (8.6)
Two hand weedings at 20 and 40 DAT	1.0 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.00 (0.0)	1.0 (0.0)	1.00 (0.0)	1.00 (0.0)
Weedy	7.60 (58.7)	7.41 (55.9)	4.57 (21.8)	4.46 (20.8)	4.90 (25.1)	4.75 (23.5)	10.42 (109.5)	10.1 (104.2)
LSD (P=0.05)	0.41	0.38	0.34	0.32	0.29	0.27	0.43	0.41
Nitrogen application								
½ N at basal, ¼ N at tillering, ¼ N at panicle initiation	3.29 (11.8)	3.22 (11.3)	2.99 (9.9)	2.92 (9.5)	2.53 (7.4)	2.47 (7.1)	5.07 (26.7)	4.95 (25.5)
¼ N at 10 DAT, ½ N at tillering, ¼ N at panicle initiation	2.95 (9.7)	2.89 (9.3)	2.68 (8.2)	2.63 (7.9)	2.27 (6.1)	2.23 (6.0)	4.48 (21.1)	4.38 (20.1)
LSD (P=0.05)	0.18	0.15	0.20	0.19	0.14	0.13	0.19	0.18

*Population figures are transformed to $(\sqrt{x+1})$ and actual figures are given in parentheses, DAT- Days after transplanting

Table 2. Effect of methods of rice transplanting, nitrogen application and weed management on growth attributes in rice at 60 DAT

Treatment	Plant height (cm)		No. of tillers/hill		Dry matter accumulation (g/hill)		Leaf area index	
	2010	2011	2010	2011	2010	2011	2010	2011
Rice transplanting								
Puddled transplanting	85.5	87.3	11.3	11.4	27.1	27.9	4.74	4.76
Unpuddled transplanting	78.9	80.7	9.7	9.9	24.3	24.5	4.34	4.36
LSD (P=0.05)	4.21	4.31	0.72	0.65	1.34	1.52	0.23	0.19
Weed management								
Butachlor 1.5 kg/ha (PE) *fb* azimsulfuron 35 g/ha at 15DAT	77.0	78.8	9.9	10.0	23.5	23.9	4.37	4.39
Pretilachlor 0.75 kg/ha (PE) *fb*azimsulfuron 35 g/ha at 15 DAT	80.1	81.9	10.4	10.6	24.9	25.1	4.59	4.61
Butachlor 1.5 kg /ha *fb* cono-weeding at 20 DAT	89.9	92.4	11.6	11.7	28.9	29.1	5.24	5.26
Two hand weedings at 20 and 40 DAT	93.2	95.4	12.3	12.5	30.9	31.5	5.59	5.61
Weedy	70.6	72.3	8.3	8.4	20.2	21.3	2.93	2.94
LSD (P=0.05)	6.66	6.82	1.14	1.03	2.12	2.41	0.36	0.30
Nitrogen application								
½ N at basal, ¼ N at tillering, ¼ N at panicle initiation stages	77.1	78.9	9.9	10.1	24.0	24.5	4.32	4.34
¼ N at 10 DAT, ½ N at tillering, ¼ N at panicle initiation	87.3	89.2	11.1	11.2	27.3	27.9	4.77	4.78
LSD (P=0.05)	3.74	4.04	0.49	0.59	1.22	0.97	0.21	0.18

DAT- Days after transplanting

Initial reduced dose and delayed nitrogen application (1/4 at 10 DAT, 1/2 at tillering and 1/4 at panicle initiation) resulted in significantly higher plant height, no. of tillers/hill, dry matter accumulation and leaf area index in comparison to conventional scheduling of nitrogen. The significant variations in growth attributes were observed due to nitrogen application when needed by crop as observed by Islam *et al.* (2009).

Yield attributes and yield

The differences in 1000-grain weight were non-significant due to rice transplanting method. Puddled transplanting had significantly higher number of panicles/hill, no. of grains/panicle and higher grain yield as compared to unpuddled transplanting (Table 3). Higher values of yield attributes and grain yield under puddled transplanting were perhaps due to better partitioning of photosynthates from source to sink as a result of lower crop-weed competition owing to favourable growing conditions in puddled transplanting. The results were corroborated with the findings of Jaiswal and Singh (2001).

Amongst weed control treatments, butachlor 1.5 kg/ha followed by cono-weeding at 20 DAT had significantly more 1000-grain weight, no. of panicles/hill, no. of grains/panicle and grain yield. This might be due to effective control of weeds which in turn significantly increased the no. of panicles/hill and grains/panicle consequently improving the grain yield. Control of weeds by herbicides during early stages of rice followed by cono-weeding resulted in lower competition for growth resources that influenced the crop to grow better as evidenced in increased yield attributes. Similar findings were also observed by Singh *et al.* (2005) and Ramachandra *et al.* (2012).

Initial reduced dose and delayed nitrogen application (1/4 at 10 DAT, 1/2 at tillering and 1/4 at panicle initiation) resulted in significantly more 1000-grain weight, no. of panicles/hill, grains/panicle and grain yield in comparison to conventional scheduling of nitrogen application. Higher values of yield attributes and grain yield were probably owing to more utilization and uptake of nitrogen at active growing stages, *viz.* tillering and panicle initition. Similar findings were also observed by Awasthe (2009) and Gill and Walia (2013).

It can be concluded that butachlor 1.5 kg/ha followed by cono-weeding at 20 DAT and scheduling of N (1/4 at 10 DAT, 1/2 at tillering stage and 1/4 at panicle initiation stage) under puddled transplanting could be recommended for effective weed management and higher rice yield.

Table 3. Effect of methods of rice transplanting, nitrogen application and weed management on yield attributes, yield and weed control efficiency

Treatment	Rice yield attributes						Rice grain yield (t/ha)		Weed control efficiency (%)	
	Test weight (g/1000 seeds)		No. of panicles/hill		No. of grains/panicle					
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Rice transplanting										
Puddled transplanting	16.5	16.5	12.6	12.8	181.9	184.7	4.64	4.75	65.9	65.7
Unpuddled transplanting	16.1	16.2	11.5	11.8	161.2	163.8	4.20	4.26	53.6	53.5
LSD (P=0.05)	NS	NS	0.50	0.59	11.7	9.28	0.17	0.21	-	-
Weed management										
Butachlor 1.5 kg/ha (PE) *fb* azimsulfuron 35 g/ha at 15DAT	15.1	15.2	11.3	11.4	150.5	152.8	4.37	4.42	33.9	34.6
Pretilachlor 0.75 kg/ha (PE) *fb* azimsulfuron 35 g/ha at 15 DAT	16.1	16.2	11.9	12.0	172.8	175.5	4.52	4.63	45.7	45.7
Butachlor 1.5 kg /ha *fb* cono-weeding at 20 DAT	17.3	17.4	13.1	13.2	204.5	207.7	4.93	5.03	71.0	71.0
Two hand weedings at 20 and 40 DAT	19.2	19.2	14.3	14.5	233.7	237.4	5.42	5.53	100.0	100.0
Weedy	13.8	13.8	9.94	10.3	96.3	97.8	2.85	2.94	0.00	0.00
LSD (P=0.05)	1.18	1.18	0.80	0.93	18.6	14.6	0.28	0.33	-	-
Nitrogen application										
½ N at basal, ¼ N at tillering, ¼ N at panicle initiation	15.9	15.9	11.8	12.0	165.0	167.6	4.22	4.31	55.3	55.1
¼ N at 10 DAT, ½ N at tillering, ¼ N at panicle initiation	16.7	16.8	12.4	12.6	178.1	180.9	4.61	4.71	64.4	64.2
LSD (P=0.05)	0.66	0.66	0.48	0.49	8.51	8.46	0.14	0.15	-	-

DAT- Days after transplanting

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Crop establishment and weed management effects on rice productivity and weed dynamics

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ABSTRACT

A field experiment was conducted in strip-plot design with three crop establishment techniques and six weed management practices to study the effect of crop establishment and weed management on weeds and yield of lowland rice at Coimbatore during *Rabi* 2011-12 and 2012-13. The field was dominated by *Echinochloa colona, Cyperus difformis, Eclipta alba, Marselia quadrifoliata* and *Ammania baccifera*. The results revealed that machine planting (30 x 20 cm) and subsequent cono-weeding at 10, 20, 30 and 40 days after transplanting (DAT) registered lower density and biomass of sedges, grasses, broad-leaved and total weeds resulting in higher grain yield than other treatments. Weed control efficiency (93.2 and 90.8% in 2011-12, and 2012-13, respectively) was higher with this treatment compared with the other treatments. Next best treatment was the machine planting with pretilachlor (0.75 kg/ha at 3 DAT) + bispyribac-sodium (20 g/ha at 15 DAT) + cono-weeding at 40 DAT.

Key words: Crop establishment, Herbicides, Machine planting, Weed management

Transplanting of rice seedlings in the traditional way is laborious, time consuming and causes drudgery. The non-availability of labourers for transplanting at appropriate time leads to late planting, which results in poor yields (Singh *et al.* 2013). To get maximum returns, the cost of cultivation has also to be reduced through the minimization of the dependence on labour for transplanting. Mechanization in transplanting through use of rice transplanter reduces the cost of cultivation and large area can be transplanted within very short period (Hemmat and Taki 2003).

Weed competition is one of the prime yield–limiting biotic constraints in rice. Weeds are the most competitive in their early growth stages than at later stages and hence, the growth is affected and finally grain yield decreases (Jacob and Syriac 2005). For keeping weed population below threshold level, there is a need to evolve an effective integrated strategy involving chemical and mechanical methods. Hence, agronomical manipulations such as establishment techniques with weed management may offer an effective option for better control of weeds in rice. The present study was undertaken with an objective to study the effect of crop establishment and weed management practices on weed characteristics and yield of lowland rice

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MATERIALS AND METHODS

Field experiments were conducted at Coimbatore during *Rabi* of 2011- 12 and 2012-13. The experiment was replicated thrice in strip-plot design with three crop establishment techniques, *viz.* conventional planting (C_1), SRI marker planting (C_2) and SRI machine planting (C_3) assigned to horizontal strips and six weed management practices, *viz.* cono-weeding 4 times at 10, 20, 30 and 40 days after transplanting (W_1), pretilachlor at 0.75 kg/ha 3 DAT + cono-weeding at 20 and 40 DAT (W_2), pretilachlor at 0.75 kg/ha 3 DAT + bispyribac-sodium at 20 g/ha 15 DAT (W_3), pretilachlor at 0.75 kg/ha 3 DAT + bispyribac-sodium at 20 g/ha 15 DAT + cono-weeding at 40 DAT (W_4), bensulfuron-methyl + pretilachlor (60 g + 600 g/ha) 15 DAT + cono-weeding at 30 and 40 DAT (W_5) and un-weeded control (W_6) were allotted to vertical strips. The soil of the experimental site was clay-loam in texture, low in available N (224 and 23l kg/ha of 2011- 12 and 2012-13, respectively), medium in available P (19.0, 17.8 kg/ha of 2011- 12 and 2012-13, respectively) and high in available K (446, 549 kg/ha of 2011- 12 and 2012-13, respectively). Rice "*CO (R) 49*" was used as test variety for this experiment.

The seed requirement in SRI marker and machine planting was 8 kg/ha while for conventional planting, 40 kg/ha. Transplanting of rice seedlings with row planting (seedlings planted in lines with definite planting geometry) to ensure optimum plant population was adopted. In row planting, the population becomes more assured and intercultural operations are much easier as compared to random planting (CPG 2005). The sprouted seeds with a seed rate 40 kg/ha were sown in the wet nursery area of 20 cents (about 810 $m^{2)}$. Then 21 days old seedlings were pulled out and transplanted at the rate of two to three seedlings/hill with a spacing of 20 x 10 cm.

System of Rice Intensification (SRI), a "less water" method of production is ideal for poor farmers with relatively more family labour than land and capital. The sprouted seeds were sown on the mat nursery which was prepared by using the polythene or gunny bags on the shallow raised bed to prevent roots growing deep into the soil. Nursery area of 2.5 cents (about 100 m^2)/ha of main field was used for raising seedlings. Then 12 days old seedlings were pulled out and planted single seedling with the spacing of 25 cm × 25 cm following Baskar (2009) method.

Mechanical transplanting requires a special method of raising seedlings called mat type seedlings. About 125 plastic trays with a length and breadth of 55 x 21 cm were selected to raise seedlings for planting one ha. Soil was sieved and mixed with equal quantity of farm yard manure and spread in the plastic trays to a depth of 2 cm. Sprouted seeds were spread uniformly on the tray and pressed gently. They were covered with paddy straw and watered through rose cans for four days. After 4^{th} day, the straw was removed and water was applied by flooding so as to keep the mat soil wet throughout its growth period. To enhance the growth of seedlings, 2% foliar spray of nitrofoska (19:19:19 N: P: K) was given once at 8-12 days after sowing. When the seedlings were about 2-3 leaf stage, water was drained from the nursery and seedling mat was cut to required size using a knife and rolled and fed to the mechanical transplanter. Transplanting was done through self-propelled walking behind hitech mechanical transplanter with the spacing of 30 cm × 20 cm by running length wise of the field on the puddled and leveled field at 2 cm water depth to avoid floating of seedlings (Bell *et al.* 2003).

Herbicides were dissolved in 500 litres water and sprayed with knapsack sprayer using deflector nozzle. Pretilachlor was applied at 3 DAT and bispyribac-sodium and bensulfuron-methyl + pretilachlor were applied at 15 DAT. Weed count was recorded at 40 DAT using quadrat and expressed in number/m^2.The collected weeds were first dried in the sun and then kept in an electrical oven for 72 hours maintaining a constant temperature of 80 °C. After drying, weight of each species was taken and expressed as biomass kg/ha. The data on weed density and biomass were subjected to square root ($\sqrt{(X+2)}$) transformation before statistical analysis to normalize their distribution. Weed Control efficiency (WCE) was calculated by using standard formula.

RESULTS AND DISCUSSION

Weed density and biomass

The dominant weed flora in experimental field was *Echinochloa colona, Cyperus difformis, Eclipta alba, Marselia quadrifoliata* and *Ammania baccifera* as also reported by (Mandal *et al.* 2013). Rice establishment methods exerted significant influence on the grass density (no./m^2) recorded at 40 DAT during both the years. Grass weed density under machine planting was significantly lower being at par with SRI marker planting than conventional transplanting (Table 1). Among the weed control methods, density of grasses was significantly lower in cono-weeding at 10,20,30 and 40 DAT and pretilachlor 0.75 kg/ha *fb* bispyribac- sodium 20 g/ha + cono weeding 40 DAT. It was clearly evident that combination of two chemicals gave higher weed control efficacy than sole application. Mahajan *et al.* (2009) also reported that sequential application of pretilachlor and bispyribac-sodium was more efficient in controlling the weeds in direct-seeded rice.

Rice establishment methods and weed management practices had significant interaction on grass weed density at 40 DAT. SRI machine transplanting with cono-weeding resulted in significantly lower density of grasses, this was followed by pretilachlor *fb* bispyribac-sodium. Better efficacy of herbicides in conjunction of cono-weeding under machine planting might be due to emergence of weeds in short span in which most of the weeds were affected by herbicides (Maity and Mukherjee 2008)**.** The poor efficacy of herbicides under conventional planting was due to extended period of weed emergence in several flushes coupled with smaller period of herbicide persistence. The same trend was observed under sedges and broad leaved weed density (Table 1 and 2).

Rice establishment methods exerted significant influence on the total weed count (no./m^2) at 40 DAT. Total weed density recorded in machine planting and SRI marker planting compared to conventional transplanting (Table 1). Subbalakshmi and Pandian (2002) have also reported similar results.

Table 1. Effect of rice establishment and weed management on grass and sedge weeds density in rice

Treatment	Grasses (no./m^2) 2011-12				Grasses (no./m^2) 2012-13				Sedges (no./m^2) 2011-12				Sedges (no./m^2) 2012-13			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
W_1	2.43	1.73	1.41	1.86	3.97	2.22	1.75	2.65	2.41	1.79	1.41	1.87	1.97	1.58	1.41	1.65
	(3.9)	(1.0)	(0.0)	(1.6)	(13.8)	(2.9)	(1.1)	(5.9)	(3.8)	(1.2)	(0.0)	(1.7)	(1.9)	(0.5)	(0.0)	(0.8)
W_2	4.11	3.78	3.21	3.70	5.60	4.65	4.63	4.96	4.49	3.78	3.65	3.97	4.69	3.36	2.28	3.44
	(14.9)	(12.3)	(8.3)	(11.8)	(29.4)	(19.6)	(19.4)	(22.8)	(14.7)	(12.3)	(11.3)	(12.8)	(20.0)	(9.3)	(3.2)	(10.8)
W_3	2.64	1.82	1.82	2.09	4.64	2.77	2.31	3.24	3.30	2.30	2.08	2.56	2.51	2.02	1.97	2.17
	(5.0)	(1.3)	(1.3)	(2.5)	(19.5)	(5.7)	(3.3)	(9.5)	(7.0)	(3.3)	(2.3)	(4.2)	(4.3)	(2.1)	(1.9)	(2.7)
W_4	2.63	1.82	1.41	1.96	4.06	2.55	2.12	2.91	2.83	2.21	1.98	2.34	2.35	2.02	1.41	1.93
	(4.9)	(1.3)	(0.0)	(2.1)	(14.5)	(4.5)	(2.5)	(7.2)	(4.6)	(2.9)	(1.9)	(3.1)	(3.5)	(2.1)	(0.0)	(1.9)
W_5	2.88	2.45	2.29	2.54	5.12	3.10	2.84	3.69	2.25	1.41	1.41	1.69	1.99	1.82	1.89	1.90
	(6.3)	(4.0)	(3.2)	(4.5)	(24.3)	(7.6)	(6.1)	(12.6)	(2.2)	(0.0)	(0.0)	(0.7)	(2.0)	(1.3)	(1.6)	(1.6)
W_6	11.34	9.67	7.87	9.63	8.10	7.67	6.37	7.38	9.33	7.35	6.96	7.88	7.67	6.84	6.02	6.84
	(126.6)	(91.6)	(59.9)	(92.7)	(63.6)	(56.8)	(38.6)	(53.0)	(69.9)	(52.0)	(46.4)	(56.1)	(56.9)	(44.7)	(34.2)	(45.3)
Mean	4.34	3.55	3.00		5.25	3.83	3.34		4.10	3.14	2.92		3.53	2.94	2.50	
	(26.9)	(18.6)	(12.1)		(27.5)	(16.2)	(11.8)		(17.0)	(11.9)	(10.3)		(14.8)	(10.0)	(6.8)	
	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C
LSD (P=0.05)	0.96	0.81	0.79	0.94	0.21	1.11	0.46	1.04	0.62	0.50	0.45	0.55	0.63	0.68	0.52	0.72

Figures in parentheses are original values, which were subjected to square root ($\sqrt{(X + 2)}$) transformation

C_1- Conventional planting, C_2- SRI marker planting, C_3- SRI machine planting W_1- Cono-weeding at 10, 20, 30, 40 DAT, W_2- pretilachlor at 0.75 kg /ha 3 DAT + cono-weeding at 20 and 40 DAT, W_3- pretilachlor 0.75 kg/ha 3 DAT + bispyribac-sodium 20 g/ha 15 DAT, W_4- pretilachlor 0.75 kg/ha 3 DAT + bispyribac-sodium 20 g/ha 15 DAT + cono-weeding 40 DAT, W_5- bensulfuron-methyl + pretilachlor (60 g + 600 g/ha) 15 DAT + cono-weeding at 30 and 40 DAT , W_6- unweeded control

Table 2. Effect of rice establishment and weed management on density of broad-leaved weeds and total weeds in rice

Treatment	Broad-leaved weeds (no./m^2) 2011-12				Broad-leaved weeds (no./m^2) 2012-13				Total weeds (no./m^2) 2011-12				Total weeds (no./m^2) 2012-13			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
W_1	3.33	2.18	1.41	2.31	3.47	2.21	1.41	2.37	4.34	2.64	1.41	2.80	5.26	2.88	1.75	3.30
	(9.1)	(2.8)	(0.0)	(4.0)	(10.1)	(2.9)	(0.0)	(4.3)	(16.8)	(5.0)	(0.0)	(7.3)	(25.7)	(6.3)	(1.1)	(11.0)
W_2	10.23	8.06	6.76	8.35	12.11	9.47	8.48	10.02	11.85	9.46	8.08	9.80	14.37	10.89	9.72	11.66
	(84.5)	(63.0)	(43.7)	(63.7)	(119.2)	(87.6)	(69.9)	(92.2)	(114.1)	(87.6)	(63.3)	(88.3)	(168.6)	(116.6)	(92.5)	(125.9)
W_3	4.31	3.07	2.41	3.26	4.93	3.46	2.76	3.72	5.75	3.75	3.08	4.19	7.28	4.45	3.58	5.10
	(13.3)	(7.4)	(3.8)	(8.2)	(18.1)	(10.0)	(5.6)	(11.2)	(25.3)	(12.0)	(7.5)	(14.9)	(41.8)	(17.8)	(10.8)	(23.5)
W_4	4.11	3.01	1.41	2.85	4.20	3.00	1.41	2.87	5.33	3.64	1.98	3.65	6.28	3.95	2.12	4.12
	(12.0)	(7.1)	(0.0)	(6.4)	(12.6)	(7.0)	(0.0)	(6.5)	(21.5)	(11.3)	(1.9)	(11.6)	(30.6)	(13.6)	(2.5)	(15.6)
W_5	6.22	5.08	3.41	4.90	8.15	7.18	5.61	6.98	7.00	5.46	3.85	5.44	9.91	7.77	6.25	7.98
	(29.9)	(23.8)	(9.6)	(21.1)	(53.0)	(49.5)	(29.4)	(44.0)	(38.4)	(27.8)	(12.9)	(26.4)	(79.2)	(58.4)	(37.1)	(58.2)
W_6	13.95	10.91	10.67	11.84	16.45	13.23	12.49	14.06	20.79	16.20	14.84	17.28	20.41	16.63	15.13	17.39
	(158)	(117)	(111)	(129)	(221)	(173)	(154)	(183)	(355)	(260)	(218)	(278)	(342)	(274)	(227)	(281)
Mean	7.03	5.39	4.35		8.22	6.42	5.36		9.18	6.86	5.54		10.59	7.76	6.42	
	(51.3)	(36.8)	(28.2)		(72.4)	(55.0)	(43.2)		(95.2)	(67.4)	(50.6)		(114)	(81.2)	(61.8)	
	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C
LSD (P=0.05)	0.98	0.89	0.69	0.95	1.21	1.06	0.87	1.15	1.45	1.13	1.04	1.26	1.43	1.27	1.06	1.38

Among weed control treatments, cono-weeding resulted in lower weed density and biomass than other treatments. This might be due to the incorporation of weeds by frequent cono-weeding and smothering effect of the larger rice canopy. (Anitha and Chellappan 2011). Among the herbicidal application, pretilachlor 0.75 kg/ha *fb* bispyribac-sodium 20 g/ha + cono-weeding at 40 DAT resulted in significantly lower weed density. This may be attributed to more bioefficacy of pretilachlor *fb* bispyribac-sodium, which effectively controlled both the narrow and broad-leaved weeds. Herbicides alone were least effective in minimizing the density of weeds. This might be due to better control of weeds by pre-emergence herbicides in early stages and control of later emerging weeds, particularly sedges and broad-leaved weeds by sequential application of bispyribac-sodium at later stages (Chinnusamy *et al.* 2006).

Rice establishment methods and weed management practices had significant interaction on total weed density at 40 DAT. SRI machine planting with cono-weeding four times at 10 days interval resulted in significantly lower weed density, This was followed by pretilachlor *fb* bispyribac-sodium. Conventional transplanting resulted in maximum total weed density. This was corroborated with the findings of Cherati *et al.* (2011).

Table 3. Effect of rice establishment and weed management on total weed biomass and rice grain yield

Treatment	Total weed biomass (kg/ha)								Grain yield (t/ha)							
	2011-12				2012-13				2011-12				2012-13			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
W_1	8.56	5.93	3.73	6.07	7.83	8.13	5.44	7.13	4.74	6.47	6.98	6.06	5.19	7.11	7.61	6.64
	(71.2)	(33.2)	(11.9)	(38.8)	(59.3)	(64.1)	(27.6)	(50.3)								
W_2	14.80	10.50	8.050	11.11	11.69	9.56	8.24	9.83	4.28	5.54	6.01	5.28	3.98	6.03	6.04	5.35
	(217.4)	(107.7)	(62.8)	(129.3)	(111.0)	(89.5)	(65.9)	(88.8)								
W_3	10.90	9.78	6.66	9.13	8.18	7.89	6.29	7.45	3.84	4.83	4.67	4.45	3.72	5.31	4.56	4.53
	(117.8)	(93.7)	(42.3)	(84.6)	(53.3)	(60.3)	(37.6)	(50.4)								
W_4	9.25	6.90	4.55	6.90	8.85	8.47	6.17	7.83	4.62	6.37	6.79	5.93	4.66	7.81	7.61	6.70
	(83.5)	(45.6)	(18.7)	(49.3)	(62.7)	(69.8)	(36.1)	(56.2)								
W_5	9.51	7.05	5.13	7.23	9.11	8.61	6.36	8.03	4.43	6.06	6.75	5.74	4.43	7.01	7.08	6.17
	(88.5)	(47.7)	(24.3)	(53.5)	(66.7)	(72.2)	(38.5)	(59.1)								
W_6	17.50	15.20	13.30	15.30	23.00	18.70	17.40	19.70	2.47	2.91	3.05	2.81	2.12	2.41	2.97	2.50
	(304.1)	(228.1)	(174.6)	(235.6)	(435.9)	(348.9)	(300.6)	(361.8)								
Mean	11.80	9.22	6.90		11.45	9.92	8.32		4.07	5.36	5.71		4.02	5.95	5.98	
	(147.1)	(92.7)	(55.8)		(131.5)	(112.4)	(84.4)									
	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C	W	C	C at W	W at C
LSD (P=0.05)	1.22	2.44	0.95	2.37	1.27	1.67	0.91	1.68	0.31	0.43	0.38	0.48	0.29	0.25	0.33	0.34

Weed biomass

Rice establishment methods exerted significant influence on the total weed biomass (kg/ha) at 40 DAT. Total weed biomass in SRI machine transplanting was at par with SRI marker planting (Table 3). This might be due to suppression of initial emerging and emerged weeds on one hand and better crop growth on the other. The results are in agreement with the findings of Mohapatra *et al.* (2012).

Among the vertical strips, considerable reduction in total weed biomass was recorded with cono-weeding four times at 10 days interval and pretilachlor *fb* bispyribac-sodium. This might be attributed to the lesser number of total weeds (Table 1). This is in line with the findings of Anitha and Chellappan (2011).

Rice establishment and weed management had significant interaction on all the stages of crop. SRI machine transplanting with cono-weeding four times at 10 days interval resulted in significantly lower weed biomass or pretilachlor *fb* bispyribac-sodium, This was in conformity with the findings of Uprety (2010), who revealed that machine planting with frequent conoweeding encourages frequent loosening of soil to stimulate aerobic conditions and reduces the density of weeds, which causes reduction in dry matter and also incorporation of weed as a manure to crop.

Weed control efficiency

The maximum weed control efficiency (WCE) was recorded under machine transplanting of rice in conjunction with cono-weeding four times at 10 days interval followed by machine transplanting with pretilachlor *fb* bispyribac-sodium + cono-weeding 40 DAT (Table 4). Remesan *et al.* (2007) had also reported that the weed control efficiency was higher in mechanical weeding.

Yield

Grain yield of rice was influenced by establishment methods. SRI machine transplanting resulted in significantly higher grain yield compared to SRI marker planting and CT (Table 3). Transplanting by paddy transplanter caused minimum transplanting shocks to seedling and uniform depth of planting resulted in earlier establishment of crop and maximum number of productive tillers resulting in increase in rice yield as reported by Singh and Rao (2010).

Table 4. Effect of rice establishment and weed management on weed control efficiency in rice

Treatment	Weed control efficiency (%)	
	2011-12	2012-13
C_1W_1	86.8	86.4
C_1W_2	28.5	74.5
C_1W_3	81.3	87.8
C_1W_4	82.1	85.6
C_1W_5	76.5	84.7
C_1W_6	-	-
C_2W_1	87.7	84.5
C_2W_2	52.8	74.4
C_2W_3	82.2	82.7
C_2W_4	83.1	82.9
C_2W_5	77.3	82.2
C_2W_6	-	-
C_3W_1	93.2	90.8
C_3W_2	69.8	78.1
C_3W_3	87.8	87.5
C_3W_4	89.3	88.0
C_3W_5	86.1	87.2
C_3W_6	-	-

Data statistically not analysed

Among the weed management practices, higher grain yield was recorded in cono-weeding four times at 10 days interval which was at par with pretilachlor *fb* bispyribac-sodium + cono-weeding at 40 DAT. Ramamoorthy (2004) and Mohanty and Mohanty (2010) reported that four times cono-weeding removes most of the weeds by incorporating in the soil, frequently loosens the top soil to stimulate aerobic soil condition and provides weed-free environment. This conducive environment enhanced the growth and yield components of rice which in turn resulted in higher rice grain yield.

Crop establishment methods and weed management practices had significant interaction effect. Treatment combination of SRI machine transplanting with cono-weeding four times at 10,20,30, and 40 DAT (C_3W_1) and (C_3W_4) were at par. These results are in accordance with the findings of Mohaptra *et al.* (2012), who reported that machine planting with mechanical weeding encourages profuse tillering which increases the number of panicle/m^2 and number of grains per panicle and in turn the yield.

It can be concluded from the study that under labour scarcity condition, machine transplanting of rice with pretilachlor 0.75 kg/ha *fb* bispyribac-sodium 20 g/ha + cono-weeding at 40 DAT may be the better option for rice cultivation.

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Taxonomic diversity, distribution pattern and management implications of weed flora in rice fields of Kashmir Valley

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ABSTRACT

Invasion by problematic weed species is one of the major contributors in the loss of potential yield in rice cultivation. Therefore, weed flora associated with rice crop in Kashmir Valley was investigated. Based on extensive field surveys carried out during 2010-2013, the present study revealed that 40 plant species were growing as weeds in rice fields of Kashmir Valley, which belonged to 27 genera in 19 families. The actual weeds of rice (40 species) and the weeds (58 species) growing along raised bunds and in between undulated lands of rice fields were recorded. Six species have been reported for the first time as rice weeds. For each weed species, crucial data on growth form, life span, flowering and fruiting months, breeding and dispersal mechanisms were obtained. Weed species growing commonly in the rice fields of Kashmir Valley, as well as those growing rarely were identified. Though weed species were distributed throughout the region, the overall taxonomic diversity of weed flora in rice fields were drastically declined from North to South in Kashmir Valley. Based on the data obtained on diversity and distribution of weed flora, the paper also discusses long-term weed management in the rice fields of Kashmir Valley.

Key words: Distribution**,** Diversity, Management, Rice, Weed

Rice is an important cereal crop providing food for more than half of world's human population (Mulungu *et al.* 2011). It is a staple food to feed more than 3 billion people and to provide 50-80% daily calorie intake (Choudhary *et al.* 2011, Juraimi *et al.* 2011). In India, rice is the second most important crop after wheat, and the country is world's second largest producer of rice after China (Savary *et al.* 2005). Being the staple food, it plays a significant role in the economy of India and hence occupies a central position in national agricultural policy and food security (Dangwal *et al.* 2011). The average per hectare yield of rice in India is less as compared to China due to many factors, such as shortage and high cost of labour, lack of irrigation facilities, quality of germplasm, agricultural output and ecological conditions *etc.* but the problem of weed invasion is the major contributor in the loss of potential production. Out of total losses incurred to rice due to various biotic stressors, weeds are known to account for one-third (Rao and Nagamani 2007). Uncontrolled infestation of weeds in rice fields reduces the grain yield by 75.8, 70.6 and 62.6% in dry seeded rice, wet seeded rice and transplanted rice, respectively (Singh *et al.* 2005).

In the Indian Himalayan state of Jammu and Kashmir (J & K), particularly in Kashmir Valley, rice is regarded to be more than just the staple food. A relatively small area of about 0.27 million hectares of land are under rice cultivation in J & K and it plays a prominent role in the state's economy. In Kashmir Valley, 1,43,936 hectares of land is under rice cultivation and total rice production is 3,18,65 tons which does not cater to the local demand of rice in the Valley and thus the annual deficit in rice is 30-35%. Being an important staple food in the Kashmir Valley, the present study was undertaken to identify the current status of problematic weeds in rice fields across the Kashmir Valley, with an emphasis on taxonomic diversity and distribution pattern, which in turn, has wide management implications.

MATERIALS AND METHODS

Field surveys were conducted across the Kashmir Valley to identify the major problematic weed species in rice fields during 2010-2013. The Valley is situated in northern fringe of the Indian sub-continent between 33^{o}22' and 34^{o}50' N latitudes and 73^{o}55'and 73^{o}33' E longitudes covering an area of about 16,000 sq. km (Fig. 1). Three sites from each district of the Valley were selected. Field trips were conducted twice a month in each site for collection of weed species. During these trips, informal interviews were conducted with the farmers and agriculturalists at each site about the seasonal occurrence of weed species and important details about flowering and

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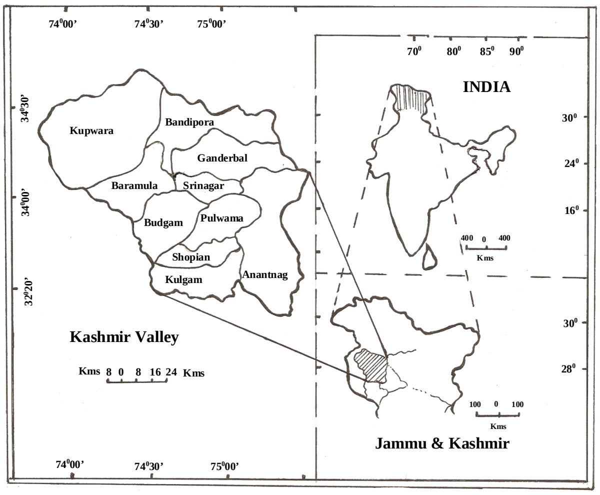

Fig. 1. Map showing the study area

fruiting periods of weed species were recorded. The collected weed plant specimens were pressed, dried, preserved and properly identified with the help of available literature (Hooker 1894, Stewart 1972, Cook 1995). The properly processed herbarium specimen of each species was deposited at Kashmir University Herbarium (KASH).

RESULTS AND DISCUSSION

During study period, 40 weed species were recorded from various rice fields across the Kashmir Valley during May to September. The weed species which grew commonly in the rice fields, their scientific name, family, growth form, life span, flowering and fruiting period is given in Table 1. The weed species which rarely grew in rice fields are presented in Table 2. While the weeds such as *Echinochloa crusgalli*, *Aeschynomene indica*, *Oenothera* sp. and *Persicaria hydropiper* sprout and grew along with the rice seedlings in the seed beds; others such as *Ranunculus trichophyllus*, *Marsilea quardifolia*, *Potamogeton nodosus* and *Persicaria hydropiper etc*. grew with rice seedlings at the time of transplantation in the prepared fields. In these weed species, both sexual and vegetative mode of reproduction are operative for their proliferation. The weed species propagated by means of different types of vegetative propagules: fragmentation (*e.g., Azolla cristata, Salvinia natans, Lemna gibba, Lemna minor, Spirodela polyrrhiza*); tubers (*e.g. Marsilea quardifolia, Sagittaria sagitifolia*); stolons (*e.g. Ranunculus trichophyllus, Utricularia aurea*); subterranean turions (e.g. *Potamogeton nodosus*). Besides, in many species, rhizomes were also the means of vegetative propagation.

During the present investigation, it was observed that the diversity of weed species in the rice fields showed a noticeable decreasing trend from north to south of the Kashmir Valley (Fig. 2). Free floating species (*e.g., Azolla cristata, Salvinia*

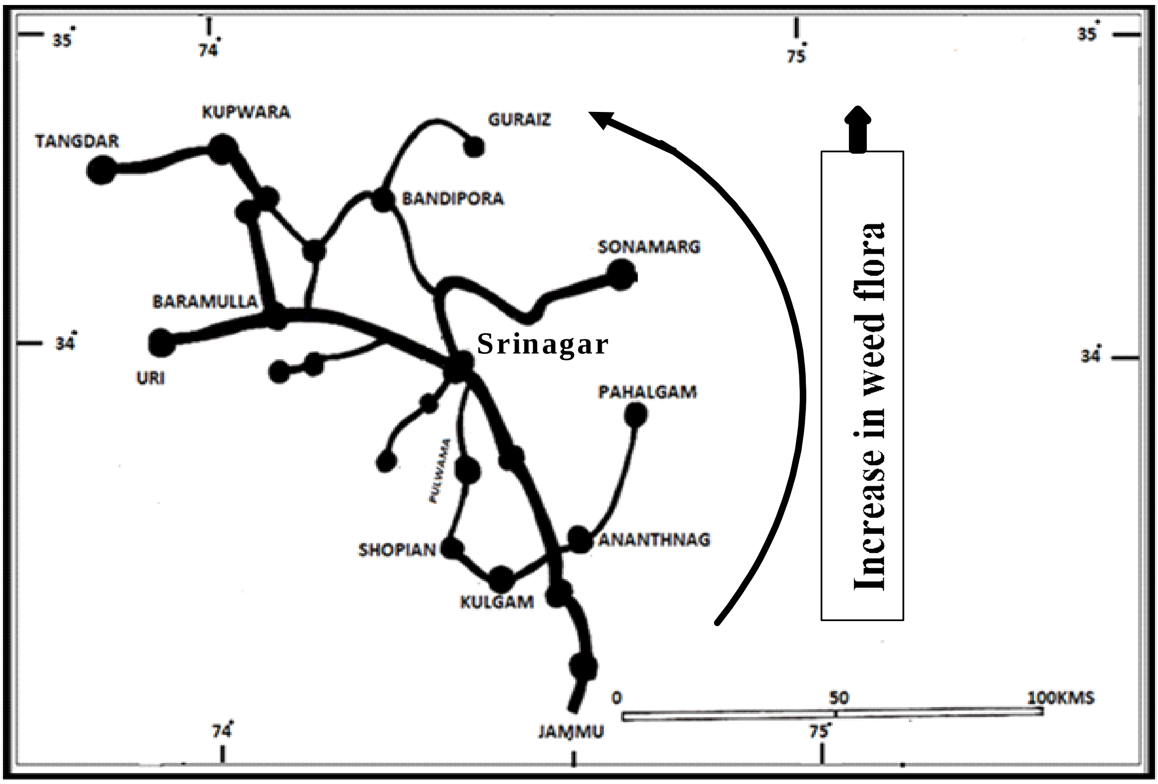

Fig. 2. Distribution pattern of weed flora showing an increasing trend from south to north in Kashmir Valley

Table 1. Weed species growing commonly in the rice fields of Kashmir Valley

Taxon	Synonym	Family	Growth form	Life span	Period of flowering/spore formation	Fruiting period
Azolla cristata Kaulf	-	Azollaceae	Free floating	Mostly annual, sometimes perennial	July-September	-
Salvinia natans L.	-	Salviniaceae	Free floating	Perennial	#July-September	-
Lemna gibba L.	-	Lemnaceae	Free floating	Perennial	July-August	Not found
Lemna minor L.	-	Lemnaceae	Free floating	Perennial	July-August	Not found
Spirodela polyrrhiza (L.) Schleid.	*Lemna polyrrhiza* L.	Lemnaceae	Free floating	Perennial	July-August	Not found
Ranunculus trichophyllus Charix	*Batrachium trichophyllum* (Chaix) Bosche	Ranunculaceae	Rooted submerged	Perennial	Jun-August	July-September
Najas oguraensis Miki	*Cauliniao guraensis* (Miki) Nakai.	Najadaceae	Rooted submerged	Annual	July-August	July-September
Marsilea polycarpa Hook. and Grev	*Marsilea quardifolia* L.	Marsilaceae	Rooted floating	Perennial	#June-July	-
Utricularia aurea Loureiro	*Utricularia confervifolia* Jackson ex D. Don	Lentibulariaceae	Rooted floating	Mostly perennial, sometimes annual	June-August	July-September
Potamogeton nodosus Pioret.	-	Potamogetonaceae	Rooted floating	Perennial	July-August	August-September
Persicaria hydropiper (L.) Delarbre	*Polygonum hydropiper* L.	Polygonaceae	Rooted emergent	Perennial	July-September	August-October
Sagittaria sagittifolia L. (sea)	*Sagittaria trifolia* Linn.	Alismataceae	Rooted emergent	Perennial	July-August	July-September
Aeschynomene indica L.	-	Fabaceae	Rooted emergent	Mostly perennial, sometimes annual	June-August	August-October
Echinochloa crusgalli (L.) Beauv.	-	Poaceae	Rooted emergent	Annual	June-September	July-October

*First reports as rice weed; #: Period of flowering

natans, Utricularia aurea and species of *Lemna*) were absent in the rice fields of South Kashmir (districts of Anantnag, Pulwama, Shopian, Kulgam) and also in Budgam district of central Kashmir, however, these species grew abundantly in the rice fields of district Srinagar and North Kashmir districts of Ganderbal, Bandipora and Baramulla. It was also found that diversity of weed species in rice fields again declined towards Kupwara district of North Kashmir. The species, which grew throughout rice fields of Kashmir Valley include: *Ranunculus trichophyllus, Marsilea polycarpa, Potamogeton nodosus, Persicaria hydropiper, Aeschynomene indica* and *Echinochloa crusgalli.*

During the present study, 40 plant species growing as weeds in rice fields of Kashmir Valley were recorded. These species belonged to 27 genera in 19 families; of the latter, 11 belonged to dicotyledons, 7 to monocotyledons and 3 to pteridophytes. With regard to growth-forms, 5 were free floating, 3 rooted submerged, 4 rooted floating and 29 rooted emergent and all the rooted emergent species grew in marshy semi-aquatic habitats. The sedges (Cyperaceae) constituted 14 species, waterwort (Elatinaceae) and loosestrife (Lythraceae) with 3 species each and grasses (Poaceae) with 2 species. The perennials constitutee 58% and annuals 42% of the total weed species of rice fields.

Moody (1989) reported 1405 weed species from the rice fields of other parts of the India. Of these, 92 species were recorded during the present study from Kashmir Himalaya. The present study revealed that among these 92 weed species, only 36 species are actually growing as weeds in the rice fields (Table 1 and 2) and the remaining weed species (58 species) are growing in the undulated lands/or on the raised bunds between the rice fields, hence these species do not compete with rice with respect to the available resources. During the present study, 6 weed species (*Azolla cristata, Carex dimorpholepsis, C. schlagintweitiana, Elatine ambigua, Lemna gibba* and *Najas oguraensis*) have been reported for the first time from rice fields of India.

Distribution pattern

The study also revealed that diversity of weed species in the rice fields of Kashmir Valley declined from North to South and mostly the free floating species were noticeably absent in the rice fields of South Kashmir. The major dispersal mechanisms of weed species were by water, birds, soil adhering to farm machinery and contaminants of cultivated rice seed stocks (Barrett 1980). During the present investigation, it was observed that the species which produce seeds are present in rice fields of whole Kashmir Valley.

Table 2. Weed species growing rarely in the rice fields of Kashmir

Taxon	Synonym	Family	Growth form	Life span	Flowering period	Fruiting period
Carex fedia Nees	*Carex wallichiana* Presc	Cyperaceae	Rooted emergent	Perennial	May-June	July
**Carex dimorpholepis* Steud.	*Carex cernua* Boott	Cyperaceae	Rooted emergent	Perennial	June	July
**Carex schlagintweitiana* Boeck.	*Carex setigera* D. Don	Cyperaceae	Rooted emergent	Perennial	June	July
Cyperus compressus L.	-	Cyperaceae	Rooted emergent	Annual	July-August	August-September
*Cyperus distans*L.	*Cyperus elatus* Rottboll	Cyperaceae	Rooted emergent	Perennial	July-August	August-September
Cyperus elatus L.	-	Cyperaceae	Rooted emergent	Perennial	July-August	August-September
Cyperus iria L.	-	Cyperaceae	Rooted emergent	Mostly annual, sometimes perennial	July-September	September October
Cyperus pangorei Rottboll		Cyperaceae	Rooted emergent	Perennial	August-September	September October
Cyperus pilosus Vahl	*Cyperus obliquus* Nees	Cyperaceae	Rooted emergent	Perennial	August-September	September October
Cyperus pygmaeus Rottboll	*C. michelianus* (L.) Del.	Cyperaceae	Rooted emergent	Annual	July-August	September
Eleocharis atropurpurea (Retz.) J.Presl & C.Presl	*Scirpus atropurpureus* Retzius	Cyperaceae	Rooted emergent	Annual	July-August	September
Fimbristylis dichotoma (L.) Vahl	*Scirpus dichotomus* L.	Cyperaceae	Rooted emergent	Mostly perennial, sometimes annual	June-July	August
*Fimbristylis dichotoma*ssp. *podocarpa* (Nees) T. Koyama	-	Cyperaceae	Rooted emergent	Annual	June-July	August
Fimbristylis littoralis Gaudichaud	-	Cyperaceae	Rooted emergent	Annual, sometimes biennial	June-July	August-September
Bergia ammannioids Roxb.ex Roth.	-	Elatinaceae	Rooted emergent	Annual	June-July	August
**Elatine ambigua* Wright	-	Elatinaceae	Rooted emergent	Annual	June-July	August
Elatine triandra Svhkuhr	-	Elatinaceae	Rooted emergent	Annual	June-July	August
Ammannia auriculata Wild.	*Ammannia arenaria* (Kunth) Koehne	Lythraceae	Rooted emergent	Mostly annual, sometimes perennial	June-July	August
Rotala densiflora (Roth) Koehne		Lythraceae	Rooted emergent	Annual	June-July	August
Rotala indica (Roth) Koehne		Lythraceae	Rooted emergent	Mostly annual, sometimes perennial	June-July	August
Echinochloa colona (L.) Link	*Panicum colonum* L.	Poaceae	Rooted emergent	Annual	July-August	September
Dopatrium junceum (Roxb.) Buch.-Ham.	*Gratiola juncea* Roxburgh	Scrophulariaceae	Rooted emergent	Annual	July-August	September
Hydrilla verticillata (L.f.) Royle	-	Hydrocharitaceae	Rooted submerged	Perennial	June-July	August - September
Hydrocharis dubia (BI.) Backer	-	Hydrocharitaceae	Rooted floating	Perennial	August - September	October
Juncus articulatus L.	-	Juncaceae	Rooted emergent	Perennial	June-July	August
Lathyrus aphaca L.		Fabaceae	Rooted emergent	Perennial	June-July	August

*First reports as rice weed

Rice fields are favorite habitat for birds because of abundant presence of food in the form of seeds and they are important in local as well as long-distance dispersal of aquatic plants and undoubtedly play an important role in the establishment of new genotypes in existing populations and dispersion of populations into new regions (Harwell and Orth 2002). However, the species which reproduce by vegetative means only are less widely distributed and are found in the rice fields of those areas which are connected to main water bodies particularly with the Valley lakes. The flow of water from one location (from the Valley lakes in central Kashmir to rice fields in North) to another particularly downstream movement determines the distribution of these weeds. Hydrochory, *i.e.* dispersal by water, is one of the major dispersal mechanisms for plants along river corridor (Johansson and Nilsson 1993).

Management implications

Most of these weed species flower during June-September and fruiting starts from August-September (Table 1). Majority of the vegetative propagules are produced during August-September. The knowledge of life history traits can be utilized to identify the weak points in the plant's life cycle, and exploit them for long-term management (Madsen 1993); for instance, most of the weeds documented produce fruits and vegetative propagules during August-September. Therefore, removal of these weeds physically or by using herbicides in the month of July would be a cost-effective control to check their prolific growth and spread.

The various modes of vegetative propagation operative in these species makes them serious weeds and difficult to control. Therefore, knowledge about timing of formation and germination of these propagules is critical in their long-term management. For effective management of weed species such as *Echinochloa crusgalli*, *Aeschynomene indica* and *Persicaria hydropiper*, seeds of these species should be separated from the seeds of rice by employing different separation methods *e.g.* winnowing, sieving, floating method *etc*. Moreover, deep ploughing of seed beds and fields before transplantation could also prove helpful in controlling the spread of these weeds as it exposes the different vegetative propagules like rhizomes, stolons, turions *etc*. to direct sunlight that results in drying and ultimately death and decay of these propagules.

Another critical factor in weed management is the correct taxonomic identification of the problematic weed species, which is crucial in the removal of seedlings of target species at the time of transplantation. For instance, seedlings of *Oryza sativa* and *Echinochloa crusgalli* are very much similar and difficult to segregate at vegetative phase. However, these two species can be separated on the basis of the lower portion of underground part of these two species. The culm and roots of *Echinochloa crusgalli* are white while in *Oryza sativa* the lower portion of stem and roots are brown in colour. Cutting of weed species particularly the sedges and grasses at the time of flowering stage (best stage for correct identification) is another measure for effective management of these species.

To summarize, the present study revealed 40 plant species to grow as weeds in rice fields across the Kashmir Valley. Diversity of these weed species is more in rice fields of northern part as compared to southern part of the Valley. Information regarding the correct taxonomic identification, modes of reproduction and life history pattern are important for long-term management of these weeds.

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Weed density and diversity in jute under long-term experiment in jute-rice-wheat cropping system

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ABSTRACT

Studies on the impact of long-term fertilizer application on changes in weed community composition are important and likely to provide insight into the effects of prolonged fertilizers on weed community structure and infestation. Nine treatments of long term fertilizers experiment, *viz*. (i) control (plots which did not receive NPK fertilizers or farm yard manures (FYM) (ii) 50% of recommended doses of NPK (iii) 100% NPK (recommended dose of fertilizers) (iv) 150% NPK, (v) 100% NPK + hand weeding (No herbicides application in jute, rice and wheat (vi) 100% NPK + Zn (vii) 100% NP, (viii) 100%N (ix) 100% NPK+FYM 10 t/ha/year before sowing of jute with four replication were included in the present investigation. A total of 12 weed species were recorded under different fertilizer treatments. Significantly higher total weed density (733/m^2) was recorded in 100% NPK + FYM treatments compared to other treatments. Significant variation in weed species was also recorded in different fertilizers treatment. *Cyperus rotundus* density was comparatively higher in control, 50% NPK and 100% NPK + Hand weeding plot. *Echinochloa* colona density was higher in 150% NPK, 100% NPK + Zn and 100% NP. Comparatively higher broad-leaved weed density were recorded in 100% NPK + FYM. The highest Shannon-weiner index (H'=2.02), Simpson diversity index (D'=0.81) and weed species evenness (E'=0.81) were recorded in 100% NPK + FYM and the lowest (H'=1.0, D'=0.62 and E'=0.5) in control plot. Thus, weed management strategies in FYM applied jute field should be given highest priority for getting higher fibre yield.

Key words: Fertilizers, FYM, Jute, LTFE, Weed diversity, Weed management, Yield

Weeds are important components of agricultural ecosystems. Weed communities and their diversity play a significant role in determination of the nature of weed management strategies to be adopted in crops and cropping system (Storkey and Cussans 2007). Development of integrated weed management strategy needs knowledge of weed ecology and biology in agro-ecosystems (Wilson *et al.* 2009) and inclusion of multiple tactics, such as the prevention, avoidance, monitoring, and suppression of weeds (Buhler 2002). Fertilizer application is one of the most wide spread agronomic practices that are used to improve soil fertility and enhance crop productivity. Simultaneously, it significantly affects weed growth and its community composition directly through affecting soil nutrient availability and indirectly through intensifying resource competition between crops and weeds and results in new selective pressures to weed species and thus change the occurrence frequencies (Das and Yaduraju 1999, Andreasen and Skovgaard 2009, Smith *et al.* 2010).

While improving the crop's yield and quality, fertilizers profoundly influence the diversity of the whole weed community and its individual component (Wan *et al.* 2012). To fulfill the increasing demand of jute fibre. It is inevitable to increase the productivity in a sustainable manner as the area under jute is constant since last 30 years. The weeds in jute fields are considered as a major problem as they reduce fibre yield up to 80% and hence, it is inevitable to develop weed management strategies to control weeds (Ghorai 2008, Ghorai *et al.* 2013). Studies on the impact of long-term fertilizes application on changes in weed community composition are important and are likely to provide insight into the effects of prolonged fertilizer use on weed community structure and infestation. Therefore, this study was undertaken to examine the effect of long term uses of manure and fertilizer application on density and diversity of weeds in jute to provide a scientific basis for developing an integrated weed management strategy for jute under jute-rice-wheat cropping system.

MATERIALS AND METHODS

A long-term field experiment was established at the Central Research Institute for Jute and Allied Fibres (CRIJAF) Barrackpore (22°452 N, 88°262 E, 9.0 m msl) in 1971 on the new alluvial soil in the hot

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humid sub tropic of eastern India for jute (*Corchorus olitorius* L)-rice (*Oryza sativa* L.)- wheat (*Triticum aestivum* L.)- cropping system. The soil was a sandy loam (hyperthermic, typic eutrochrept, US soil taxonomy). The experiment was laid out in randomized block design (RBD) and all the plots were separated by concrete ridges and irrigation furrows to provide irrigation plot by plot. Seven treatments, *viz*. (i) control (plots which did not receive NPK fertilizers or farm yard manures (FYM) (ii) 50% of recommended doses of NPK (iii) 100%NPK (recommended dose of fertilizers) (iv) 150% NPK, (v) 100% NPK + hand weeding (No herbicides application in jute, rice and wheat (vi) 100% NPK + Zn (vii) 100% NP, (viii) 100%N (ix)100% NPK+FYM at 10 t/ha/year before sowing of jute with four replication were included in the present investigation. Recommended doses of N–P–K for jute were 60–13–25 kg/ha,

The N, P and K fertilizers was applied in the form of urea, single super phosphate and muriate of potash, respectively. After harvesting of wheat in the month of last week of March, the land was prepared for sowing of jute. The weed control in jute was done manually by hand weeding and/or wheel hoe or by scrapper and butachlor at 1.0 kg/ha at 20-25 DAS. For weed control in rice, butachlor at 1.0 kg/ha was applied 10 days after translating (DAT) followed by one manual weeding at 30- 35 DAT. For controlling the weed in wheat, 2,4-D at 500 g/ha was applied followed by one manual weeding at 45 DAS.

The sample of weeds was collected by using four randomly selected 0.5 × 0.5 m quadrat (0.25 m^2) in each plot of size 20 × 10 m before weeding at 25 DAS in both 2012 and 2013. Weeds falling in quadrats were counted species wise, calculated and presented in number of weeds/m^2 and were transformed prior to analysis, using square root transformation $\sqrt{(x + 0.5)}$. Importance Value Index (IVI) of a plant species was calculated to have overall picture of ecological importance of a species in relation to community structure by adding relative frequency, relative density and relative dominance. The biodiversity of the weeds was measured including: the species richness R (*i.e.* the total number of species occurred in field); the species diversity, which was measured by the Shannon-Wiener index *i.e. H*‹§=”*Pi*log *Pi,* in which *Pi* is the proportion of individual numbers of the *i* species to the total individual number of each species in the quadrats. It was calculated from the formula as *Pi = Ni/N*, of which *N* is the total individual number of each weed species and *Ni* is the individual number of the *I* species; the degree of community dominance, as measured by the Simpson index, *D* = 1-”*Pi*²; the community evenness, as measured by the evenness index (Pielou index), *J = H1/logS*. The Duncan Multiple Range Test (DMRT) was worked out where variance ratio (‘F’ test) was significant at P d”0.05 by using SPSS v. 16.0.

RESULTS AND DISCUSSION

A total of 12 weed species observed in the experimental plots were *Cyperus rotundus*, *Brachiaria ramose*, *Digitaria sanguinalis*, *Echinochloa colona, Eleusine indica*, *Amaranthus viridis, Physalis minima Cleome viscosa*, *Digera arvensis, Phyllanthus niruri, Portulaca oleracea* and *Trianthema portulacastrum.* Application of different doses of fertilizers affected the weed community and composition in jute. The significant difference (P= 0.05) in total weeds density was observed among different manure and fertilizers treatments (Table 1). Significantly higher weed density was recorded in 100% NPK+ FYM treatments compared to all other treatments. The weed density in 150% NPK, 100% NPK and 50% NPK was almost similar but higher than control and 100% NP treatment.

The influence of fertilizers on weed density has been reported by many researchers (Moss *et al.* 2004, Wan *et al.* 2012). Das and Yaduraju (1999) in wheat, Nie *et al.* (2009) in rice and Mohammaddoust *et al.* (2009) in barley reported that balanced nutrient and higher NPK favoured crop growth but in case of jute, because of its very small and delicate seedling and non-tillering behaviour, it cannot compete with weed during initial 20-25 days. Weed density in 100% NPK + HW was also significantly higher than other treatments except 100% NPK + FYM. Species wise variation in weed density was also observed in different fertilizers and manure treatments. *Cyperus rotundus* density was higher in control and 50% NPK and 100% NPK + HW treatments. Among the grass, weeds *Echinochloa colona* density was the highest in 100% NPK + Zn, 150% NPK and 100% NPK + FYM treatments. Density of broad-leaved like *Physalis mimina* and *Phyllanthus niruri* was higher under 100% NPK + FYM. Weeds like *Brachiaria ramose* and *Digera arvensis* were only recorded in 100% NPK + FYM plot. Different fertilizer treatments had different levels of available N, P and K in soil which influenced weed density and its growth. Banks *et al.* (1976) observed that total weed density was lowest in plots receiving no fertilizer and highest in these plots receiving N, P, K, while some weed species populations decreased as fertility became more balanced.

Table 1. Weed density (no./m^2) in jute under different fertilizers treatment (pooled data of 2012 and 2013)

Weed species	Control	50% NPK	100% NPK	150% NPK	100% NPK + HW	100 % NPK + Zn	100% NP	100% N	100% NPK+ FYM
Cyperus rotundus	13.21 (174)	12.75 (162)	7.91 (62)	4.95 (24)	19.30 (372)	8.86 (78)	6.96 (48)	7.65 (58)	3.81 (14)
Echnichloa colona	6.36 (40)	8.97 (80)	9.62 (92)	13.36 (178)	6.96 (48)	13.58 (184)	10.12 (102)	6.04 (36)	13.51 (182)
Eleusine indica	4.42 (19)	4.95 (24)	7.52 (56)	5.70 (32)	4.95 (24)	9.19 (84)	3.54 (12)	2.92 (8)	8.28 (68)
Digitaria sanguinalis	3.67 (13)	3.94 (15)	3.81 (14)	3.54 (12)	3.54 (12)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	4.95 (24)
Trianthema portulacastrum	2.92 (8)	2.92 (8)	1.58 (2)	3.81 (14)	3.24 (10)	3.24 (10)	0.71 (0.0)	2.92 (8)	4.53 (20)
Physalis minima	0.71 (0.0)	3.24 (10)	9.72 (94)	4.95 (24)	6.96 (48)	2.55 (6)	4.06 (16)	9.41 (88)	15.31 (234)
Phyllanthus niruri	0.71 (0.0)	3.24 (10)	2.55 (6)	4.06 (16)	2.74 (7)	0.71 (0.0)	2.92 (8)	4.95 (24)	6.96 (48)
Digera arvensis	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)	6.12 (37)
Amaranthus viridis	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	2.55 (6)	2.55 (6)	1.58 (2)	2.55 (6)	2.55 (6)	5.34 (28)
Cleome viscosa	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	2.55 (6)	2.55 (6)	1.22 (1)	2.55 (6)	2.55 (6)	5.34 (28)
Portulaca oleracea	0.71 (0.0)	0.71 (0.0)	0.71(0.0)	3.67 (13)	3.67 (13)	2.55 (6)	3.67 (13)	3.67 (13)	5.87 (34)
Brachiraia ramose	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)	4.06 (16)
Total	16.0^{ab}	17.6^{bc}	18.1^{c}	18.0^{c}	23.4^{d}	19.3^{c}	14.5^{a}	15.7^{ab}	27.1^{e}

Original value in parentheses transformed by square root transformation x+0.5. Sigificant differences by different letters DMRT

Table 2. Importance value index (IVI) of weed species in jute under different fertilizers treatments

Weed species	Control	50% NPK	100% NPK	150% NPK	100% NPK + HW	100 % NPK + Zn	100% NP	100% N	100% NPK + FYM
Cyperus rotundus	157	118	37	31.2	144	57.5	59.4	58.9	11.2
Echnichloa colona	52.4	67	77.8	82.3	30.6	110	106	42.6	56
Eleusine indica	35.9	30.4	36.4	38	20.1	60.4	25	16.6	27
Digitaria sanguinalis	31.2	26.7	18.4	21	14.4	0	0	0	15.5
Trianthema portulacastrum	33.9	18.8	18	22	0	16.8	0	0	72
Physalis minima	0	17.9	97	31	30.6	13.8	29.1	81.3	145
Phyllanthus niruri	0	20.3	15	24.5	10.5	0	21.1	32.4	22
Digera arvensis	0	0	0	0	0	0	0	0	19
Amaranthus viridis	0	0	0	13.7	10	13.9	16.3	14.4	16.6
Cleome viscosa	0	0	0	13.8	8.6	12	16.7	14.4	14.93
Portulaca oleracea	0	0	0	22	15.6	16	26	23	17.4
Brachiraia ramose	0	0	0	0	0	0	0	0	11.8

Although, fertilizers clearly promoted crop growth, many studies have shown that nutrients benefit weeds more than crops (Liebman and Davis 2000, Sindel and Michael 1992). Thus, the effects of fertilization on weed density may vary with weed species and their composition. Dominance of *Cyperus rotundus* was observed in lower doses of fertilizer application and had an Importance Value Index (IVI) of 157,144 and 118 in control, 50 % NPK and 100 % NPK + hand weeding, respectively (Table 2.) *Cyperus rotundus* is a perennial sedge, which can survive with low available nutrients, as it propagates mainly through vegetative parts (tubers and rhizomes) and once it is established in the field, it is very difficult to control. It has been reported as one of the worst weeds in the world (Holm 1977). Furthermore, *Cyperus* dominated in fields because of slow growth of the crop in control (no fertilizer) and 50% NPK treatment. Once *Cyperus* established with a higher density, it did not allow the growthand establishment of other weed species (Kumar *et al.* 2012).

Dominance of *Echinochloa colona* was recorded in 100% NPK+ Zn (IVI=110), 100% NP (IVI=106) and 150% NPK (IVI=82) *i.e.* in balanced and higher fertilizers doses. The highest weed density of broad-leaved weeds was recorded in 100% NPK + FYM. The type of manure that was applied in this long-term experiment was cow dung with waste of feeds that was derived from dairy farms; weeds like *Echinochloa colona*, *Digera arvensis, Phyllanthus niruri*, *Physalis minima* are used as animal feed in this area and these may have returned to field with FYM. FYM affects weed species diversity by increasing seed density or by introducing species as FYM is a source of many weed seeds (Cook *et al.* 2007, Walia *et al.* 2014).

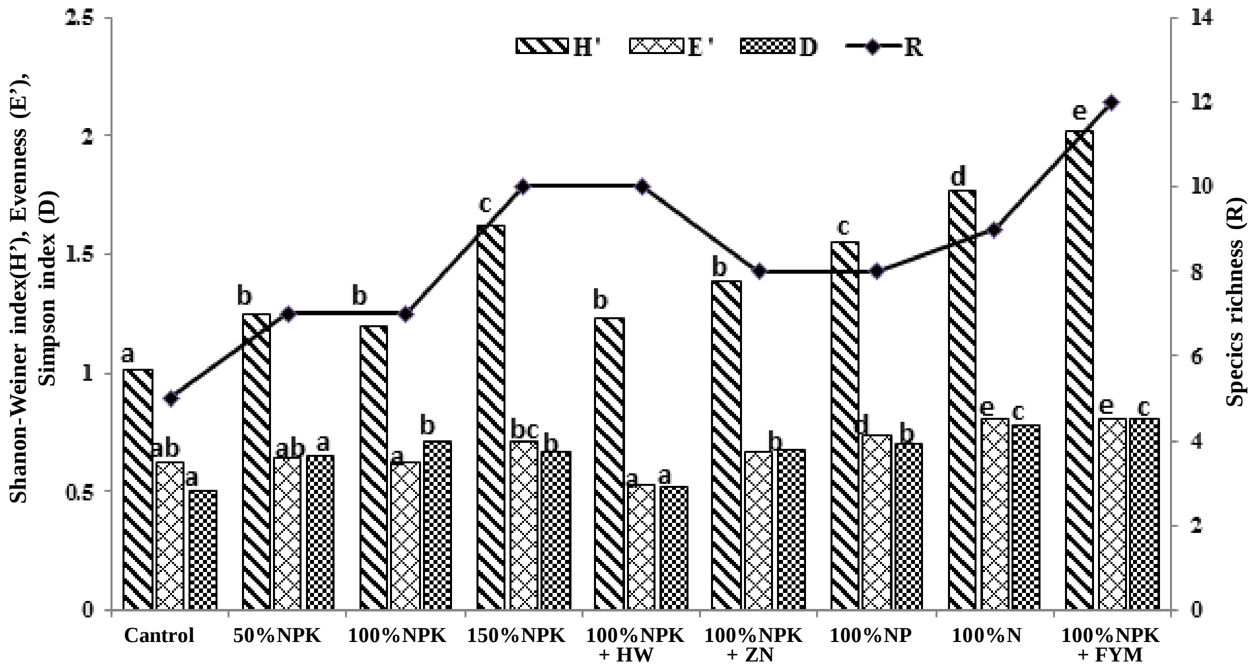

Fig. 1. Effect of different fertilizers and manure treatments on Shanon-Weiner index(H'), Evenness (E'), Simpson index (D) and Specie richness (R)of weeds. Different letters indicate significant differences among the treatments in the same season (P < 0.05).

Weed diversity

The weed species richness (R) was the highest (12) in 100% NPK + FYM and the lowest (5) in control plot (Fig. 1). The species richness under all other treatments was in order of 150% NPK (9) > 100% N (8) =100% NP =100% NPK + Zn (8)> 100% NPK (7)= 50% NPK and was higher in 150% NPK and 100% NPK + FYM treated plots because of higher density of broad-leaved weeds and higher available nutrient in this treatment which enhances germination and weed growth of many weed species (Charles *et al.*, 2006).

The weed diversity (Shannon's H1) was significantly higher (Pd" 0.05) in 100% NPK + FYM and lower in control plot compared to other treatments (Fig. 1). If weed species are equally distributed, the diversity and evenness will be more but dominance of some weed species will lead to decrease in diversity and evenness of weed species in an ecosystem (Wilson *et al.* 2003). *Cyperus* was dominant in control and 50% NPK treatments led to decrease in the weed diversity. The Simpson diversity index (D') was significantly higher in 100% NPK + FYM and 100% N compared to other treatments. The higher weed diversity in 100% NPK + FYM due to high available nutrients and weed species diversity was also affected by FYM as it is source of many weed seeds (Liemann and Davis 2000).

The weed species evenness (E') in 100% NPK + FYM and 100% N was almost same but significantly higher compared to other treatments. The lowest Simpson Index in 100% NPK + hand weeding and control plot was mainly due to the highest density of *Cyperus rotundus* in this treatment as *Cyperus* was dominat in control plot. Hand weeding is not effective in managing *Cyperus* as it grows from vegetative underground parts and hence long term use of single method of weed control increases the density of *Cyperus* in hand weeding plot.

Thus, it may be concluded that recommended doses of fertilizer recorded medium levels of weed density, and higher level of NPK and NPK integration with FYM recorded higher weed density and diversity. Higher infestation of *Cyperus rotundus* was recorded under lower doses of fertilizer while, higher infestation of *Echnichloa colona* was recorded under higher doses of fertilizers. The highest weed species richness and diversity was observed under 100% NPK + FYM (10 t/ha) treatment. Hence, weed management practices in FYM applied field should be given the highest priority.

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Control of complex weed flora in wheat by metribuzin + clodinafop application

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ABSTRACT

A field experiment was carried out at Pantnagar during *Rabi* season of 2010-11 and 2011-12 to test the efficacy of different doses of metribuzin 42% + clodinafop-propargyl 12% WG in wheat and associated weeds. 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 500 g/ha was significantly at par with its higher dose at 600g/ha, and two hand weedings at 30 and 50 DAS recorded the lowest density of *Phalaris minor* and *Chenopodium album*, *Coronopus didymus*, *Melilotus* spp., *Rumex* spp. and *Fumaria parviflora* at 30 and 60 days after application as compared to rest of the treatments. Maximum grain yield was recorded in metribuzin 42%+ clodinafop-propargyl 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-leaf weeds in wheat.

Key words: Chemical control, Clodinafop-propargyl, Metribuzin, Wheat

Wheat gets 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 up to 66% reduction in wheat grain yield (Angiras *et al.* 2008, Kumar *et al.* 2011) or even more depending upon the weed densities, 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 have been recommended against complex weed flora. This combination has been found promising in the situation where isoproturon was effective against *P. minor,* whereas against complex weed flora dominated by *A. ludoviciana*, *Lolium temulentum* and *Poa annua*, combination of isoproturon + 2,4-D was not very effective. Under such situation, a suitable combination of clodinafop or pinoxaden with some broad-spectrum herbicides like sulfosulfuron and metribuzin was 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* 2010-11 and 2011-12 at G.B Pant University of Agriculture and Technology, Pantnagar to evaluate the bio-efficacy of metribuzin 42% + clodinafop-propargyl 12% WG. The soil of the experimental field was clay loam in texture, medium in organic C (0.67%), available P (29.6 kg/ha) and K (176.4 kg/ha) with pH 7.2**.** Ten treatments were evaluated in randomized block design with three replications. The treatments comprised of there doses of metribuzin + clodinafop-propargyl 400, 500 and 600 g/ha as test product and isoproturon 75% WP 1333.3 g/ha, metribuzin 70% WP 300 g/ha, sulfosulfuron 75% WG 33.3 g/ha, clodinafop-propargyl 15% WP 400 g/ha, mesosulfuron-methyl 3% + iodosulfuron-methyl sodium 0.6% WG 400 g/ha as commercial standards, as well as two manual weedings at 30 and 50 days after sowing (DAS), and untreated control. Wheat "*UP- 2565*" was sown on November 23, 2010 and November 18, 2011, respectively. The data on density and dry weight of total weeds were taken at 30 and 60 DAS and grain yield (t/ha) was recorded at the time of harvesting.

In addition to bio-efficacy, a separate experiment was also carried out to observe the phytotoxicity of metribuzin + clodinafop-propargyl on wheat crop and to see the residual effect of metribuzin + clodinafop-propargyl on succeeding crop of maize. Metribuzin + clodinafop-propargyl at 500 and 1000 g/ha were applied at 35 DAS of wheat crop using prescribed volume of water and surfactant and untreated check was maintained for comparison. 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 were 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.

RESULTS AND DISCUSSION

Effect on weeds

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

Efficacy against grassy weeds

Metribuzin + clodinafop-propargyl at 500 and 600 g/ha was significantly at par with two hand weedings at 30 and 50 DAS of wheat, which recorded the lowest weed density at 30 and 60 days as compared to rest of the treatments (Table 1 and 2). Application of sulfosulfuron 33.3 g/ha and mesosulfuron-methyl + iodosulfuron-methyl sodium 400 g/ha were however, significantly superior over untreated control, but found to be least effective against *P. minor* as compared to rest of the treatments, when observed at 30 and 60 days after treatment.

Efficacy against broad-leaved weeds

Metribuzin + clodinafop-propargyl 500 g/ha was at par with its higher dose, *i.e*. 600 g/ha and mesosulfuron-methyl + iodosulfuron-methyl sodium 400 g/ha, metribuzin 300 g/ha and two hand weedings at 30 and 50 DAS recorded lowest density of weeds at 30 and 60 days after treatment against broad-leaved weeds, *viz. C. album, C. didymus, Melilotus* spp.,and *F. parviflora (*Table 1 and 2). Clodinafop-propargyl 400 g/ha was found to be ineffective against broad-leaved 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).

Table 1. Effect of metribuzin+clodinafop-propargyl and other herbicides on density of weeds at 30 DAS 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 (4.5)*	4.28 (17.3)	5.3 (2.5)	2.54 (6.7)	4.0 (2.2)	2.49 (5.3)	4.0 (2.2)	2.49 (5.3)	2.3 (1.8)	2.08 (4.0)	3.0 (2.0)	1.83 (2.7)
Metribuzin + clodinafop-propargyl	500	1250	7.7 (2.9)	2.75 (6.7)	0.3 (1.1)	1 (0.0)	0.0 (1.0)	1 (0.0)	1.0 (1.4)	1.42 (1.3)	0.0 (1.0)	1.42 (1.3)	0.0 (1.0)	1.0 (0.0)
Metribuzin + clodinafop-propargyl	600	1250	2.3 (1.8)	1.83 (2.7)	15.7 (4.1)	4.43 (18.7	14.3 (3.9)	5.97 (34.7)	5.3 (2.5)	3.40 (10.7	11.3 (3.5)	3.60 (12.0	7.0 (2.8)	3.20 (9.3)
Isoproturon	1333.3	-	32.0 (5.7)	5.29 (27)	1.0 (1.4)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.42 (1.3)	1.0 (1.4)	1.0 (0.0)
Metribuzin	300	-	33.0 (5.8)	5.13 (25.3)	4.7 (2.4)	2.08 (4.0)	3.7 (2.2)	1.83 (2.7)	3.7 (2.2)	2.49 (5.3)	1.7 (1.6)	1.42 (1.3)	1.0 (1.4)	1.42 (1.3)
Clodinafop-propargyl	400	-	3.7 (2.2)	1.83 (2.7)	1.7 (1.6)	1.42 (1.3)	1.0 (1.4)	1.42 (1.3)	2.3 (1.8)	1.83 (2.7)	1.3 (1.5)	1.83 (2.7)	0.7 (1.3)	1.83 (2.7)
Mesosulfuron-methyl + iodosulfuron-methyl sodium + surfactant	400	500	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	1.0 (1.4)	1.0 (0.0)	0.7 (1.3)	1.0 (0.0)	0.7 (1.3)	1.42 (1.3)
Sulfosulfuron + surfactant	33.3	1250	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	1.0 (1.4)	1 (0.0)
Hand weeding at 30 and 50 DAS	-	-	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	0.0 (1.0)	1.0 (0.0)	1.0 (1.4)	1.0 (0.0)	0.0 (1.0)	1 (0.0)
Untreated control	-	-	72.0 (8.5)	8.15 (65.3)	13.7) (3.8	4.87 (22.7	17.0 (4.2)	5.85 (33.3)	6.0 (2.6)	3.78 (13.3	13.0 (3.7)	3.40 (10.7	6.3 (2.7)	3.58 (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 # Mean of three replications

Table 2. Effect of metribuzin + clodinafop-propargyl and other herbicides on density of weeds 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 + iodosulfuron-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; Data are mean of three replications

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

Treatment	Product dose (g/ha)	Surfactant (ml/ha)	Weed dry weight (g/m^2) at 30 DAS			WCE %	Weed dry weight (g/m^2) at 60 DAS			WCE%
			GW	BLW	Total		GW	BLW	Total	
Metribuzin + clodinafop-propargyl	400	1250	2.0	7.9	9.9	93.79	4.8	8.9	13.7	93.45
Metribuzin + clodinafop- propargyl	500	1250	0.0	1.3	1.3	99.18	0.0	0.0	0.0	100.0
Metribuzin + clodinafop- propargyl	600	1250	0.0	0.0	0.0	100.00	0.0	0.0	0.0	100.0
Isoproturon	1333.3	-	12.6	23.0	35.6	77.68	26.3	37.5	63.8	69.50
Metribuzin	300	-	5.2	3.1	8.3	94.79	6.7	1.7	8.4	95.98
Clodinafop-propargyl	400	-	1.7	52.3	54.0	66.14	4.5	93.5	98.0	53.15
Mesosulfuron-methyl + iodosulfuron-methyl sodium + surfactant	400	500	23.8	2.3	26.1	83.36	40.8	3.3	44.1	78.91
Sulfosulfuron + surfactant	33.3	1250	21.3	13.5	34.8	78.18	29.9	20.9	50.8	75.71
Hand weeding at 30 and 50 DAS	-	-	0.0	0.0	0.0	100.00	4.0	3.4	7.4	96.46
Untreated control	-	-	74.1	85.4	159.5	00.00	117.5	91.7	209.2	00.00
LSD (P=0.05)			11.8	5.8	13.1	-	35.2	5.3	35.0	-

Data are mean of three replications, GW= Grassy weeds, BLW= Broad-leaved weeds

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 grassy weed dry weight was recorded with metribuzin + clodinafop-propargyl 500 g/ha at par with its higher dose *i.e.* at 600 g/ha and mesosulfuron-methyl + idosulfuron-methyl sodium 400 g/ha, metribuzin 300 g/ha, and twice hand weedings at 30 and 50 DAS. Similar 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.

Table 4. Effect of metribuzin + clodinafop- propargyl and other herbicides on yield attributes 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	5.55
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	5.63	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 + iodosulfuron-methyl sodium + surfactant	400	500	99.8	101.3	248.7	231.7	44.1	42.9	4.90	5.11
Sulfosulfuron + surfactant	33.3	1250	100.1	99.8	259.0	224.0	44.5	42.3	5.31	4.88
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	4.26	3.14
LSD (P=0.05)			NS	NS	14.4	29.4	2.3	1.3	0.62	0.90

Data are mean of three replications

Weed control efficiency

Among the herbicidal treatments, the hundred per cent weed control efficiency against grassy and broad-leaved weeds was recorded with the application of metribuzin + clodinafop-propargyl 600 g/ha, which was followed by its lower dose applied at 500 g/ha at 30 and 60 DAS, respectively. However, lowest weed control efficiency was recorded with sole application of metribuzin 300 g/ha at both the stages of observations *i.e*. 30 and 60 DAS.

Effect on crop

Unchecked weed growth reduced grain yield of wheat by 43% when compared with metribuzin + clodinafop-propargyl 600 g/ha. Maximum yield (5.63 and 5.59 t/ha) was recorded from metribuzin + clodinafop-propargyl 600 g/ha, which was followed by its lower dose 500 g/ha (4.15 t/ha) and twice hand weeding at 30 and 50 DAS (5.60 and 5.54 t/ha). Higher grain yield with metribuzin + clodinafop-propargyl 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 maize crop

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

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

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Comparative efficacy of post-emergence herbicides on yield of wheat

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ABSTRACT

Weeds are one of the most important factors that impose a great threat to crop yield. In order to alleviate weed infestation in wheat (*Triticum aestivum* L.), efficacy of various doses of ACM 9 were tested during *Rabi* 2010 to 2011 at Norman E. Borlough Crop Research Center, Pantnagar, Uttarakhand. Results revealed that ACM 9 applied at 1000 and 1200 g/ha severely reduced total density and dry weight of weeds as compared to control, while poor weed control was achieved using clodinafop 400 g/ha and metribuzin 300 g/ ha. Highest grain yield of wheat was recorded with ACM 9 at 1200 g/ha (4.09 t/ha) during 2010 while in 2011, it was with ACM 9 at 1000 g/ha (4.16 t/ha). Post-emergence application of ACM 9 at 1200 and 1000 g/ha caused increase in wheat yield (18.2 and 97.4% during 2010 and 2011, respectively) over control. Highest number of spike and grains per spike were obtained from plots treated with ACM 9 at 1200 and 1000 g/ha as post-emergence. Based on the depressed wheat yield obtained, clodinafop 400 g/ha and metribuzin 300 g/ha can be said to be phytotoxic to crop plants.

Key words: ACM 9, Chemical control, Herbicides, Wheat, Yield

Wheat (*Triticum aestivum* L) is a major grain crop in India and staple food for billions of people of the world. India is among the top ten producers of wheat in the world and is grown on 29.8 million hectares with a total production of 95.76 million tons. The constraints limiting wheat production in India includes uneconomical holdings, illiteracy, poor economic conditions of farmers, unavailability of quality fertilizers at time of sowing, expensive fertilizers, waterlogging, salinity and low organic matter in most soils. Among the many factors adversely influencing wheat productivity, weed infestation is one of them. Weeds compete with crop plants for nutrients, light, space, moisture and many other growth (Gupta 2004). Weeds may encourage the development of diseases; provide shelter and acts as an alternate host for pests (Marwat *et al.* 2005). Weed infestation is one of the main causes of low wheat yield not only in India but all over the world, as it reduces wheat yield by 37-50% (Waheed *et al.* 2009).

Thus, weed management is indispensable for increasing crop production. Under such circumstances, judicious use of herbicides is the only suitable way for effective and economical weed control. Numerous post-emergence herbicides are available globally to control weeds in wheat crop, that cause plant death by affecting protein or RNA biosynthesis. Post-emergence application of sulfosulfuron against *P. minor* provided 251% wheat yield compared to weedy check. Keeping this in mind, the present study on bio-efficacy of ACM 9 as post-emergence herbicide against predominant weeds of wheat was conducted to assess the efficiency of this herbicide.

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MATERIALS AND METHODS

An experiment was conducted on wheat at Norman E. Borlough Crop Research Center, Pantnagar Uttarakhand, during *Rabi* season of 2010-11 and 2011-12 at 29^0N Latitude, 27.3^0E Longitude and at an altitude of 243.8 meters above the mean sea level. The experiment was laid out in randomized block design (RBD) with three replications comprising nine different weed control treatments, *viz.* five different doses of ACM 9 applied at 500, 600, 800, 1000 and 1200 g/ha, clodinafop-propargyl 15% WP at 400 g/ha, metribuzin 70% WP at 300 g/ha twice hand weeding at 30 and 60 DAS and weedy as control. Wheat variety *'PBW 502'* was sown in 23 cm spacing using 100 kg seed/ha on November 25, 2010 and December 12, 2011. Herbicides were applied at 2-3 leaf stage of weeds using knapsack sprayer fitted with a flat fan nozzle with the spray volume of water 500 L/ha while hand weeding treatment was practiced twice at 30 and 60 DAS. Thirty and 45 days after herbicidal application, the grown weeds in area of 0.25 × 0.25 m within each plot were collected randomly at two places in each plot and total weed density was calculated. The weeds inside each quadrate were uprooted, cleaned and dried. After drying, weight and weed control efficiency was calculated using standard formula. At maturity, the wheat plants were harvested and air dried for 3 days. The grain yield was determined as kg/plot. Besides, spike (no./m^2), grains/spike and 1000 were determined. Means were compared at 5% levels of significance by the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Weed flora at experimental site was similar during both the year and comprised of *Phalaris minor, Polygonum plebenjium, Melilotus indica, Medicago denticulata, Chenopodium album* and *Cyperus rotundus.*

Effect of herbicides on density and dry weight of weeds

Density of weeds infesting the experimental field in 2011 was lesser than that in 2010. This may be due to more rainfall in 2011, which would have suppressed the growth of some weed species. Weed density and dry biomass varied significantly under different weed control treatments. Total weed density and dry weight decreased with increase in dose of ACM 9 at both stages of application during both years. Maximum reduction in total weed density was recorded with application of ACM 9 1200 g/ha. This treatment was closely followed by ACM 9 1000 g/ha and 800 g/ha (Table 1).

The total dry matter accumulation was found to be higher at 45 DAA as compared to 30 DAA (Table 2). Weed dry matter is a better parameter to measure the competition than weed number (Bhanumurthy and Subramanian 1989). Unweeded control recorded significantly higher weed biomass during both the year at both the stage of crop growth due to unchecked growth of weeds. Herbicide formulations and hand weeding significantly reduced weed population and weed biomass in both seasons as compared to unweeded check. Lower weed dry weight in weed control treatments may be ascribed to lesser number of weeds and rapid depletion of carbohydrate reserves of weeds through rapid respiration (Hill and Santlemann 1969). Among various herbicides tried, ACM 9 at 1200 g/ha recorded the lowest weed dry matter followed by its lower dose applied at 1000 g/ha at both the stages of crop growth, while clodinafop 500 g/ha was least effective, which is attributed to the differential efficacy of herbicides in suppressing the weed growth.

Among various herbicides, higher weed control efficiency was obtained with application of ACM 9 at 1000 and 1200 g/ha, while it was low with clodinafop 400 g/ha and metribuzin 300 g/ha due to its phytotoxic effect it resulted in lesser weed control efficiency.

Effect of herbicides on wheat yield

Application of herbicides increased yield attributes as compared to control. Results revealed that there were significant differences between herbicide efficiency of all the weed control treatments on most of the biological parameters assessed in both seasons as compared to weedy check. The yield contributing factors, *viz.* spikes (no./m^2) and grains/ spike were significantly influenced by weed management practices (Table 3). Higher spikes (no./ m^2) and grains/spike were recorded with ACM 9 at 1000 g/ha and remained at par with application of same herbicide at 1200 and 800 g/ha during both the

Table 1. Effect of different doses of ACM 9 on density and dry weight of weeds at different stages

Treatment	Dose (g/ha)	Total weedy density (no./m^2)			
		30 DAA		45 DAA	
		2010-11	2011-12	2010-11	2011-12
ACM 9	500	3.3(25.4)	2.0(6.7)	3.7(4.0)	2.0(6.7)
ACM 9	600	2.9(18.6)	2.0(6.6)	2.8(16.4)	1.2(2.4)
ACM 9	800	2.1(7.9)	1.6(4.0)	2.8(15.9)	0.6(1.0)
ACM 9	1000	0.8(1.3)	0.5(0.7)	2.4(10.6)	0.5(0.7)
ACM 9	1200	0.0(0.0)	1.6(4.0)	1.6(4.0)	0.5(0.7)
Clodinafop	400	5.5(241.3)	5.2(176.1)	5.0(148.7)	4.4(78.1)
Metribuzin	300	4.0(56.0)	3.4(29.4)	3.4(29.3)	2.9(18.0)
HW	30 and 60 DAS	4.5(94.0)	4.1(61.4)	4.4(78.0)	3.8(46.1)
Weedy	-	5.7(298.7)	5.3(198.7)	5.3(192)	5.4(228.7)
LSD (P=0.05)	-	0.4	0.3	0.3	0.4

Table 2. Effect of different doses of ACM 9 on dry weight and WCE of weeds at different stages

Treatment	Dose (g/ha)	Total weed dry weight (g/m^2)				Weed control efficiency (%)			
		30 DAA		45 DAA		30 DAA		45 DAA	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
ACM 9	500	(2.3) 1.2	(0.9)0.5	(10.4)2.4	(1.7)1.0	97.4	99.2	93.4	99.5
ACM 9	600	(2.1)1.1	(0.6)0.5	(9.3)2.3	(0.9)0.5	97.7	99.5	94.1	99.7
ACM 9	800	(1.4)0.9	(0.4)0.3	(7.7)2.2	(0.5)0.4	98.4	99.6	95.1	99.9
ACM 9	1000	(0.8)0.6	(0.1)0.6	(5.5)1.9	(0.0)0.0	99.1	99.9	96.5	100
ACM 9	1200	(0.0)0.0	(0.6)0.4	(3.4)1.5	(0.7)0.4	100.0	99.5	97.8	99.8
Clodinafop	400	(18.9)3.8	(11.2)2.4	(38.7)3.7	(40.5)3.7	78.9	89.6	75.3	88.4
Metribuzin	300	(15.7)2.8	(5.3)1.5	(18.7)3.0	(11.3)2.4	82.5	95.2	88.0	96.8
HW	30 & 60 DAS	(9.6)2.3	(3.9) 1.5	(22.4)3.1	(3.2)1.4	89.3	96.43	85.7	99.1
Weedy	-	(89.9)4.4	(109.3)4.7	(156.4)5.0	(349.1)	0.0	-	0.0	0.0
LSD (P=0.05)	-	0.2	0.8	0.3	0.7	-	-	-	-

Original Values in parentheses were original and transformed to log (X+1) for analysis

Table 3. Effect of different doses of ACM 9 on wheat yield during *Rabi* 2010-11

Treatment	Dose (g/ha)	Spikes (no./m^2)		Grains/spike		1000 grain weight (g)		Grain yield (t/ha)		% increase of grain yield over control	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
ACM 9	500	362	342	45.3	43.7	42.7	42.0	4.01	4.00	15.9	89.6
ACM 9	600	365	348	47.3	43.8	42.8	41.9	4.05	4.04	17.0	91.6
ACM 9	800	371	351	45.1	44.0	42.8	42.1	4.06	4.12	17.1	95.4
ACM 9	1000	382	365	44.2	44.3	42.2	42.1	4.07	4.16	17.6	97.4
ACM 9	1200	383	332	43.7	43.5	42.0	41.5	4.09	3.98	18.2	88.5
Clodinafop	400	326	302	44.6	41.9	42.3	40.4	3.73	3.35	7.8	59.0
Metribuzin	300	260	293	42.3	40.3	41.7	40.1	3.61	3.36	4.3	59.4
Hw	30&60 DAS	349	320	39.2	42.1	42.4	41.0	4.02	3.96	16.1	87.8
Weedy	-	240	254	30.5	37.4	39.9	39.9	3.46	2.11	-	-
LSD (P=0.05)	-	43.7	43.7	5.6	2.9	NS	1.6	0.13	0.23	-	-

year. Hand weeding twice and application of ACM at 800, 1000 and 1200 g/ha were found at par to each other with respect to all yield attributes. The highest grain yield of wheat was recorded with ACM 9 at 1200 g/ha (4.09 t/ha) during 2010 while in 2011 it was with ACM 9 at 1000 g/ha (4.16 t/ha). This was followed by its lower dose applied at 800 g/ha. The post-emergence application of clodinafop 400 g/ha and metribuzin 300 g/ha produced lower grain yield as compared to application of ACM 9 at all the doses. These results were in accordance with other research workers (Sharma *et al*., 2007) wherein reduction in grain yield was reported due to metribuzin application. The per cent increase in grain yield with application of ACM 9 1500 and 1000 was to an extent of 18.2 and 97.4% during 2010 and 2011, respectively over weedy check. This significant increase in grain yield was due to effective weed control and also high yield parameters like spikes (no./m^2) and grains/spike. In general, all herbicide treatments gave superior grain yield over weedy check.

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Management of mixed weed flora in barley with tank-mix application of isoproturon with metsulfuron and 2,4-D

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ABSTRACT

A field experiment was conducted with eight treatments comprising individual application of isoproturon 0.75 and 1.00 kg/ha and tank mix application of isoproturon 0.75 and 1.00 kg/ha with metsulfuron 0.004 kg/ha each and isoproturon 1.00 and 1.25 kg/ha with 2,4-D 0.50 kg/ha each including hand weeding twice and a weedy check. All herbicidal treatments resulted in significant reduction of count and dry matter of total weeds, thereby giving significantly higher grain yield of barley over weedy check. Application of isoproturon + metsulfuron 1.00 + 0.004 kg/ha and isoproturon + 2,4-D 1.25 + 0.5 kg/ha was statistically similar to hand weeding twice with significant reduction of weed count and dry matter resulting in higher weed control efficiency. Tank mix application of all combinations gave significantly higher grain yield of barley. However, isoproturon + metsulfuron 1.00 + 0.004 kg/ha recorded similar higher grain yield of 1.72 t/ha as comparable to hand weeding twice (1.72 kg/ha), which was 8.6 to 27.3 % higher over remaining herbicide treatments. Highest net returns due to weed control and marginal benefit cost ratio of Rs 4661/ha and 2.32, respectively was obtained with isoproturon + metsulfuron 1.00 + 0.004 kg/ha followed by isoproturon + metsulfuron 0.75 + 0.004 kg/ha with corresponding values of Rs 3560/ha and 1.86.

Key words: 2,4-D, Barley, Economics, Isoproturon, Metsulfuron, Tank mix, Weed indices, Yield

Barley (*Hordeum vulgare* L.), an important crop of temperate regions of Himachal Pradesh is grown in an area of 21.24 thousand hectares with a production of 22.94 thousand metric tonnes (Anonymous 2012-13). It is mainly grown for feed, fodder purposes and for the preparation of local tribal beverage. Reasons for low productivity of barley in the region include use of low yielding varieties, cultivation under low fertility and non irrigated conditions and losses caused by weeds and diseases. The yield reduction in barley depends upon type and density of associated weed flora (Walia and Brar 2001). Among weeds, *Phalaris minor* and *Avena ludoviciana* are the most serious problems in barley (Singh *et al*. 1995). Due to strong competitiveness, these weeds can cause yield reduction in the range of 15 to 50% (Morishta and Thill 1988). Similarly, *Chenopodium album, Lepidium sativa, Anagallis arvensis* are other broad-leaved weeds, which also compete with crop causing yield reduction up to 25%. El Bawab and Kholousy (2003) reported that controlling weeds by herbicide treatments increased grain yield by about 40.3 and 13.6% when compared to unweeded and hand weeding treatments, respectively. Though under conditions of Himachal Pradesh, isoproturon and 2,4-D have been recommended to control complex weed flora, 2,4-D fails to control certain broad-leaf weeds like *Rumex dentatus, Malva parviflora, Lathyrus aphaca* and *Fumaria parviflora* effectively. Hence, other broad-leaf herbicides *i.e.* metsulfuron-methyl with isoproturon was evaluated against complex weed flora in barley.

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MATERIALS AND METHODS

A field experiment was conducted during *Rabi* 2006-07 and 2007-08 at Experimental Farm of Rice and Wheat Research Centre, Malan, CSK Himachal Pradesh Krishi Vishvavidyalaya Palampur. The experiment was conducted on silty clay loam soil having pH 5.9 with medium total available nitrogen, phosphorus and potassium. The experiment was laid out in randomized block design with eight treatments comprising individual application of isoproturon 0.75 and 1.00 kg/ha and tank mix application of isoproturon 0.75 and 1.00 kg/ha with metsulfuron 0.004 kg/ha each and isoproturon 1.00 and 1.25 kg/ha with 2,4-D 0.5 kg/ha each including hand weeding twice and weedy check. Crop was raised with recommended package of practices except treatments. The individual herbicides were first dissolved individually in the container, then these were mixed in the sprayer tank for tank mix application of two herbicides. All herbicide treatments were applied at 2-3 leaf stage of weeds. A knapsack sprayer fitted with flat fan nozzle using 750 litres of water per hectare was used for spraying the herbicide. Weed population was taken by quadrate method and dry weight was done as per standard method. Data on total weed count was subjected to “x+1 square root transformation to normalize the distribution. The grain yield of barley was recorded at harvest from the net plot area. Economics of the treatments was computed based on prevalent market prices. The price of barley grain mixture was ` 8.60/ kg. The various impact assessment indices namely weed control efficiency (WCE), weed index (WI), herbicide efficiency index (HEI) and weed management index (WMI) were calculated as per standard formulae.

RESULTS AND DISCUSSION

Barley crop was infested with both grassy and broad-leaved weeds. However, grassy weeds were predominant. The major weeds present in experimental site were *Phalaris minor, Avena ludoviciana, Lolium temulentum, Poa annua, Vicia sativa, Anagallis arvensis* and *Coronopus didymus.*

Effect on weeds

Different weed control treatments except isoproturon 0.75 kg/ha brought about significant variation in total weed count. In hand weeding treatment, significantly lower total weed count and dry matter accumulation was recorded. Among herbicides, isoproturon + metsulfuron 1.00 + 0.004 kg/ha and isoporturon+2,4-D 1.25 + 0.5 kg/ha were statistically similar to each other and they reduced total weed density effectively and equally comparable to two hand weedings. (Table 1). Yadev *et al.* (2006) also proved the superiority of metsulfuron + isoproturon 0.004 +0.75 or 0.004 + 1.00 kg/ha in reducing weed density in wheat.

All weed control treatments were significantly superior over weedy check in reducing dry matter accumulation of total weeds. Hand weeding twice, isoproturon + metsulfuron 1.00 +0.004 kg/ha and isoproturon + 2,4-D 1.25 + 0.5 kg/ha were at par to each other but significantly superior over rest of the treatments. This was reflected in higher weed control efficacy (WCE) values of 89.0, 75.3 and 71.5% achieved by these respective treatments. Efficacy to control weeds by remaining weed control treatments ranged from 69.1 to 63.3% (Table 1).

Effect on crop

The pooled data (Table 1) revealed that all weed control treatments were significantly superior over weedy check in enhancing grain yield of barley. Weeds when allowed to grow throughout crop season caused 45.1% reduction in grain yield. Almost similar significantly higher yield was obtained from isoproturon + metsulfuron 1.00 + 0.004 kg/ha and handweeding. However, all weed control treatments of tank mix application of isoproturon with metsulfuron or 2,4-D were comparable to these in influencing grain yield.

The increase in grain yield of barley due to application of isoproturon + metsulfuron 1.00 + 0.004 kg/ha and hand weeding twice ranged from 8.7 to 27.3% over rest of the herbicidal treatments and 82.0% over weedy check. These results were similar to the findings of Ram and Singh (2009). Higher grain yield of wheat with isoproturon + metsulfuron 1.00 + 0.004 kg/ha was also reported by Singh and Singh (2002). Superiority of isoproturon and 2,4-D was also proved by Bharat and Kachroo (2007) in wheat.

Impact assessment

Grain yield was negatively associated with weed count (r= -0.949) and weed biomass (r= -0.954). HEI, which indicates weed killing potential, was highest (7.46) under hand weeding twice. Among herbicides, isoproturon + metsulfuron 1.00 + 0.004 kg/ha proved to be superior in recording highest HEI value of 3.32 followed by isoproturon+2,4-D 1.25 + 0.5 kg/ha. Efficacy of herbicide was lowest in isoproturon 0.75 kg/ha. Isoproturon + metsulfuron 1.00 + 0.004 kg/ha had the highest WMI of 1.09 followed by isoproturon + metsulfuron 750 + 0.004 kg/ha (0.98), while weedy check had lowest weed management index (WMI) followed by isoproturon 0.75 and 1.00 kg/ha (Table 1).

Economic impact

All chemical control treatments were economicaly viable over hand weeding twice and weedy check. Manual weed control was costly in comparison to herbicides. Because of higher grain yield, isoproturon + metsulfuron 1.00 + 0.004 kg/ha gave the highest gross returns of ` 14,801 and 6,674/ha, respectively, due to weed control which was closely followed by hand weeding twice with corresponding values of ` 14,783 and 6656/ha. Lowest values (` 11,619 and 3,492/ha) for these respective parameters were obtained with isoproturon 0.75 kg/ha. However, due to lower weed control cost, all herbicide treatments were superior to

Table 1. Effect of different treatments on total weed count, weed dry weight, yield of barley and impact indices (on the basis of pooled data of two years)

Treatment	Weed count (no./m^2)	Weed dry matter (g/m^2)	Grain yield (t/ha)	Weed index (%)	Weed control efficiency (%)	HEI	WMI
Isoproturon 0.75 kg/ha	10.20 (103.6)	6.03 (35.9)	1.35	21.50	63.25	1.17	0.68
Isoproturon 1.0 kg/ha	8.82 (77.3)	5.78 (32.9)	1.47	14.47	66.32	1.66	0.84
Isoproturon 0.75 kg/ha + metsulfuron 4 g/ha	8.47 (71.3)	5.54 (30.2)	1.58	8.08	69.08	2.18	0.98
Isoproturon 1.0 kg/ha + metsulfuron 4 g/ha	7.63 (57.8)	4.97 (24.2)	1.72	0.00	75.25	3.32	1.09
Isoproturon 1.0 kg/ha + 2,4-D 0.5 kg/ha	8.48 (71.5)	5.83 (33.5)	1.54	10.28	65.69	1.85	0.96
Isoproturon 1.25 kg/ha + 2,4-D 0.5 kg/ha	7.76 (59.8)	5.32 (27.8)	1.58	8.02	71.53	2.37	0.94
Hand weeding twice	3.06(8.87)	3.35 (10.7)	1.72	0.12	89.03	7.46	0.92
Weedy check	14.09 (197.9)	9.90 (97.6)	0.94	45.09	0.00	0.00	0.00
LSD (P=0.05)	4.83	2.19	0.24				

Values in parentheses are means of original values, Herbicide Efficiency Index (HEI) and Weed Management Index (WMI)

Table 2. Effect of treatments on economics

Treatment	Cost of weed control (x10^3 `/ha)	Gross returns (x10^3 `/ha)	GR_{WC} (x10^3 `/ha)	NR_{WC} (x10^3 `/ha)	MBCR
Isoproturon 0.75 kg/ha	1.58	11.62	3.49	1.91	1.21
Isoproturon 1.0 kg/ha	1.67	12.66	4.53	2.86	1.71
Isoproturon 0.75 kg/ha + metsulfuron 4 g/ha	1.92	13.60	5.48	3.56	1.86
Isoproturon 1.0 kg/ha + metsulfuron 4g/ha	2.01	14.80	6.67	4.66	2.32
Isoproturon 1.0 kg/ha + 2,4-D 0.5 kg/ha	1.84	13.28	5.15	3.31	1.80
Isoproturon 1.25 kg/ha+ 2,4-D 0.5 kg/ha	2.00	13.61	5.49	3.49	1.74
Hand weeding twice	6.40	14.78	6.66	0.26	0.04
Weedy check	0	8.13	0	0	-

GR_{WC} = Gross returns due to weed control, NR_{WC}= Net returns due to weed control, MBCR=Marginal benefit cost ratio

hand weeding twice in influencing net returns and B:C ratio (Table 2). Efficient weed control with isoproturon + metsulfuron 1.00 + 0.004 kg/ha resulted in highest net returns of ` 4,661/ha with B:C ratio of 2.32 and was followed by isoproturon + metsulfuron 0.75 + 0.004 kg/ha (Table 2). These results were in direct conformity with Ram and Singh (2009).

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Weed control in soybean with propaquizafop alone and in mixture with imazethapyr

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ABSTRACT

A field experiment was conducted at the Product Testing Unit, JNKVV, Jabalpur during *Kharif* season 2013 and 2014 to adjudge the efficacy of propaquizafop and imazethapyr mixture against weeds in soybean. Grassy weeds were predominant (76.25%) in the experimental field compared with broad-leaved weeds (23.75%). However, *Echinochloa colona* (33.90%) and *Dinebra retroflexa* (23.90%) were predominant in soybean but, other weeds (*Cyperus rotundus, Cynodon dactylon, Alternanthera philoxeroides, Eclipta alba and Mollugo pentaphylla*) were also present. Post-emergence application of propaquizafop (75 g/ha) alone curbed only grassy weeds. However, its efficacy was improved when applied in combination with imazethapyr being higher under propaquizafop + imazethapyr mixture applied at 53 + 80 g/ha or higher rate (56 + 85 g/ha). Yield attributing characters and yield were superior under propaquizafop + imazethapyr mixture applied at 56 + 85 g/ha followed by 53 + 80 g/ha which were comparable to hand weeding twice at 20 and 40 DAS.

Key words: Economics, Imazethapyr, Propaquizafop, Soybean, Weed control, Yield

Soybean (*Glycine max* (L) Merrill) is called "Miracle crop" of the 21st century because of its multiple uses. Being a rainy season crop, it suffers severely due to weed stress. If weeds are not controlled during critical period of crop-weed competition, there is identical reduction in the yield of soybean from 58 to 85%, depending upon the types and intensity of weeds (Kewat *et al.* 2000). Presently, imazethapyr is being in use as a post-emergence herbicide for controlling weeds in soybean to a level of satisfaction (Patel *et al*. 2009). However, its efficacy has not been tested with propaquizafop for wide spectrum weed control in soybean. Keeping the above facts in view, the present investigation was under taken to find out suitable dose of propaquizafop and imazethapyr mixture for effective control of weeds and higher seed yield of soybean.

MATERIALS AND METHODS

A field experiment was conducted at the Product Testing Unit, JNKVV, Jabalpur during *Kharif* 2013 and 2014. The soil of the experimental field was black clay soil having pH 7.2, EC 0.32 dS/m, OC 0.62%, available N, P, K 365, 16, 327 kg/ha, respectively. The nine treatments comprising of four doses of propaquizafop + imazethapyr mixture (47 + 70, 50 + 75, 53 + 80 and 56 + 85 g/ha), alone application of propaquizafop (75 g/ha) and imazethapyr (100 g/ha) as post-emergence at 15 days after sowing and pendimethalin (1000 g/ha) as pre-emergence at 2 days after sowing, hand weeding twice at 20 and 40 DAS including weedy check, were laid-out in randomized block design with three replications. Soybean variety '*JS 97-52*' was grown in the experimental field with recommended package of practices. Fertilizers were applied uniformly at 20, 60 and 20 kg N, P and K/ha, respectively. All the herbicides were applied by manually operated knapsack sprayer fitted with flat fan nozzle using spray volume of 500 L/ha. The species-wise weed population was recorded by the least-count quadrat (0.25 m^2) method at 30 DAA. Similarly the weed biomass was recorded and weed-control efficiency was calculated accordingly. The economic analysis of each treatment was done on the basis of prevailing market prices of the inputs used and outputs obtained under each treatment.

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RESULTS AND DISCUSSION

Effect on weeds

The weed density averaged over two seasons revealed that grassy weeds (76.25%) were dominant in soybean compared to non grassy weeds (23.75%). *Echinochloa colona* was rampant (33.90%) amongst the grassy weeds closely followed by *Dinebra retroflexa* (23.90%). However, other monocot weeds like *Cyperus iria* (11.44%) and *Cynodon dactylon*

(7.00%) and dicot weeds like *Alternanthera philoxeroides* (7.50%), *Eclipta alba* (8.24%) and *Mollugo pentaphylla* (8.08%) were also present in less numbers with soybean in weedy check plots.

All the weed contol treatments identically reduced the density of individual weed species including dry weight over weedy check, which had the maximum density of weeds (279.33/m^2) and weed dry weight (535.63 g/m^2). Post-emergence application of propaquizafop (75 g/ha) alone gave effective control of grassy weeds (*Echinochloa colona*, *Dinebra retroflexa*, *Cynodon dactylon*) but failed to curb broad-leaved weeds (*A. philoxeroides, E. alba and M. pentaphylla*). However, its efficacy was improved when applied in combination with imazethapyr at 53 + 80 g/ha or higher rate (56 + 85 g/ha) and reduced the population of *Echinochloa colona*, *Dinebra retroflexa*, *Cyperus rotundus, Cynodon dactylon, Alternanthera philoxeroides, Eclipta alba* and *Mollugo pentaphylla* to the tune of 83.5, 78.1, 67.4, 65.5, 70.7, 73.3 and 70.6%, respectively and proved superior over lower rates of mixture and alone application of propaquizafop (75 g/ha), pendimethalin (1000 g/ha) and even to imazethapyr (100 g/ha) applied alone (Table 1). The results were in close conformity to the findings of Tiwari and Mathew (2002) and Pradhan *et al.* (2010). Post-emergence application of propaquizafop + imazethapyr mixture at the lowest rate (47 + 70 g/ha) curtailed the weed biomass production to the tune of 61.4% at 30 DAA. But, the reduction in weed biomass was well marked when applied at higher rates being higher when propaquizafop + imazethapyr mixture was applied at 53 + 80 g/ha or higher rate (56 + 85 g/ha). The presence of propaquizafop + imazethapyr mixture in non lethal concentration at the site of action could be the reason for poor activity of propaquizafop + imazethapyr mixture when applied at the lowest dose (47 + 70 g/ha) but, the reverse was true when it was applied at higher rates. However, none of the herbicidal treatments proved superior over hand weeding twice which caused 98.9% reduction in weed biomass due to elimination of all sorts of weeds during the course of weeding. Similar views were also endorsed by Singh and Jolly (2004).

Effect on yield reduction

Yield reduction due to presence of weeds in soybean was maximum (63.1%) in weedy plots, which was arrested in the plots receiving mechanical and chemical weed control measures. Alone application of pendimethalin (1000 g/ha) as pre-emergence, propaquizafop (75 g/ha) and imazethapyr (100 g/ha) as post-emergence scaled down the yield reduction to the tune of 50.3, 41.4 and 37.5%, respectively. However, post-emergence application of propaquizafop + imazethapyr mixture checked the yield reduction identically (7.9%) at 53 + 80 g/ha or

Table 1. Influence of herbicides on weed population (30 DAA), weed biomass, weed control efficiency and weed index at harvest in soybean (mean data of 2 seasons)

Treatment	Weed population (no./m^2)							Weed biomass (g/m^2)	WCE (%)	Weed index (%)
	Echinochloa colona	*Dinebra retroflexa*	*Cyperus iria*	*Cynodon dactylon*	*Alternanthera philoxeroides*	*Eclipta alba*	*Mollugo pentaphylla*			
Propaquizafop + imazethapyr (47 + 70 g/ha) 15 DAS	6.15 (37.33)	5.21 (26.67)	4.49 (19.67)	3.48 (11.67)	3.67 (13.00)	3.62 (12.67)	3.76 (13.67)	14.41 (207.08)	61.34	33.01
Propaquizafop + imazethapyr (50 + 75 g/ha)	5.67 (31.67)	4.98 (24.33)	4.22 (17.33)	3.33 (10.67)	3.49 (11.67)	3.29 (10.33)	3.29 (10.33)	13.25 (175.13)	67.30	22.86
Propaquizafop + imazethapyr (53 + 80 g/ha) 15 DAS	5.08 (25.33)	4.49 (19.67)	3.81 (14.00)	3.08 (9.00)	2.97 (8.33)	2.85 (7.67)	2.96 (8.33)	11.79 (138.53)	74.14	7.95
Propaquizafop + imazethapyr (56 + 85 g/ha) 15 DAS	4.06 (16.00)	3.89 (14.67)	3.29 (10.33)	2.61 (6.33)	2.48 (5.67)	2.61 (6.33)	2.68 (6.67)	9.95 (98.60)	81.59	6.89
Propaquizafop (75 g/ha) 15 DAS	5.84 (33.67)	5.08 (25.33)	4.56 (20.33)	3.29 (10.33)	3.89 (14.67)	4.26 (17.67)	3.89 (14.67)	14.19 (200.99)	62.48	41.44
Imazethapyr (100 g/ha) 15 DAS	6.23 (38.33)	5.49 (29.67)	4.05 (16.00)	3.48 (11.67)	3.13 (9.33)	3.02 (8.67)	3.23 (10.00)	14.04 (196.71)	63.27	37.54
Pendimethalin (1000 g/ha) 2 DAS	6.69 (44.33)	5.90 (34.33)	4.88 (23.33)	3.89 (14.67)	4.10 (16.33)	4.45 (19.33)	4.22 (17.33)	15.77 (248.16)	53.67	50.28
Hand weeding (2) 20 and 40 DAS	1.86 (3.00)	2.04 (3.67)	1.95 (3.33)	1.46 (1.67)	1.46 (1.67)	1.34 (1.33)	1.34 (1.33)	2.56 (6.07)	98.87	0.00
Weedy check	9.86 (96.67)	8.22 (67.00)	5.67 (31.67)	4.33 (18.33)	4.45 (19.33)	4.91 (23.67)	4.81 (22.67)	23.15 (535.63)	0.00	63.06
LSD (P=0.05)	0.33	0.27	0.37	0.43	0.31	0.39	0.40	0.28	-	-

Table 2. Influence of herbicides on yield attributing traits, yield and economics of soybean (mean data of 2 seasons)

Treatment	Doses	Pods/ plant	Seeds/ pod	Seed index (g)	Seed yield (t/ha)	Haulm yield (t/ha)	GMR (x10^3 `/ha)	NMR (x 10^3 `/ha)	B:C Ratio
Propaquizafop + imazethapyr	47 + 70 g/ha	31.40	2.20	6.76	1.59	3.45	44.31	23.68	2.15
Propaquizafop + imazethapyr	50 + 75 g/ha	34.67	2.23	6.84	1.83	3.99	51.04	30.32	2.46
Propaquizafop + imazethapyr	53 + 80 g/ha	40.00	2.27	7.01	2.19	4.33	60.47	39.66	2.91
Propaquizafop + imazethapyr	56 + 85 g/ha	40.67	2.27	7.01	2.21	4.35	61.14	40.23	2.92
Propaquizafop	75 g/ha	27.53	2.23	6.41	1.39	3.18	38.89	19.11	1.97
Imazethapyr	100 g/ha	30.40	2.23	6.55	1.48	3.35	41.44	20.98	2.02
Pendimethalin	1000 g/ha	25.93	2.17	6.15	1.18	2.71	33.02	11.96	1.58
Hand weeding	2	41.33	2.33	7.18	2.38	4.57	65.56	36.14	2.23
Weedy check	-	21.80	2.03	5.92	0.88	2.44	24.96	6.04	1.32
LSD (P=0.05)	-	2.52	NS	0.22	0.19	0.27	-	-	-

higher rate 56 + 85 g/ha (6.9%) and proved superior to its lower rates (47 + 70 and 50 + 75 g/ha). Similar results were reported by Pradhan *et al.* (2010) on application of propaquizafop + imazethapyr mixture

Effect on crop

Yield attributing traits and seed yield in soybean was affected significantly due to different weed control treatments (Table 2). The values of yield attributing traits, *viz.* pods/plant, seeds/pod and seed index, were superior under propaquizafop + imazethapyr mixture applied at 53 + 80 and 56 + 85 g/ha and these proved significantly superior to its lower rates (47 + 70 and 50 + 75 g/ha), alone application of propaquizafop (75 g/ha), imazethapyr (100 g/ha), pendimethalin (1000 g/ha) and weedy check but was comparable to hand-weeding. The seed and haulm yields of soybean increased appreciably when the weeds were controlled either by herbicides or hand-weeding. The seed and haulm yields were lower when propaquizafop + imazethapyr was applied at the lowest rate (47 + 70 g/ha) but these were increased further with corresponding increase in application rates being higher at rate 53 + 80 and 56 + 85 g/ha. However, hand weeded plots recorded maximum seed and haulm yields and proved significantly superior to other herbicidal treatments but at par to propaquizafop + imazethapyr mixture applied at 53 + 80 and 56 + 85 g/ha. Similar views have been reported by Singh and Singh (2000).

Economics

Minimum net monetary returns was fetched under weedy check plots as a result of lower seed and haulm yields. However, post-emergence application of propaquizafop + imazethapyr mixture at 53 + 80 or higher rate (56 + 85 g/ha) was found more remunerative, as they fetched higher net monetary returns and benefit-cost ratio. The low investment under combined application of propaquizafop and imazethapyr (53 + 80 g/ha and 56 + 85 g/ha) as post-emergence coupled with good economic yield might be the reason for higher NMR and B:C ratio over lower rates of propaquizafop + imazethapyr mixture (47 + 70 and 50 + 75 g/ha), alone application of propaquizafop (75 g/ha), imazethapyr (100 g/ha), pendimethalin (1000 g/ha) and even to hand weeding as advantage of maximum gross monetary returns was nullified due to higher variable cost for control of weeds (` 10,500 /ha). Similar findings have also been reported by Kewat *et al.* (2000) and Tiwari *et al.* (2007).

It was concluded that post-emergence application of propaquizafop + imazethapyr mixture at 53 + 80 g/ha found more remunerative compared to alone application of propaquizafop (75 g/ha), imazethapyr (100 g/ha), pendimethalin (1000 g/ha) and even to hand weeding twice.

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Integrated weed management in blackgram

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ABSTRACT

A field experiment was conducted during *Kharif*, 2005 and 2006 at the Pulses and Oilseeds Research Sub-station, Beldanga, Murshidabad, West Bengal to evolve an integrated weed management (IWM) practice in blackgram. *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Cyperus rotundus*, *Cleome viscosa* and *Physalis minima* were the dominant weeds. Pre-emergence application of pendimethalin either at lower dosage (0.75 kg/ha) along with one hand weeding at 40 days after sowing or at higher dosage (1.0 kg/ha) without any integration with hand weeding proved to record higher seed yield (1.09 and 1.03 t/ha, respectively. In addition, use of 30% higher seed rate than the normal rate of 22.0 kg/ha was found to effectively suppress the weeds and further enhance the yield level. Season-long weed competition caused an average yield reduction of 26.4% as compared to IWM in blackgram.

Key words: Blackgram, Chemical control, Integrated weed management, Pendimethalin, Seed rate, Yield

Weeds pose a serious problem in wet (*Kharif*) season. Losses even up to 50 - 60% (Yadav 1992) have been recorded due to weeds in blackgram (*Vigna mungo* L.). Weeds may mechanically be managed by one hand weeding at 20 days after sowing (DAS) followed by (*fb*) another weeding at about 40 DAS. But manual hand weeding is labour-intensive and tedious and does not ensure weed removal at critical stage of crop-weed competition. Moreover, continuous rainfall during the season makes the manual weeding impracticable (Shweta and Singh 2005). Even non-availability and high wages of labour during critical period warrant an effective and economical weed control practice. Though chemical herbicides become cost-effective, their efficacies are greatly reduced during *Kharif* due to uncertain rainfall (Bhowmick and Gupta 2005). Thus, it is a major challenge to maximize productivity of this important pulse crop. Under this situation, an integrated weed management (IWM) practice involving both chemical and other agronomic manipulation may be an efficient tool, as increasing crop density seems to be an alternative to shift crop-weed competition in favour of crop (Shweta and Singh 2005). Hence, evolving a proper management strategy was felt to avert such yield loss due to weeds in blackgram.

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MATERIALS AND METHODS

A field experiment was conducted during two consecutive *Kharif* seasons of 2005 and 2006 at the Pulses and Oilseeds Research Sub-station, Beldanga, Murshidabad, West Bengal, located at 23^0 55 N latitude and 88^0 15 E longitude with an altitude of 19.0 m above mean sea level. The experimental soil was sandy loam in texture and slightly alkaline in reaction (pH 7.3) besides having a content of 0.20% organic C, 75.0 kg available P_2O_5/ha, 49.0 kg available K_2O/ha, 16.8 kg available S/ha and EC value of 0.39 dS/m. Treatments comprised of five levels of weed management *viz.* weedy check, one hand weeding at 20 DAS, one hand weeding at 40 DAS, pendimethalin 30 EC as pre-emergence (PE) 1.0 kg/ha alone and 0.75 kg/ha in combination with one hand weeding at 40 DAS, and three different seed rates *viz.* normal 22.0 kg/ha, and 30 and 50% higher than normal. Thus, a set of fifteen treatment combinations was replicated three times in a factorial randomized block design, keeping individual plot size of 4 x 3 m. Blackgram variety '*Sarada'* ('*WBU 108*') was sown on 18^{th} and 9^{th} August in rows 30 cm apart, and harvested on 16^{th} and 2^{nd} November in 2005 and 2006, respectively. The land remained fallow prior to the test crop during both the years of study. A uniform basal dose of 20 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha were applied in all the plots. Endosulfan 35 EC at 1.5 ml/liter of water was sprayed at 30 DAS in all the plots. Other recommended package of practices, except weed management and seed rate treatments, was adopted to grow the experimental crop. A knapsack sprayer fitted with flat-fan nozzle was used to apply the herbicide on the first day after sowing with a spray volume of 600 litre/ha. Weed data were recorded at 30 and 60 DAS by placing a quadrat of 50 × 50 cm area randomly at five spots in each plot. Observations on height of crop plants were also recorded at 30 and 60 DAS. Data on seed yield along with yield attributes were recorded at harvest.

RESULTS AND DISCUSSION

Weed flora

The experimental field was mainly colonized by *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Cyperus rotundus*, *Cleome viscosa* and *Physalis minima* (Table 1). Similar observation was earlier reported by Bhowmick and Gupta (2005).

Effect of weed management

There was significant impact of weed management treatments on the reduction of density and biomass of weeds during both the years of study (Table 2). Shweta and Singh (2005) reported similar kinds of results. Integration of reduced dose of pendimethalin at 0.75 kg/ha (PE) with one hand weeding at 40 DAS caused remarkable reduction in weed growth at 60 DAS over remaining treatments (Table 2) and resulted in the highest mean seed yield of 1.09 t/ha. Bhowmick and Gupta (2005) reported similar findings. Such increase in crop yield (Table 3) was due to improvement in the values of yield attributes *viz*. number of branches/plant (13.6), number of productive pods/plant (33.0), number of seeds/pod (6.45) and 1000-seed weight (40.3 g), besides lesser crop-weed competition through better control of weeds (mean of two years). Rathi *et al.* (2004) were of similar opinion. Excellent performance of pendimethalin 0.75 kg/ha (PE) + one hand weeding (40 DAS) might be due to initial control of weeds through the chemical herbicide followed by subsequent hand weeding at 40 DAS, which prevented further emergence of weeds. This finding might also be substantiated with the results of Pazahanivelan and Kandasamy (1996) who reported that application of pendimethalin at 1.0 kg/ha as pre-emergence followed by either fluazifop-p-butyl at 0.25 kg/ha as post-emergence or late hand weeding at 40 DAS gave effective weed control and recorded higher seed yield in rainfed pigeonpea. Sole application of pendimethalin (PE) at higher dose (1.0 kg/ha) was also found effective to record significantly higher seed yield (1.03 t/ha) by imparting a sound weed management, especially at 30 DAS during both the years. Bhandari *et al.* (2004) also reported significant reduction in weed growth with the higher doses of alachlor, pendimethalin or fluchloralin. The treatment pendimethalin at 1.0 kg/ha (PE), however, yielded at par with the application of same herbicide at 0.75 kg/ha (PE) along with one hand weeding at 40 DAS (IWM) in both the years. Compared with the plots receiving IWM treatment, the seed yield losses amounted to an average of 26.4% due to uncontrolled weed growth (Table 3). Kumar and Angiras (2005) also recorded significantly lower seed yield in unweeded plots when combined with conventional planting.

Effect of seed rate

Increasing seed rate from normal to 30% higher resulted in numerical increase in seed yield from 0.97 to 1.02 t/ha and subsequently the yield level declined at 50% higher seed rate (0.94 t/ha), though such increase or decrease in seed yield did not occur in significant proportion during both the years (Table 3). No significant yield differences among varying seed rates were earlier recorded at Pantnagar (IIPR 2002). Similar trend was also observed for weed biomass and density although Shweta and Singh (2005)

Table 1. Common weed flora prevalent in the experimental field of blackgram

Scientific name	Family	Common name	Local name
Grass			
Cynodon dactylon (L.) Pers.	Poaceae	Bermuda grass	Durba
Dactyloctenium aegyptium (L.) P. Beauv. Willd.	Poaceae	Star grass	Makra
Digitaria sanguinalis (L.) Scop.	Poaceae	Large crabgrass	Keoai
Echinochloa colona (L.) Link.	Poaceae	Jungle rice	Shyama
Sedge			
Cyperus rotundus L.	Cyperaceae	Purple nut sedge	Motha
Broad-leaved			
Cleome viscosa L.	Capparidaceae	Spider flower	Jungli hurhur
Commelina benghalensis L.	Commelinaceae	Tropical spiderwort	Kansira
Euphorbia hirta L.	Euphorbiaceae	Garden spurge	Bandudhi
Parthenium hysterophorus L.	Asteraceae	Wild carrot weed	Parthenium
Physalis minima L.	Solanaceae	Ground cherry	Bantepari

Table 2. Effect of treatments on weed growth and plant height of blackgram

Treatment	Weed biomass (g/m^2)				Weed density (no./m^2)				Plant height (cm)			
	30 DAS		60 DAS		30 DAS		60 DAS		30 DAS		60 DAS	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Weed management												
Hand weeding at 20 DAS	80.9	60.4	112.4	99.3	396.0	302.2	424.0	497.2	25.1	26.3	49.8	53.9
Hand weeding at 40 DAS	112.7	92.4	104.4	86.8	537.3	411.1	408.9	401.2	22.8	24.7	49.3	50.4
Pendimethalin at 1.0 kg/ha PE	38.4	45.9	102.4	76.1	377.8	258.2	350.0	357.0	25.9	27.1	51.8	54.1
Pendimethalin at 0.75 kg/ha PE + Hand weeding at 40 DAS	67.6	48.7	70.7	67.8	392.9	297.6	320.9	308.0	25.4	26.8	52.0	54.2
Weedy check	103.1	94.5	140.0	143.5	523.6	432.7	812.4	720.2	23.6	24.4	42.3	44.4
LSD (P=0.05)	15.5	13.1	26.1	12.9	32.6	22.6	52.4	16.3	NS	NS	3.6	7.3
Seed rate												
Normal	78.8	74.6	105.1	96.9	453.3	344.8	466.5	461.3	23.5	25.2	48.9	51.9
30 % higher	74.3	64.2	100.0	89.4	433.9	334.9	447.7	447.3	24.9	26.9	55.8	55.5
50 % higher	88.5	66.4	112.9	97.7	449.3	341.3	477.5	461.6	25.2	25.4	42.4	46.8
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	12.7	NS	NS	2.8	5.6
Interaction												
LSD (P=0.05)	26.9	NS	NS	22.4	56.5	NS	NS	NS	NS	NS	NS	NS

DAS: Days after sowing; NS: Not significant; PE: Pre-emergence.

Table 3. Effect of treatments on yield attributes and seed yield of blackgram

Treatment	Branches/plant		Productive pods/plant		Seeds/pod		1000-seed weight (g)		Seed yield (t/ha)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Weed management										
Hand weeding at 20 DAS	11.7	12.7	28.2	25.5	6.3	6.2	36.2	38.6	0.94	1.00
Hand weeding at 40 DAS	11.4	12.5	25.4	25.2	6.2	5.8	35.4	38.0	0.93	0.99
Pendimethalin at 1.0 kg/ ha PE	11.9	13.1	29.1	33.2	6.3	6.2	37.9	40.3	0.99	1.07
Pendimethalin at 0.75 kg/ ha PE + hand weeding at 40 DAS	13.1	14.0	30.2	35.8	6.5	6.4	38.3	42.3	1.05	1.15
Weedy check	10.8	11.8	23.1	21.9	5.9	5.7	34.9	36.1	0.81	0.81
LSD (P=0.05)	NS	1.34	2.06	2.89	0.25	0.42	1.31	3.25	0.08	0.12
Seed rate										
Normal	12.3	13.3	27.4	27.7	6.3	6.2	36.9	39.0	0.94	1.01
30 % higher	12.8	13.8	28.4	33.1	6.5	6.7	37.8	40.5	0.97	1.06
50 % higher	10.3	11.4	25.8	24.1	5.8	5.3	34.9	37.6	0.93	0.94
LSD (P=0.05)	1.19	1.04	1.60	2.24	0.20	0.33	1.02	NS	NS	NS
Interaction										
LSD (P=0.05)	NS	NS	NS	5.01	0.44	0.73	NS	NS	NS	NS

DAS: Days after sowing; NS: Not significant; PE: Pre-emergence

recorded significantly lower weed density and dry matter up to 50% higher seed rate as compared to the normal recommendation. They also reported that use of 50% higher seed rate yielded significantly higher than normal seed rate but was at par with 30% higher seed rate. Higher values of seed yield and yield attributes were recorded under normal and 30% higher seed rates in both the years. The highest seed yield with the use of 30% increased seed rate might be due to significant improvement of crop growth and yield attributes as well as effective suppression of weed growth at 60 DAS (Table 2) over that of 50% higher seed rate. Conversely, poor yield might be due to greater competition among the crop plants for growth resources when 50% higher seed rate was followed. According to Davies and Ballingall (2008), grain legumes grown at higher seed rates would tend to compete more effectively with weeds, but this must be balanced with optimum seed rates for matching economic yield benefits.

Effect of interaction

There was no significant interaction between weed management and seed rate in respect of seed yield in both the years (Table 3), indicating that different seed rates might not significantly be affected by weed management practices and that the effect of weed management might not differ significantly with the differential rates of seeding. The effect of interaction was not significant for almost all the growth and yield attributes of the crop. However, Das (2008) advocated good crop husbandry along with pre-emergence herbicide application and one hand weeding to control late emerging annuals as well as perennial weeds.

On the basis of two-year study, it might be suggested that pre-emergence application of pendimethalin either at lower dosage of 0.75 kg/ha along with one hand weeding at 40 DAS or at higher dosage (1.0 kg/ha) alone, besides using normal seed rate (22.0 kg/ha) may be a good weed management practice for maximizing productivity of *Kharif* blackgram in West Bengal.

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Effect of herbicides on weeds growth and yield of greengram

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ABSTRACT

A field experiment was conducted during *Kharif* season of 2009 and 2010 to study t-he effect of pre- and post-emergence herbicides on weeds, growth, symbiotic traits and grain yield of greengram. Post-emergence application of imazethapyr at 75 g/ha 17 days after sowing was found to be effective for controlling sedges, grassy and broad-leaf weeds as well as in improving grain yield of greengram and net returns whereas imazethapyr at lower doses (25 and 40 g/ha), did not control weeds effectively. Weed free and two hand weeding treatments gave higher grain yield than the other treatments during both the year. Imazethapyr at 25, 40 and 75 g/ha and pendimethalin at 0.75 and 1 kg/ha had negative effect on different symbiotic parameters such as nodule number, dry weight and leghaemoglobin content as compared to two hand weeding.

Key words: Chemical control, Greengram, Imazethapyr, Nodulation, Weeds

Greengram [*Vigna radiata* (L.) Wilczek] is an important grain legume grown during *Kharif* season. It is threatened by luxuriant growth of weeds due to high monsoon rainfall and short stature of the crop.. Greengram is not very competitive against weeds and, therefore, weed control is essential to ensure proper crop growth, especially in early stages.The magnitude of yield losses in greengram caused by weeds depends upon weed species, their densities and crop-weed competition period. Yield losses due to weeds ranged from 30 to 85% (Pandey and Mishra 2003, Raman and Krishnamoorthy 2005, Mirjha *et al*. 2013). Herbicides have also been reported for their negative effect on legume-*Rhizobium* interactions that either directly affect the rhizobial structure (Anderson *et al*. 2004) or indirectly reduce the photosynthate transport to symbiotic organ ''nodules'' for N_2 fixation (Ahemad and Khan 2011). Hence, the present study was done to see the effect of pre- and post-emergence herbicides on weeds, growth, symbiotic traits and grain yield of greengram.

MATERIALS AND METHODS

A field experiment was conducted during *Kharif* 2009 and 2010 at the research farm of Punjab Agricultural University, Ludhiana (30° 56'N, 72° 52'E, altitude 247 m), Punjab. Soil of the experimental site was loamy sand (80.3% sand, 14.3% silt and 5.4% clay), having pH 8.7, organic carbon 0.29%, available P 11.5 kg/ha and available K 410 kg/ha. A total of 68.8 cm (22 rainy days) and 45.4 cm (29 rainy days) rainfall was received during the crop growing season in 2009 and 2010, respectively (Fig. 1). Nine treatments (Table 1) were arranged in a randomized block design with three and four replications during 2009 and 2010, respectively. Imazethapyr was sprayed at 17 days after sowing (DAS) and pendimethalin as pre-emergence during both the year. These herbicides were sprayed using water 375 L/hectare with a knapsack sprayer fitted with a flat fan nozzle. In the case of two hand weeding, weeds were removed manually with a *khurpa* (hand tool) at 20 and 40 DAS. In case of unweeded check plots weeds were allowed during the whole crop growing season.

The crop was sown on 10 July, 2009 and 9 July, 2010. The sowing of cultivar '*PAU 911*' was done in rows 30 cm apart using a seed rate of 20 kg/ha. Each plot measured 6.0 m × 2.70 m in 2009 and 4.00 m × 2.10 m in 2010. The crop was harvested on 29 September, 2009 and 23 September, 2010.

Data on weed species count were recorded at 60 DAS from a randomly selected area measuring 50 × 50 cm from each plot and then converted to weed species count per m^2 area. Weed species after taking the weed count data were dried together plot-wise and the data converted to dry matter of weeds in kg/ha. Weed control efficiency (WCE), at harvest, was calculated as per standard formula.

Data on symbiotic parameter *viz*. number and dry weight of nodules and leghaemoglobin were recorded at 40 DAS. Five plants per plot were

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randomly selected for number and dry weight of nodules, and average was worked out. Leghaemoglobin content in nodules was determined (Wilson and Reisenauer, 1963) extracted with Drabkin's solution and absorbance of extract was read at 560 nm.

Observations on phytotoxic effects of herbicides were observed visually. At maturity, data on plant height, branches/plant and pods/plant were recorded from randomly selected five plants from each plot, and seeds/pod from randomly selected 20 pods. Biological yield and grain yield was recorded on the basis of whole plot area and converted into kg/ha. From the produce of each plot 100 seeds were taken for 100-seed weight data. Harvest index (HI) was also calculated.

RESULTS AND DISCUSSION

Effect on weeds

The major weed flora was *Cyperus rotundus* (nut grass), *Eleucine aegyptiacum* (crow foot grass), *Trianthema portulacastrum* (horse purslane) and *Commelina benghalensis* (day flower) during 2010 (Table 1). At 60 DAS, weedy check recorded the highest weed density of *Cyperus rotundus*, *Trianthema portulacastrum* and *Commelina benghalensis*, whereas hand weeding recorded the lowest number of weeds followed by imazethapyr 5 g/ha. In general, the post-emergence herbicide, imazethapyr 75 g/ha controlled the weeds more effectively than pendimethalin at different rates of application. Similarly, lowest dry matter of weeds was found in two hand weeding and imazethapyr 75 g/ha.

During both the year, dry matter of weeds was the highest in weedy check at harvest. Lowest weed dry matter was observed in two hand weeding, which was at par with application of imazethapyr 75 g/ha in 2009 (Table 2). Dry matter of weeds was higher during 2010, which might be due to change in site which had higher weed seed bank and more rainy days during the crop growth period (Fig. 1).

Amongst herbicide treatments in 2009, imazethapyr 75 g/ha recorded lowest dry matter of weeds followed by pendimethalin 1.00 kg/ha, whereas in 2010, pendimethalin 0.45 kg/ha as pre-emergence + one hand weeding had the lowest dry matter of weeds followed by post-emergence herbicide imazethapyr 75 g/ha. Imazethapyr has been reported to provide effective control of weeds in greengram (Singh *et al*. 2014a), blackgram (Aggarwal *et al*. 2014) and lentil (Singh *et al*. 2014b). Weed free recorded the highest weed control efficiency. Two hand weeding recorded the highest weed control efficiency in both the year, followed by imazethapyr 75 g/ha in 2009 and pendimethalin 0.45 kg/ha + hand weeding 30 DAS and imazethapyr 75 g/ ha. in 2010 due to lower dry matter of weeds.

Symbiotic parameters

In 2009, number of nodules/plant was significantly higher in weed free than other treatments

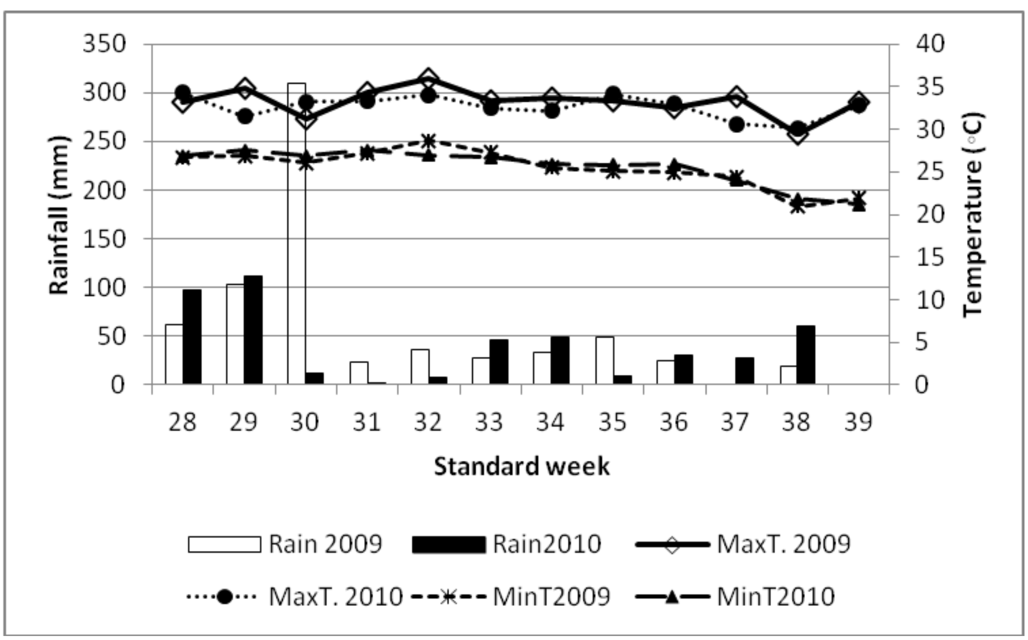

Fig. 1. Weekly mean weather conditions of maximum temperature, minimum temperature and rainfall in 2009 and 2010 during the greengram crop season

Table 1. Population of different weed species and dry matter of weeds as affected by different weed control treatments in greengram at 60 DAS during *Kharif* 2010

Treatment	No. of weeds/m^{2*}				Dry matter of weeds* (kg/ha)
	Cyperus rotundus	*Eleucine aegyptiacum*	*Trianthema portulacastrum*	*Commelina benghalensis*	
Hand weeding (HW) at 20 and 40 DAS	4.9 (24)	1.0 (0)	1.0 (0)	1.0 (0)	16.7 (280)
Pendimethalin 0.45 kg/ha + HW at 30 DAS	5.8 (34)	2.9 (8)	1.0 (0)	1.0 (0)	21.4 (460)
Pendimethalin 0.75 kg/ha	5.7 (32)	3.6 (16)	1.3 (1)	2.1 (4)	23.2 (540)
Pendimethalin 1.00 kg/ha	6.5 (45)	2.3 (7)	1.8 (3)	1.8 (3)	560 (23.6)
Imazethapyr 25 g/ha	4.9 (25)	6.5 (44)	2.3 (5)	1.8 (3)	19.2 (370)
Imazethapyr 40 g/ha	5.9 (35)	4.9 (26)	1.6 (2)	1.6 (2)	18.1 (330)
Imazethapyr 75 g/ha	3.4 (17)	3.0 (10)	1.3 (1)	1.0 (0)	16.7 (280)
Weedy check	7.9 (63)	5.6 (31)	4.0 (16)	3.0 (9)	50.4 (2550)
Weed free	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)
LSD(P=0.05)	(1.7)	(1.9)	(1.1)	(NS)	(3.0)

*Values are square root transformed ($\sqrt{x+0.5}$), original value mentioned in parentheses

Table 2. Dry matter of weeds and weed control efficiency at harvest as influenced by different weed control treatments in greengram

Treatment	Dry matter of weeds* (kg/ha)		Weed control efficiency (%)	
	2009	2010	2009	2010
Hand weeding (HW) at 20 and 40 DAS	24.3(593)	18.9(357)	75.2	92.7
Pendimethalin 0.45 kg/ha+ HW at 30 DAS	30.1(907)	35.7(1279)	61.8	74.0
Pendimethalin 0.75 kg/ha	31.3(981)	52.5(2767)	59.3	43.6
Pendimethalin 1.00 kg/ha	28.8(833)	55.2(3065)	65.5	37.6
Imazethapyr 25 g/ha	45.7(2092)	64.0(4107)	12.4	16.4
Imazethapyr 40 g/ha	35.6(1277)	59.7(3571)	46.4	27.3
Imazethapyr 75 g/ha	25.8(667)	51.7(2678)	72.2	45.5
Weedy check	48.8(2388)	70.0(4910)	-	-
Weed free	1.0(0)	1.0(0)	100	100
LSD (P=0.05)	(1.7)	(4.1)		

*Values are square root transformed $\sqrt{x+0.5}$, original value mentioned in parentheses

which was, however, at par with two hand weedings (20 and 40 DAS). The parameters significantly reduced with imazethapyr application at different doses during both the years (Table 3). Hand weeding recorded maximum nodule dry weight during both the year. In 2009, leghaemoglobin content was significantly higher under weed free which was at par to hand weeding and pendimethalin 0.45 kg/ha. + HW at 30 DAS whereas, in 2010, leghaemoglobin content was significantly higher under hand weeding which was statistically at par with weed free treatment. In 2010, number of nodules was low but bold in size and effective as reflected in their dry weight and leghaemoglobin content. It was found that imazethapyr 40 and 75 g/ha had negative effect on different symbiotic parameters like nodule number, dry weight and leghaemoglobin content. *Rhizobium* infects plant roots through root hairs and thus it was hypothesized that herbicides affecting root hair development might interfere with nodulation. Ahmad and Khan (2010) also reported negative effects of quizalafop-p-ethyl and clodinafop on growth, symbiosis, grain yield, and nutrient uptake by greengram plants and their effects enhanced gradually with the increase in dose of herbicides.

Effect on crop

Weed control treatments significantly influenced plant height, branches/plant, pods/plant, seeds/pod and 100-seed weight (Table 4). In general, these plant growth and yield attributes were superior in the case of weed free, hand weeding, pendimethalin 0.45 kg/ha. + HW at 30 DAS and imazethapyr 75 g/ha treatment.

The biological yield was recorded as highest in weed free followed by two hand weeding, which was significantly higher than other treatments. Similarly, weed free followed by two hand weeding registered the highest grain yield, which was significantly higher than other treatments in 2010 but at par with imazethapyr 75 g/ha in 2009 (Table 5). Imazethapyr when applied at lower dose (25 and 40 g/ha.) was

Table 3. Symbiotic parameters as influenced by different weed control treatments in greengram at 40 DAS

Treatment	Number of nodules/ plant		Dry weight of nodules (mg/plant)		Leghaemoglobin content (mg/g fresh weight of nodules)	
	2009	2010	2009	2010	2009	2010
Hand weeding (HW) at 20 and 40 DAS	29.7	25.3	55.3	49.5	1.95	1.70
Pendimethalin 0.45 kg/ha+ HW at 30 DAS	27.0	25.0	50.5	47.3	1.89	1.60
Pendimethalin 0.75 kg/ha	26.3	24.0	49.0	45.8	1.72	1.54
Pendimethalin 1.00 kg/ha	25.7	23.7	48.5	45.0	1.68	1.51
Imazethapyr 25 g/ha	25.7	22.3	48.5	45.3	1.65	1.50
Imazethapyr 40 g/ha	23.3	21.7	45.5	42.1	1.58	1.47
Imazethapyr 75 g/ha	22.0	21.0	44.0	40.0	1.56	1.46
Weedy check	26.3	29.7	47.8	45.3	1.70	1.52
Weed free	30.3	23.8	52.7	48.8	1.99	1.68
LSD (P=0.05)	1.7	0.5	0.7	0.5	0.11	0.06

Table 4. Plant growth and yield attributes of greengram as influenced by weed control treatments

Treatment	Plant height (cm)		Branches/ plant		Pods/plant		Seeds/pod		100-seed weight (g)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Hand weeding (HW) at 20 and 40 DAS	71.4	58.6	5.53	5.20	27.9	21.8	11.9	12.0	3.07	3.45
Pendimethalin 0.45 kg/ha+ HW at 30 DAS	67.2	57.7	5.53	4.55	22.9	19.1	11.0	11.2	2.97	3.37
Pendimethalin 0.75 kg/ha	57.9	53.9	4.87	4.75	21.1	17.2	10.8	11.5	3.00	3.22
Pendimethalin 1.00 kg/ha	60.2	59.3	5.73	4.65	25.3	16.5	11.4	11.1	3.00	3.25
Imazethapyr 25 g/ha	63.4	55.7	6.27	4.45	12.7	8.6	10.0	11.1	2.73	3.50
Imazethapyr 40 g/ha	67.0	48.3	6.13	4.70	18.1	13.4	10.2	10.7	2.90	3.42
Imazethapyr 75 g/ha	57.1	55.7	5.80	4.60	25.5	18.1	10.9	11.1	2.73	3.25
Weedy check	68.0	51.1	4.40	3.85	17.6	8.7	10.3	10.8	2.53	3.17
Weed free	67.7	61.3	6.00	5.55	29.1	25.5	11.2	12.4	3.13	3.70
LSD (P=0.05)	4.9	4.22	0.51	0.66	3.2	2.56	1.0	1.04	0.19	0.31

Table 5. Grain yield, biological yield and harvest index of greengram as influenced by weed control treatments

Treatment	Grain yield (t/ha)		Biological yield (t/ha)		Harvest index (%)	
	2009	2010	2009	2010	2009	2010
Hand weeding (HW) at 20 and 40 DAS	1.58	1.40	5.88	6.43	26.88	21.75
Pendimethalin 0.45 kg/ha+ HW at 30 DAS	1.31	1.28	5.53	5.89	23.67	21.71
Pendimethalin 0.75 kg/ha	1.28	0.96	5.23	5.50	24.53	17.51
Pendimethalin 1.00 kg/ha	1.46	0.85	5.93	4.97	24.59	17.06
Imazethapyr 25 g/ha	0.72	0.41	3.06	2.83	23.39	14.47
Imazethapyr 40 g/ha	1.06	0.67	4.05	3.54	26.20	18.89
Imazethapyr 75 g/ha	1.48	1.13	5.18	5.53	28.56	20.42
Weedy check	0.76	0.33	2.96	2.41	25.82	13.86
Weed free	1.68	1.61	6.32	6.64	26.56	24.22
LSD (P=0.05)	0.18	0.15	0.82	0.68		

ineffective in controlling weeds and improving the productivity of greengram. However, imazethapyr 75 g/ha was found to be effective for controlling sedges, grassy and broad-leaf weeds as well as in improving grain yield of greengram than at lower doses due to its high weed control efficiency (Table 2). Harvest index was recorded maximum in imazethapyr 75 g/ha (28.5%) in 2009 and in weed free treatment (24.2%) in 2010.

Imazethapyr at high dose (75 g/ha) not only controlled the weeds effectively but also improved grain yield of greengram as a post-emergence herbicide. Similarly, imazethapyr 90 g/ha. at 21 or 28 DAS has been reported to provide effective control of weeds in blackgram (Veeraputhiran *et al*. 2008). The grain yield was lower in 2010 than in 2009 due to heavy incidence of weeds causing more crop-weed competition and reduced crop yield.

Table 6. Economics of greengram as influenced by weed control treatments

Treatment	Gross returns (x10^3 `/ha)		Net returns (x10^3 `/ha)		B:C ratio	
	2009	2010	2009	2010	2009	2010
Hand weeding (HW) at 20 and 40 DAS	69.52	61.51	50.82	42.81	3.72	3.29
Pendimethalin 0.45 kg/ha+ HW at 30 DAS	57.60	56.28	40.76	39.44	3.42	3.34
Pendimethalin 0.75 kg/ha	56.50	42.42	41.85	27.77	3.86	2.90
Pendimethalin 1.00 kg/ha	64.11	37.31	49.14	22.35	4.28	2.49
Imazethapyr 25 g/ha	31.50	18.00	17.35	3.85	2.23	1.27
Imazethapyr 40 g/ha	46.68	29.44	32.23	14.99	3.23	2.04
Imazethapyr 75 g/ha	65.16	49.72	49.96	34.52	4.29	3.27
Weedy check	33.66	14.70	19.96	1.00	2.46	1.07
Weed free	73.88	70.71	53.93	50.76	3.70	3.54

Economics of different weed control treatments (Table 6) showed that weed free treatment gave the maximum gross returns and net returns. Among herbicides, high gross returns, net returns and B:C ratio were obtained in imazethapyr 75 g/ha followed by pendimethalin 1.00 kg/ha in 2009 whereas in 2010, pendimethalin 0.45 kg/ha. + hand weeding at 30 DAS gave the maximum gross returns and net returns followed by imazethapyr 75 g/ha.

It was concluded that imazethapyr 75 g/ha as post-emergence herbicide was found to be effective for controlling sedges, grassy and broadleaf weeds as well as in improving grain yield of greengram when there was scarcity of labour.

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Control of nutsedge and other weeds in sugarcane with ethoxysulfuron

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ABSTRACT

A field experiment was carried out at Pantnagar, Uttarakhand during 2009-10 and 2010-11 to study the effect of rates of herbicide ethoxysulfuron for the control of *Cyperus rotundus* and other weeds in sugarcane. Ethoxysulfuron at 60 g/ha effectively reduced the density of *Cyperus rotundus* as well as *Trianthema monogyna, Digera arvensis, Cleome viscosa* and *Ipomoea* spp. The highest cane yield was obtained with hand weeding thrice at 30, 60 and 90 days after planting. Among the herbicides, ethoxysulfuron at 60 g/ha being at par with ethoxysulfuron at 56.25 g/ha recorded significantly higher cane yield than 2,4-D at 1000 g/ha.

Key words: Bio-efficacy, Ethoxysulfuron, Sugarcane

Sugarcane being a long duration crop with slow initial growth habit initial log growth and wider row spacing favours competition between crop and weeds for the inputs supplied is severely affected by weeds. *Cyperus rotundus* emerges even before the germination of sugarcane and removes moisture from field causing poor germination of sugarcane sets. Besides it, other weeds also emerge at later stages causing reduction in cane yield. Various workers have estimated loss in cane yield due to weeds form 12 to 83% (Sathyavelu *et al.* 2002 and Kanwar *et al.* 1992). Only a few chemicals are avilable for control of *Cyperus rotundus* and other weed flora in sugarcane. Therefore, this study was undertaken to evaluate the bio-efficacy of ethoxysulfuron for the control of *Cyperus rotundus* and other weeds in sugarcane.

MATERIALS AND METHODS

A field experiment was conducted during 2009-10 and 2010-11 at NEB Crop Research Centre of G.B.P.U.A.&T., Pantnagar to evaluate the bio-efficacy of ethoxysulfuron (Sunrise 15 WG) against *Cyperus rotundus* and other weeds in sugarcane. The soil of the experiment field was silty-clay-loam in texture, medium in organic C (0.58%), higher in available P (35.6 kg /ha) and medium in available K (164.5 kg/ha) content with a pH of 7.6. Sugarcane "*Co Pant 90223*" was planted on March 07, 2009 and April 09, 2010 with recommended package of practices at a row spacing of 75 cm. Different doses of ethoxysulfuron 46.87, 56.25 and 60 g/ha were compared with 2,4-D Na salt 1000 g/ha along with hand weeding at 30,60 and 90 days after planting (DAP) and weedy check (Table 1). All the herbicides were applied at 3-4 leaf stage of *C. rotundus*. Thus, six treatments were replicated thrice in randomized block design. Treatments were applied by using a knapsack sprayer at a spray volume of 500 litres of water/ha. The data on density (no./m^2) and dry matter accumulation (g/m^2) of weeds was taken at 30 and 60 DAS. Data on density and dry weight of weeds were subjected to $\log_e(x+1)$ transformation before statistical analyses.

To study the phytotoxic effect of this herbicides on crop, visual rating on the scale of 0 -10 for two treatments of ethoxysulfuron *i.e.* 60 and 120 g/ha was made and compared with untreated check.

RESULTS AND DISCUSSION

The major weeds of experimental field in weedy plots were *Cyperus rotundus*, *Echinochloa* spp, *Digitaria sanguinalis, Dactyloctenium aegyptium, Trianthema monogyna, Digera arvensis* and *Ipomoea* spp. during 2009. However, *Cyperus rotundus*, *Echinochloa* spp, *Digitaria sanguinalis, Bracharia reptans, Trianthema monogyna, Cleome viscosa* and *Ipomoea* spp. were the predominant weeds during 2010.

All the weed control treatments caused significant reduction in the density of total weeds over weedy check during both the years. The highest reduction in the density of total weeds occurred with the execution of three hand weedings at 30, 60 and 90 days after planting (DAP). The lowest weed density was observed with ethoxysulfuron at 60 g/ha though the differences were non-significant, when compared with ethoxysulfuron at 46.87 and 56.25 g/ha at 30 and 60 days during both the years. Application of ethoxysulfuron at all the rates effectively controlled

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Table 1. Weed density as influenced by ethoxysulfuron in sugarcane during 2009

Treatment	Dose (g/ha)	Weed density/m^2								
		CR	ES	DS	BR	TM	CV	IS	OW	Total
30 Days after application										
Ethoxysulfuron	46.87	10	13	7	4	3	3	0	5	3.83(45)
Ethoxysulfuron	56.25	5	16	5	3	2	1	0	4	3.61(36)
Ethoxysulfuron	60.00	3	12	8	3	1	0	0	3	3.43(30)
2,4-D Na salt 80 WP	1000.0	43	15	7	4	7	0	0	4	4.39 (80)
Hand weeding at 30, 60, and 90 DAP	-	16	2	0	1	0	0	0	1	3.05(20)
Untreated control	-	92	14	8	3	28	12	4	7	5.13(168)
LSD (P=0.05)		-	-	-	-	-	-	-	-	0.54
60 Days after application										
Ethoxysulfuron	46.87	5	32	7	4	3	3	1	3	4.08(58)
Ethoxysulfuron	56.25	3	27	9	5	0	1	0	4	3.91(49)
Ethoxysulfuron	60.00	1	29	11	3	0	0	0	3	3.87(47)
2,4-D Na salt	1000.0	19	31	9	5	4	1	0	5	4.32(74)
Hand weeding at 30, 60, and 90 DAP	-	3	1	0	0	0	0	1	1	1.95(6)
Untreated control	-	45	29	12	5	12	7	5	9	4.83(124)
LSD (P=0.05)		-	-	-	-	-	-	-	-	0.37

Table 2. Weed Density as influenced by ethoxysulfuron 15 WG in sugarcane during 2010

Treatment	Dose (g/ha)	Weed density/m^2								
		CR	ES	DS	BR	TM	CV	IS	OW	Total
30 Days after application										
Ethoxysulfuron	46.87	13	13	13	5	1	3	0	5	3.99(53)
Ethoxysulfuron	56.25	8	18	9	4	0	1	0	4	3.81(44)
Ethoxysulfuron	60.00	5	15	11	3	0	0	0	4	3.64(37)
2,4-D Na salt	1000.0	32	17	12	4	3	1	1	5	4.33(75)
Hand weeding at 30, 60, and 90 DAP	-	19	1	3	0	0	0	0	0	3.18(23)
Untreated control	-	71	18	11	5	24	4	3	8	4.93144)
LSD (P=0.05)		-	-	-	-	-	-	-	-	0.51
60 Days after application										
Ethoxysulfuron	46.87	5	25	16	5	1	3	0	8	4.16(63)
Ethoxysulfuron	56.25	0	21	13	7	0	1	0	5	3.87(47)
Ethoxysulfuron	60.00	0	23	15	5	0	0	0	4	3.87(47)
2,4-D Na salt	1000.0	12	24	17	5	3	0	0	7	4.23(68)
Hand weeding at 30, 60, and 90 DAP	-	4	3	1	0	0	0	0	1	2.30(9)
Untreated control	-	29	27	15	7	9	5	7	11	4.71(110)
LSD (P=0.05)		-	-	-	-	-	-	-	-	0.32

*Original values are given in parenthesis, DAA – Days after application of herbicide; *CR= Cyperus rotundus, ES= Echinochloa* spp, *DS= Digitaria sanguinalis, BR= Bracharia reptans, TM= Trianthema monogyna, CV= Cleome viscosa, IS= Ipomoea spp,* OW=other weeds

the *C. rotundus,* and broad- leaved weeds, but it was not effective against grassy weeds (Table 1 and 2).

All the weed control treatments recorded significantly lower dry weight of weeds in comparison to weedy check (Table 3). The lowest dry weight of all the weeds were recorded with three hand weedings at 30, 60 and 90 DAP at both the stages. Application of ethoxysulfuron at 56.25 and 60 g/ha recorded significantly lower dry weight of broad-leaved weeds and sedge at 30 and 60 days during 2009 and at 30 days during 2010 over 2,4-D Na salt. During 2010, at 60 days, application of this herbicide at 56.25 and 60.0 g/ha caused complete control of *Cyperus rotundus*.

Effect on crop

It was observed that the weeds in untreated weedy plot on an average reduced the cane yield by 53.4 and 55.0% during 2009 and 2010, respectively, when compared with hand weeding (Table 4). The highest cane yield (102.0 and 108.3 t/ha) was recorded from three weedings at 30, 60 and 90 DAP. Application of ethoxysulfuron at 56.25 and 60 g/ha being at par recorded higher cane yield as compared to ethoxysulfuron at 46.87 g/ha and 2,4 D Na salt.

Table 3. Weed dry weight (g/m²) as influenced by ethoxysulfuron 15 WG in sugarcane

Treatment	Dose (g/ha)	30 DAA						60 DAA					
		2009			2010			2009			2010		
		Grassy	Broad-leaved	Sedge	Grassy	Broad-leaved	Sedge	Grassy	Broad-leaved	Sedge	Grassy	Broad-leaved	Sedge
Ethoxysulfuron	46.87	3.73 (40.8)	1.84 (5.3)	1.36 (2.9)	3.85 (46.0)	2.00 (6.4)	1.46 (3.3)	4.30 (73.0)	2.61 (12.6)	0.79 (1.2)	4.50 (88.7)	2.50 (11.2)	0.83 (1.3)
Ethoxysulfuron	56.25	3.78 (42.9)	1.03 (1.8)	0.83 (1.3)	3.85 (46.0)	1.50 (3.5)	1.06 (1.9)	4.34 (76.0)	2.00 (6.4)	0.53 (0.7)	4.44 (84.1)	1.99 (6.3)	0.00 (0.0)
Ethoxysulfuron	60.00	3.74 (41.1)	0.69 (1.0)	0.53 (0.7)	3.82 (44.4)	0.59 (0.8)	0.74 (1.1)	4.32 (74.0)	1.69 (4.4)	0.18 (0.2)	4.44 (83.5)	1.79 (5.0)	0.00 (0.0)
2,4-D Na salt	1000.0	3.74 (41.3)	2.09 (7.1)	2.80 (15.5)	3.83 (45.0)	2.36 (9.6)	2.66 (13.3)	4.33 (75.0)	2.92 (17.5)	1.44 (3.2)	4.44 (84.0)	2.67 (13.4)	1.39 (3.0)
Hand weeding 30,60 and 90		0.47 (0.6)	0.00 (0.0)	1.13 (2.1)	0.53 (0.7)	0.00 (0.0)	1.19 (2.3)	0.26 (0.3)	0.18 (0.2)	0.41 (0.5)	0.83 (1.3)	0.00 (0.0)	0.41 (0.5)
Untreated control	-	3.97 (52.0)	3.22 (24.1)	3.69 (39.2)	3.91 (49.0)	3.42 (29.6)	3.36 (27.9)	4.29 (72.0)	4.04 (55.9)	2.84 (16.2)	4.40 (80.3)	4.02 (54.5)	2.61 (12.6)
LSD (P=0.05)	-	0.54	0.27	0.39	0.52	0.24	0.36	0.67	0.30	0.33	0.65	0.25	0.28

*Original values are given in parenthesis, DAA – Days after application of herbicide

Table 4. Yield attributing characters and cane yield as influenced by ethoxysulfuron 15 WG in sugarcane

Treatment	Dose (g/ha)	No. of millable cane (2 m row length)		Cane length (cm)		Cane girth (cm)		Cane yield (t/ha)	
		2009	2010	2009	2010	2009	2010	2009	2010
Ethoxysulfuron	46.87	91	94	256	258	8.5	8.5	71.6	72.3
Ethoxysulfuron	56.25	97	101	260	267	8.6	8.7	76.8	80.6
Ethoxysulfuron	60.00	103	109	271	274	8.8	8.8	82.3	86.8
2,4-D Na Salt	1000.0	84	87	251	255	8.4	8.3	68.3	70.0
Hand weeding 30,60 and 90	-	136	145	274	280	8.9	9.3	102.0	108.3
Untreated control	-	58	60	215	235	6.7	7.8	47.5	48.7
LSD (P=0.05)	-	14	15	21	23	NS	NS	6.8	7.2

No phytotoxicity symptoms, *viz*. stunting, yellowing/chlorosis, necrosis, epinasty and hyponasty were observed on sugarcane after the application of ethoxysulfuron either at 60 and 120 g/ha during the entire crop season.

On the basis of two years field experiment, it was concluded that ethoxysulfuron at 60 g/ha provide excellent control of *Cyperus rotundus* and broad-leaf weeds while it was ineffective against grassy weeds.

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Weed management in spring-planted sugarcane

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ABSTRACT

A field experiment was conducted during 2008-09 and 2009-10 at the Agricultural Research Farm of C.C.R. (P.G.) College Muzaffarnagar (U.P.) to study the integration of chemical and cultural weed management practices in spring planted sugarcane. The experiment consisted of ten treatments laid out in randomized block design with three replications. *Cyperus rotundus*, *Cynodon dactylon* and *Sorghum halepense* were observed as major weeds in both the year. All the weed management practices led to significant reduction in density and dry matter of weeds when compared to weedy check. Hoeing done at 30, 60, 90 DAP recorded lowest weed density (23.77 and 22.07/m^2) and dry matter (8.71 and 8.34 g/m^2) with mean WCE of 57.0% and was found at par with the application of glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP (density 24.14 and 23.29/m^2, dry matter 10.99 and 10.61 g/m^2 and WCE 45.5%). The mean reduction in cane yield ranged from 39.0% under weedy conditions to 8.0% with the crop received 03 hoeing at 30, 60 and 90 DAP and it was closely followed by the glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP and atrazine 2.0 kg/ha as pre-emergence + one hoeing at 60 DAP**.** Further, the cane yield was recorded highest (88.8 t/ha) when crop raised with 3 hoeing at 30, 60, 90 DAP which was closely followed (87.9 t/ha) by glyphosate 1.0 kg/ha as pre- emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP.

Key words: Cane yield, Chemical control, Herbicide, Sugarcane, Weed management,

The projected requirement of sugar in 2030 is 36 million tonnes, which is about 50% higher than the resent production. To achieve this target, sugarcane production should be about 500 million tonnes from the current 350 million tonnes for which the production has to be increased by 7-8 million tonnes annually. This increase in production has to be achieved from the existing area through increased productivity and sugar recovery (Anonymous 2011). Though, there are several pre-requisites to realize full potential of the crop but minimizing the weed menace is of utmost importance.

Delayed germination, slow initial growth and lateral spread, wide row space and adequate supply of nutrients and moisture in sugarcane provide favorable environment for weed infestation. Sugarcane suffers from weed competitions which reduces its yield to the tune of 15-75% and even more, if not managed effectively. Further in sugarcane, a number of weed species belonging to the broad-leaf weeds, grassy weeds and sedges morphology infest the crop.

Hand hoeing in sugarcane has been the most widely practiced method of weed control by farmers. However, in recent years, its practical and economic feasibility has been limited by unfavourable weather conditions, unavailability of laborer during critical period of weeding and also their high wages. Therefore, chemical control of weeds is considered economical in sugarcane (Kumar *et al.* 2014). Several herbicides have been tried in sugarcane with varying degree of success, but information on combined use of chemical and cultural practices are scarce. Keeping this in view, the present investigation was undertaken to study the integrated weed management practices in spring planted sugarcane.

MATERIALS AND METHODS

A field experiment was conducted during 2008-09 and 2009-10 at the Agricultural Research Farm of C.C.R. (P.G.) College Muzaffarnagar (U.P.) to study the integration of chemical and cultural weed management practices in spring planted sugarcane. The soil of the experimental site was sandy loam of Indo-Gangetic alluvial origin, very deep (>2m), well drained, flat and classified as non-calcareous mixed hyperthemic *Udic Ustochrept*, having pH 7.6 and was low in organic carbon (0.46%), medium in available P (15 kg/ha) and K (198 kg/ha) with available nitrogen of 152.0 kg/ha. The experiment consisted of ten treatments, *viz.* weedy check (T_1), weed free (T_2), three hoeings at 30, 60 and 90 days after planting

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(DAP) (T_3), atrazine 2.0 kg/ha as pre-emergence + 2, 4-D 1.0 kg/ha at 60 DAP (T_4), atrazine 2.0 kg/ha as pre-emergence after 1st irrigation followed by 2, 4-D 1.0 kg/ha at 60 DAP (T_5), glyphosate 1.0 kg/ha as pre-emergence to sugarcane + atrazine 2.0 kg/ha after 1st irrigation+ hoeing at 90 days after planting (T_6), paraquat dichloride 500 ml/ha + atrazine 2.0 kg/ha after 1st irrigation (T_7), atrazine 2.0 kg/ha as pre-emergence+ one hoeing at 60 DAP (T_8), metribuzin 1.0 kg/ha as pre-emergence after 1st irrigation followed by 2,4- D 1.0 kg/ha at 60 DAP (T_9) and metribuzin 1.0 kg/ha as pre- emergence + one hoeing at 60 DAP (T_{10}) were laid out in randomized block design with 3 replications.

Mid-late maturing sugarcane (*Cos 97264*) was planted 75 cm apart in the first fortnight of March during both the years using a seed rate of 50,000 three budded setts/ha. All the recommended agronomic practices were followed throughout the cropping period. Herbicides as per treatments were applied as spray using 700 liters of water per hectare with the help of knapsack sprayer. The crop was harvested in during 1st fortnight of March during both the years of experimentation. Data pertaining to density and dry matter accumulation by weeds were subjected to square root transformation prior to statistical analysis.

RESULTS AND DISCUSSION

Cyperus rotundus, *Cynodon dactylon* and *Sorghum halepense* were observed as major weeds in both the year. Other weeds present in the field were *Euphorbia hirta, Cleome viscosa, Phyllanthus niruri, Cannabis sativa, Luffa graveolans, Trichosanthes cucumerina* and *Physalis minima.*

Effect on weeds

The density and dry matter accumulation of weeds decreased significantly due to weed control treatments compared to un-weeded check (Table 1). As expected, three hoeing at 30, 60, 90 DAP recorded lowest weed density (23.77 and 22.07/m^2) at 120 DAP which was significantly superior to rest of the treatments during 1st year. During 2nd year, application of glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP and atrazine 2.0 kg/ha as pre-emergence + one hoeing at 60 DAP were found to be at par with three hoeing at 30,60,90 DAP. The remaining treatments, significantly reduced weed density by 32.5 and 36.2% during 2008-09 and 2009-10, respectively when it was compared to unweeded check. The results corroborated with the findings of Raskar (2004) and Pratap *et al.* (2013).

Total dry matter accumulation by weeds also followed a similar trend and was lowest (8.71 and 8.34 g/m^2) under three hoeing at 30, 60, 90 DAP when compared to rest of the treatments. Among the integration of herbicides + cultural practice, minimum accumulation of dry matter (10.99 and 10.61 g/m^2) in weeds was observed with the application of glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP followed by atrazine 2.0 kg/ha as pre-emergence + one hoeing at 60 DAP, paraquat dichloride 500 kg/ha+ atrazine 2.0 kg/ha after 1st irrigation and metribuzin 1.0 kg/ha as pre-emergence + one hoeing at 60 DAP over un-weeded check. Reduction in weed density and total dry matter accumulation may be due to removal of weeds at critical stage with repeated hoeing and pre-emergence application of herbicides followed by one hoeing at appropriate time (Table 1). The results were in close conformity with the findings of Singh and Lal (2008). The highest weed control efficiency (mean 57.0 %) was observed under three hoeing at 30, 60, 90 DAP followed by glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP (mean 45.5%) and atrazine 2.0 kg/ha as pre-emergence + one hoeing at 60 DAP (mean 39.5%) treatment.

Effect on sugarcane

Data on cane yield (Table 2) revealed that it ranged from 58.9 t/ha under weedy check to 96.5 t/ ha under weed free conditions. Further, cane yield was highest (88.8 t/ha) when crop was raised with 3 hoeing at 30, 60, 90 DAP. It was closely followed by glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP (87.9 t/ha), atrazine 2.0 kg/ha as pre-emergence + one hoeing at 60 DAP (87.2 t/ha), paraquat dichloride 500 kg/ha+ atrazine 2.0 kg/ha after 1st irrigation (86.6 t/ha) and metribuzin 1.0 kg/ha as pre-emergence + one hoeing at 60 DAP (86.1 t/ha). Higher cane yield was due to the generation of higher yield attributes, *viz*. number of millable canes, cane girth and length. Lowest value of millable canes was recorded with weedy check being significantly lower than weed free, three hoeing at 30, 60, 90 DAP and glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP, respectively. The cane length and girth followed the same trends as NMC. Application of herbicides *fb* cultural practices removed weeds effectively during critical weed crop competition stage resulting in profuse tillering and their conversion in more number of millable canes with increased length and girth.

Table 1. Effect of weed management practices on weeds at 120 days after planting in spring planted sugarcane

Treatment	Weed population (no./m^2) at 120 DAP										Total weed dry matter (g/m^2) at 120 DAP		Weed control efficiency (%)	
	Cyperus rotundus		*Cynodon dactylon*		*Sorghum halepense*		Other weeds		Total weeds					
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
T_1	2.91 (8.0)	2.62 (6.3)	2.40 (5.2)	2.39 (5.2)	2.55 (6.0)	2.54 (5.9)	2.22 (4.4)	2.21 (4.4)	4.92 (23.7)	4.75 (22.1)	3.02 (8.71)	2.96 (8.3)	56.8	57.1
T_2	2.94 (8.1)	3.02 (8.6)	2.60 (6.3)	2.59 (6.2)	2.78 (7.2)	2.77 (7.2)	2.38 (5.1)	2.37 (5.1)	5.23 (26.9)	5.23 (27.3)	3.80 (13.9)	3.70 (13.2)	30.8	31.9
T_3	2.91 (7.9)	2.96 (8.3)	2.54 (6.00)	2.54 (5.9)	2.72 (6.9)	2.72 (6.9)	2.35 (5.1)	2.35 (5.1)	5.15 (25.9)	5.17 (26.2)	3.71 (13.2)	3.65 (12.8)	34.3	33.7
T_4	2.81 (7.4)	2.66 (6.6)	2.47 (5.6)	2.47 (5.6)	2.62 (6.3)	2.61 (6.3)	2.27 (4.6)	2.26 (4.6)	4.96 (24.1)	4.87 (23.2)	3.38 (10.9)	3.31 (10.6)	45.5	45.4
T_5	2.84 (7.6)	2.86 (7.69)	2.49 (5.7)	2.48 (5.7)	2.67 (6.6)	2.67 (6.6)	2.46 (5.5)	2.45 (5.5)	5.10 (25.5)	5.10 (25.5)	3.62 (12.6)	2.56 (12.2)	37.4	36.9
T_6	2.83 (7.5)	2.69 (6.7)	2.48 (5.7)	2.47 (5.6)	2.64 (6.5)	2.64 (6.4)	2.28 (4.7)	2.78 (4.7)	4.99 (24.4)	4.90 (23.6)	3.55 (12.1)	3.49 (11.7)	39.7	39.3
T_7	2.92 (8.1)	3.01 (8.6)	2.59 (6.2)	2.58 (6.2)	2.75 (7.1)	2.74 (7.1)	2.37 (5.1)	2.37 (5.1)	5.20 (26.5)	5.24 (27.1)	3.69 (13.2)	3.65 (12.8)	34.5	33.9
T_8	2.88 (7.9)	2.86 (7.7)	2.53 (5.9)	2.53 (5.9)	2.70 (6.8)	2.69 (6.7)	2.34 (4.9)	2.33 (4.9)	5.11 (25.6)	5.09 (25.3)	3.66 (12.9)	3.62 (12.6)	35.6	34.8
T_9	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.00)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	-	-
T_{10}	3.72 (13.4)	3.83 (14.2)	3.12 (9.2)	3.12 (9.25)	2.89 (7.8)	2.88 (7.8)	2.38 (5.22)	2.38 (5.20)	6.02 (35.7)	6.07 (36.5)	4.53 (20.1)	4.45 (19.4)	-	-
LSD (P=0.05)	0.28	0.26	0.30	0.31	0.23	0.35	0.33	0.33	0.34	0.33	0.42	0.47	-	-

Figures in parentheses are original values. Data transformed to ($\sqrt{x + 0.5}$)

T_1- Three hoeing at 30 ,60, 90 DAP , T_2- Atrazine 2.0 kg/ha as pre- emergence + 2,4-D 1.0 kg/ha at 60 DAP, T_3- Atrazine 2.0 kg/ha as pre-emergence after 1st irrigation + 2,4-D 1.0 kg/ha at 60 DAP, T_4- Glyphosate 1.0 kg/ha as pre- emergence + Atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP, T_5- Paraquat dichloride 500 ml/ha+ atrazine 2.0 kg/ha after 1st irrigation T_6- Atrazine 2.0 kg/ha as pre-emergence + one hoeing at 60 DAP T_7- Metribuzin 1.0 kg/ha as pre-emergence after 1st irrigation + 2,4-D 1.0 kg/ha at 60 DAP T_8- Metribuzin 1.0 kg/ha as pre-emergence + one hoeing at 60 DAP T_9- Weed free, T_{10}- Weedy check.

These findings are in corroboration with the results of Singh and Kumar (2013) and Kumar *et al.* (2014).

Weed index (%)

Weed index in cane yield ranged from 39.0% under weedy conditions to 8.0% when the crop received 3 hoeings at 30, 60 and 90 days after planting stage and was closely followed by the application of glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP and atrazine 2.0 kg/ha as pre-emergence + one hoeing at 60 DAP**.**

Effect on economics

Crop grown under weed free conditions involved highest cost of cultivation of ` 38,000/ha against ` 30,554/ha in weedy check (Table 2). Data on economics revealed that net returns ranged from ` 50,049/ha in weedy check to ` 94,012/ha under weed free conditions. Among the herbicidal treatments. application of glyphosate 1.0 kg/ha as pre-emergence + atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP recorded highest net returns of ` 84,052/ha with B:C ratio of 3.33 followed by atrazine 2.0 kg/ha as pre-emergence + one hoeing at 60 DAP (` 83,534/ ha), paraquat dichloride 500 kg/ha+ atrazine 2.0 kg/ ha after 1st irrigation (` 82,923/ha) and metribuzin 1.0 kg/ha as pre-emergence + one hoeing at 60 DAP (` 82,619/ha). Higher economic returns were due to higher yields.

Thus, the application of glyphosate 1.0 kg/ha as pre-emergence + atrazine 2 kg/ha applied after first irrigation + one hoeing at 90 days after planting was found to be effective for weed control and it produced higher yield attributes and cane yield with higher returns under north Indian conditions. This IWM practice effectively reduced the weed menace during early slow growth period of sugarcane while the

Table 2. Effect of weed management practices on cane yield, yield attributes and weed index in spring planted sugarcane

Treatment	No. of millable canes ($x10^3$ /ha)		Cane length (cm)		Cane girth (cm)		Cane yield (t/ha)			Weed index (% reduction in yield)	Cost of cultivation ($x10^3$ `/ha)	Net returns ($x10^3$ `/ha)	B:C ratio
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	Mean				
T_1	118.9	119.2	273.6	279.1	7.0	7.2	88.0	89.6	88.8	8.0	36.22	85.30	3.35
T_2	110.1	110.4	245.2	250.1	6.4	6.6	80.3	81.7	81.0	16.1	33.68	77.10	3.29
T_3	114.2	114.6	253.3	258.4	6.5	6.7	84.1	85.5	84.8	12.1	34.97	81.08	3.32
T_4	118.0	118.9	265.9	271.2	6.9	7.1	87.2	88.5	87.9	9.0	36.10	84.05	3.33
T_5	116.2	116.6	260.6	265.8	6.8	7.3	85.9	87.3	86.6	10.3	35.57	82.92	3.33
T_6	117.0	117.4	265.3	270.6	6.8	7.0	86.5	87.8	87.2	9.7	35.71	83.53	3.34
T_7	112.3	112.7	249.4	254.4	6.4	6.6	83.4	84.7	84.1	12.9	34.15	80.82	3.37
T_8	115.1	115.5	256.2	261.3	6.7	7.2	85.6	86.5	86.1	10.8	35.10	82.62	3.36
T_9	120.0	121.0	278.1	283.7	7.0	7.2	95.9	97.1	96.5	-	38.00	94.01	3.48
T_{10}	72.0	72.5	221.0	225.4	5.7	5.9	58.6	59.2	58.9	39.0	30.55	50.05	2.64
LSD (P=0.05)	6.3	9.1	22.1	22.6	NS	0.6	8.3	8.6	8.5	-	-	10.03	0.28

DAP= Days after planting of sugarcane

T_1- Three hoeing at 30 ,60, 90 DAP , T_2- Atrazine 2.0 kg/ha as pre- emergence +2,4-D 1.0 kg/ha at 60 DAP, T_3-Atrazine 2.0 kg/ha as pre- emergence after 1st irrigation + 2,4-D 1.0 kg/ha at 60 DAP, T_4- Glyphosate 1.0 kg/ha as pre- emergence + Atrazine 2.0 kg/ha after 1st irrigation + one hoeing at 90 DAP ,T_5- Paraquat dichloride 500 ml/ha+ atrazine 2.0 kg/ha after 1st irrigation T_6- Atrazine 2.0 kg/ha as pre- emergence + one hoeing at 60 DAP T_7- Metribuzin 1.0 kg/ha as pre-emergence after 1st irrigation + 2,4-D 1.0 kg/ha at 60 DAP T_8-Metribuzin 1.0 kg/ha as pre-emergence + one hoeing at 60 DAP T_9-Weed free, T_{10}- Weedy check.

hoeing done at 90 DAP eradicated residual weed flora from the field. In this way, this approach of chemical weed control fb mechanical weed control proved effective after the sole mechanical weed control method of 3 hoeing at 30, 60 and 90 DAP.

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Integrated weed management in turmeric

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ABSTRACT

Ten weed control treatments *viz*. metribuzin (700 g/ha) or pendimethalin (1000 g/ha) each followed by (*fb*) hoeing twice; metribuzin (700 g/ha), pendimethalin (1000 g/ha) or atrazine (750 g/ha) each followed by i) fenoxaprop (670 g/ha) + metsulfuron-methyl (4 g/ha) or ii) straw mulch *fb* hoeing; weed free (hand weeding thrice) and weedy check] were evaluated for weed control in turmeric on a silty clay loam soil at Palampur during 2012 and 2013. Treatment constituting of fenoxaprop + metsulfuron-methyl were phytotoxic. Pendimethalin *fb* hoeing and pendimethalin /metribuzin /atrazine *fb* mulch *fb* hoeing were comparable to weed free in reducing population of *Echinochloa colona*, *Digitaria sanguinalis*, *Panicum dicotomiflorum*, *Cyperus iria* and *Aeschynomene indica*. Metribuzin *fb* mulch *fb* hoeing significantly reduced the count of *Ageratum conyzoides* and *Galinsoga parviflora* upto 60 DAS. Metribuzin/pendimethalin *fb* hoeing and pendimethalin/ metribuzin/ atrazine *fb* mulch *fb* hoeing resulted in significantly higher plant height, leaves per plant, number of shoots per plant, plant dry matter accumulation, rhizome weightperplant and fresh rhizome yield over other treatments. Atrazine/ pendimethalin/metribuzin *fb* mulch *fb* hoeing increased fresh rhizome yield by 1.54-1.68 times over weed free. Metribuzin *fb* mulch *fb* hoeing resulted in highest gross and net returns due to weed control. Marginal benefit cost ratio (MBCR) was highest under pendimethalin *fb* mulch *fb* hoeing (54.67) followed by atrazine *fb* mulch *fb* hoeing (50.73), metribuzin *fb* mulch *fb* hoeing (46.2) and pendimethalin *fb* hoeing (24.86). Weeds in weedy check reduced rhizome yield by 78.2% over metribuzin *fb* mulch *fb* hoeing.

Key words: Integrated weed managment, Metribuzin, Metsulfuron, Mulch, Pendimethalin, Turmeric

Low and mid hills of Himachal Pradesh are important turmeric growing areas. It is an alternative to maize in *Kharif* season particularly in areas infested by wild boars, stray animals and porcupines. It has slow initial growth rate and shallow root system. As a result, it is invaded by a variety of weeds. Weeds compete with turmeric for nutrients, moisture and space and cause 35-75% yield reduction (Krishnamurthy and Ayyaswamy 2000). Generally, for the control of weeds, farmers do manual weeding, but with increase in labour cost and scarcity of labour, manual weed control has become a difficult task. Mulching with straw is another approach adopted by the farmers that conserves soil moisture and maintains soil temperature for the benefit of the crop (Mahey *et al*. 1986), besides suppressing weeds (Hossain 2005). Pre emergence herbicides, *viz*. pendimethalin (Kumar and Reddy 2000), atrazine (Singh and Mahey 1992) or metribuzin (Gill *et al*. 2000), save the crop from severe weed competition at an early stage. However, sole dependence on any single method may not provide effective weed management in a long duration crop like turmeric. The weeds need to be removed during 70 to 160 days after planting, indicating that it needs a longer weed free period than other crops. This necessitates development of an effective and economically better integrated weed control strategy for realizing higher productivity of turmeric. Keeping these points in view, the present investigation was conducted under mid–hill conditions of Himachal Pradesh.

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MATERIALS AND METHODS

The field experiment was conducted during 2012 and 2013 at Palampur in randomized block design with three replications. The experimental soil was silty clay loam, acidic (pH 6.1), medium in available N (326 kg/ha), and high in available P (25.8 kg/ha) and K (276.4 kg/ha). The treatments consisted of metribuzin 0.7 kg/ha *fb* hoeing twice, metribuzin 0.7 kg/ha *fb* fenoxaprop 67 g/ha+ metsulfuron-methyl 4 g/ha, metribuzin 0.7 kg/ha *fb* straw mulch 10 t/ha *fb* hand weeding, pendimethalin 1.0 kg/ha *fb* hoeing twice, pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha, pendimethalin 0.7 kg/ha *fb* straw mulch 10 t/ha *fb* hand weeding, atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha, atrazine 0.75 kg/ha *fb* straw mulch 10 t/ha *fb* hand weeding, weed free and weedy check. Turmeric variety '*Pitamber*' was planted on 2 June, 2012 and 5 June, 2013 in rows 30 cm apart using a seed rate of 2.5 t/ha. The crop was fertilized with 60 kg N, 180 kg P and 100 kg K/ha. through urea (46%), single super phosphate (16% P_2O_5) and muriate of potash (K_2O), respectively, at the time of planting. The herbicides and interculture operations were applied as per the treatments to different plots. Metribuzin/ pendimethalin/atrazine were applied as pre- emergence, fenoxaprop + metsulfuron-methyl as post emergence. Straw mulch was applied immediately after spray and hoeing were done at 25-35 and 45-55 DAP. Herbicides were applied with knapsack power sprayer using 600 L water per hectare. Mulching was done after the herbicides were sprayed on second day as per treatment. Care was taken to ensure uniform thickness of the mulch and coverage of whole area of the plot. The rest of the management practices were adopted in accordance with the recommended package of practices. Data on density and dry weight of weeds were recorded at 60 DAS and at harvest. The weed count and dry weight data were subjected to square root transformation ($\sqrt{x+1}$). When the leaves turned yellow and dry, the crop from net plots was harvested. The rhizomes were dug taking care that they were not cut or damaged, then cleaned to remove soil and weighed for fresh weight. The crop was harvested on 4 January 2013 and 30 December 2013. Economics of the treatments was computed based on the prevalent market prices of the inputs used and rhizomes produced.

RESULTS AND DISCUSSION

Effect on weeds

The major weeds of the experimental field were *Cyperus iria* (41.9%), *Ageratum conyzoides* (14.1%), *Echinochloa colona* (12.9%), *Panicum dichotomiflorum* (12.5%), *Digitaria sanguinalis* (5.2%), *Aeschynomene indica* (5.2%), *Commelina benghalensis* (4.6%), *Galinsoga parviflora* (3.2%) and *Polygonum* sp. (0.6%). *Physallis minima* had also shown its sporadic appearance.

Weed control treatments brought about significant variation in the population of *E. colona* (Table 1). All the weed control treatments except pendimethalin 1.0 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha during 2012 and atrazine 750 g/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha during 2013 had significantly reduced the population of *E. colona* over weedy check.

Table 1. Effect of treatments on species-wise weed count (no./m²) at 60 DAS in turmeric

Treatment	Dose g/ha	*Echinochloa* sp.		*Digitaria* sp.	*Panicum* sp.		*Cyperus** sp.	*Ageratum* sp.		*Aeschynomene** sp.	*Galinsoga* sp.
		2012	2013	2012	2012	2013	2012	2012	2013	2012	2013
Metribuzin *fb* hoeing	700 g	2.2 (4.0)	3.2 (12.0)	1.0 (0.0)	1.7 (2.7)	2.1 (4.0)	4.4 (18.7)	2.2 (4.7)	5.1 (26.7)	1.0 (0.0)	3.2 (14.7)
Metribuzin *fb* fenoxaprop + metsulfuron-methyl	700 g *fb* 67+4 g	1.7 (2.7)	2.9 (9.3)	1.7 (2.7)	2.1 (4.0)	4.0 (22.0)	2.7 (6.7)	1.4 (1.3)	1.0 (0.0)	2.5 (6.7)	1.0 (0.0)
Metribuzin *fb* straw mulch *fb* hoeing	700 g *fb* 10 t/ha	1.8 (2.7)	1.7 (2.7)	1.8 (2.7)	1.8 (2.7)	1.0 (0.0)	3.0 (8.0)	2.4 (4.7)	1.7 (2.7)	1.0 (0.0)	1.4 (1.3)
Pendimethalin *fb* hoeing	1000 g	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	4.0 (14.7)	2.1 (4.0)	8.6 (73.3)	1.0 (0.0)	3.2 (18.7)
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl	1000 g *fb* 67+4 g	2.7 (6.7)	1.7 (2.7)	1.7 (2.7)	1.7 (2.7)	1.0 (0.0)	3.1 (9.3)	2.4 (4.7)	1.0 (0.0)	2.3 (5.3)	1.0 (0.0)
Pendimethalin *fb* straw mulch *fb* hoeing	1000 g *fb* 10 t/ha	1.7 (2.7)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)	2.5 (6.7)	2.1 (4.0)	4.3 (18.7)	1.0 (0.0)	1.7 (2.7)
Atrazine *fb* fenoxaprop + metsulfuron-methyl	750 g *fb* 67 + 4 g	1.7 (2.7)	4.6 (21.3)	2.1 (4.0)	2.5 (5.3)	4.5 (21.3)	3.0 (8.0)	2.1 (4.0)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)
Atrazine *fb* straw mulch *fb* hoeing	750 g *fb* 10 t/ha	1.0 (0.0)	1.9 (4.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	4.0 (16.0)	2.7 (6.7)	4.2 (17.3)	1.0 (0.0)	1.4 (1.3)
Weed free (3 hand weeding)	-	1.7 (2.7)	1.0 (0.0)	1.4 (1.3)	1.7 (2.7)	1.0 (0.0)	4.1 (16.0)	2.9 (8.0)	5.5 (36.0)	1.0 (0.0)	1.0 (0.0)
Weedy check	-	3.6 (12.0)	4.8 (22.7)	3.2 (9.3)	3.2 (9.3)	3.4 (17.3)	5.5 (29.3)	4.1 (16.0)	5.8 (33.3)	4.1 (16.0)	2.9 (14.7)
LSD (P=0.05)		1.3	1.2	1.3	1.3	2.3	1.3	1.3	2.4	1.2	1.3

Values in the parentheses are the original means *fb* = followed by, DAS= days after sowing; * at harvest. Metribuzin/ pendimethalin/ atrazine applied as pre- emergence, fenoxaprop + metsulfuron-methyl applied as post emergence, straw mulch applied immediately after spray and hoeings at 25-35 DAP and 45-55 DAP.

Table 2. Effect of different treatments on total weed count and dry weight in turmeric

Treatment	Dose/ha	Total weed count (no./m^2) 2012		Total weed count (no./m^2) 2013		Total weed dry weight (g/m^2) 2012		Total weed dry weight (g/m^2) 2013	
		60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
Metribuzin *fb* hoeings	700 g	4.7 (22.0)	6.1 (37.3)	9.5 (94.7)	6.4 (42.7)	3.4 (11.0)	3.9 (14.5)	4.5 (19.8)	4.8 (22.6)
Metribuzin *fb* fenoxaprop + metsulfuron-methyl	700 g *fb* 67+4g	4.3 (18.0)	6.0 (38.0)	7.2 (50.7)	5.7 (33.3)	2.8 (7.6)	4.0 (15.8)	4.7 (25.3)	4.6 (20.2)
Metribuzin *fb* straw mulch *fb* hoeing	700 g *fb* 10 t/ha	4.7 (23.3)	5.0 (25.3)	3.9 (14.7)	2.9 (9.3)	3.9 (18.3)	3.4 (13.4)	5.6 (41.1)	8.7 (88.1)
Pendimethalin *fb* hoeing	1000 g	3.6 (12.0)	5.2 (26.7)	10.7 (114.7)	6.2 (38.7)	2.3 (5.2)	3.2 (9.6)	3.6 (12.6)	3.1 (8.6)
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl	1000 g *fb* 67+ 4g	5.7 (32.7)	7.4 (56.0)	6.3 (40.0)	5.6 (33.3)	4.4 (19.5)	4.7 (21.8)	3.6 (12.1)	5.6 (31.3)
Pendimethalin *fb* straw mulch *fb* hoeing	1000 g *fb* 10 t/ha	3.1 (11.3)	4.1 (16.0)	6.1 (38.7)	5.8 (44.0)	2.5 (6.1)	2.7 (7.1)	3.8 (14.1)	5.6 (32.3)
Atrazine *fb* fenoxaprop + metsulfuron-methyl	750 g *fb* 67 + 4g	5.0 (24.7)	6.1 (37.3)	8.0 (66.7)	5.5 (29.3)	3.4 (10.9)	4.1 (15.5)	8.7 (84.2)	7.9 (74.2)
Atrazine *fb* straw mulch *fb* hoeing	750 g *fb* 10 t/ha	3.6 (12.0)	5.4 (29.3)	6.2 (38.7)	4.4 (25.3)	2.4 (4.8)	2.9 (7.7)	3.4 (13.1)	5.1 (26.5)
Weed free (3 hand weeding)	-	4.8 (23.3)	6.6 (42.7)	6.6 (45.3)	6.7 (46.7)	3.2 (10.4)	4.2 (18.1)	1.5 (1.2)	2.8 (7.1)
Weedy check	-	8.7 (76.0)	10.8 (116.7)	15.6 (244.0)	5.7 (32.0)	5.9 (34.1)	7.7 (58.3)	11.1 (120.6)	6.1 (37.2)
LSD (P=0.05)		1.9	2.2	2.0	NS	1.7	1.7	4.0	NS

Values given in the parentheses are the original means *fb* = followed by, DAS= days after sowing

Metribuzin *fb* straw mulch *fb* hoeing, pendimethalin *fb* hoeing, pendimethalin *fb* fenoxaprop + metsulfuron-methyl, pendimethalin *fb* straw mulch *fb* hoeing and atrazine *fb* straw mulch *fb* hoeing were as good as weed free in reducing the population of *E. colona* upto 60 DAS during both the year. Weed suppressing efficiency of straw mulch has also been reported by Mahey *et al.* (1986). Similarly, all the weed control treatments except atrazine *fb* fenoxaprop + metsulfuron-methyl behaved statistically alike and resulted in significantly lower count of *D. sanguinalis* during 2012-13. The count of *P. dichotomiflorum* was significantly lower under all the treatments except metribuzin 700 g/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha and atrazine 0.75 kg/ha *fb* fenoxaprop 67 g/ha + metsulfuron-methyl 4 g/ha over weedy check during both years. Effectiveness of pendimethalin 1.0 kg/ha (Kumar and Reddy, 2000), metribuzin 0.70 kg/ha (Gill *et al.* 2000) and atrazine 2.0 kg/ha (Mishra and Mishra 1982) against weeds in turmeric has been established. Count of *C. iria* was effectively reduced by different weed control treatments except metribuzin 0.7 kg/ha *fb* hoeing at harvest during 2012. Pendimethalin *fb* straw mulch + hoeing was on par with metribuzin/atrazine/pendimethalin *fb* fenoxaprop + metsulfuron, while metribuzin *fb* straw mulch *fb* hoeing was superior to other treatments in curtailing *C. iria* upto harvest.

Metribuzin, pendimethalin and atrazine each *fb* fenoxaprop 67 g/ha + metsulfuron and metribuzin + mulch + hoeing significantly reduced the count of *Ageratum* upto 60 DAS during both the years. In these treatments as well as in others, *Ageratum* appeared in large numbers after 60 DAS, resulting in a count equal or higher than in weedy check. The activity of metsulfuron-methyl and pendimethalin against *A. conyzoides* has been established (Kumar *et al*. 2013). All treatments were significantly superior to weedy check in reducing the count of *Aeschynomene indica* upto harvest during 2012. Except pendimethalin/metribuzin *fb* fenoxaprop + metsulfuron-methyl, all treatments were at par in reducing its count. Except metribuzin/pendimethalin *fb* hoeing all treatments were equally effective in reducing the count of *G. parviflora* over weedy check at 60 DAS during 2013. The activity of metsulfuron-methyl alone or in combination with other herbicides has also been well established against broad-leaf weeds (Kurchania *et al.* 2000, Sharma and Pahuja 2001, Kumar *et al*. 2010).

Owing to reduction in species-wise weed count, all the weed control treatments resulted in significant reduction in total weed count as compared to weedy check upto harvest during 2012 and upto 60 DAS during 2013 (Table 2). All the treatments during 2012 and metribuzin (700 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing during 2013 were comparable to weed free in

Table 3. Effect of different treatments on plant height, leaves/plant, shoots, crop dry weight and rhizome yield of turmeric

Treatment	Dose/ha	Plant height (cm)		Leaves /plant*	Shoots /m^2	Crop dry weight* (g/m^2)	Fresh rhizomes /plant (g)	Rhizome yield (t/ha)	
		2012	2013	2013	2013	2013	2013	2012	2013
Metribuzin *fb* hoeing	700 g	48.4	26.7	6.3	15.0	64.8	26.0	5.4	7.6
Metribuzin *fb* fenoxaprop + metsulfuron-methyl	700 g *fb* 67 + 4 g	25.2	12.7	2.0	3.3	48.2	10.7	2.8	4.9
Metribuzin *fb* straw mulch *fb* hoeing	700 g *fb* 10 t/ha	50.6	29.7	5.7	16.3	111.5	54.0	13.7	14.3
Pendimethalin *fb* hoeing	1000 g	46.7	29.3	6.3	15.3	63.4	28.7	6.3	8.8
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl	1000 g *fb* 67+ 4 g	26.4	12.0	2.0	4.1	42.2	33.3	2.8	4.6
Pendimethalin *fb* straw mulch *fb* hoeing	1000 g *fb* 10 t/ha	50.1	36.7	5.7	17.4	82.8	42.3	13.4	14.3
Atrazine *fb* fenoxaprop + metsulfuron-methyl	750 g *fb* 67 + 4 g	24.3	11.0	2.0	5.6	55.0	38.0	2.3	4.2
Atrazine *fb* straw mulch *fb* hoeing	750 g *fb* 10 t/ha	51.4	41.0	6.0	16.6	85.4	63.7	12.0	13.8
Weed free (3 hand weedings)	-	49.4	26.7	6.3	12.0	71.7	48.0	7.0	9.7
Weedy check	-	42.3	38.0	5.0	9.7	43.6	22.7	2.9	3.2
LSD (P=0.05)		7.4	7.9	0.9	3.1	11.5	12.2	2.4	1.0

affecting total weed count. All treatments except pendimethalin/atrazine *fb* fenoxaprop + metsulfuron were significantly superior to weedy check in affecting total weed dry weight upto harvest during 2012 and 60 DAP during 2013. The effectiveness of pre-emergence application of pendimethalin (Kumar and Reddy 2000), atrazine (Singh and Mahey 1992) and metribuzin (Gill *et al.* 2000) against weeds in turmeric has also been reported.

Effect on crop

Weed control treatments significantly influenced plant height (Table 3). Atrazine (750 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing was at par with metribuzin/ pendimethalin *fb* mulch *fb* hoeing, metribuzin/ pendimethalin *fb* hoeing and weed free during 2012 and weedy check and pendimethalin (1000 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing during 2013 resulted in significantly taller plants compared to other treatments. Early emergence in plots under mulch might have favored growth in terms of plant height. Favorable soil temperature and more available soil moisture for crop growth may also be responsible for taller plants in mulched plots. Weed free, atrazine *fb* mulch *fb* hoeing, metribuzin *fb* hoeing and pendimethalin (1000 g/ha) *fb* hoeing had significantly higher number of leaves/plant over weedy check. Metribuzin (700 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing, atrazine (750 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing were statistically at par with these treatments in influencing number of leaves/plant. This may be due to the early emergence of the crop in mulched plots. Metribuzin (700 g/ha) *fb* 2 hoeing, metribuzin (700 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing, pendimethalin (1000 g/ha) *fb* 2 hoeing, pendimethalin (1000 g/ha) *fb* straw mulch (10 t/ha) *fb* hoeing, atrazine (750 g/ha) *fb* straw mulch (10 t/ ha) *fb* hoeing had significantly higher number of shoots in comparison to other treatments. This might be due to more available moisture and weed free condition in the mulched treatments. Plant height, number of leaves/plant and number of shoots/plant were significantly lower where fenoxaprop + metsulfuron-methyl was included,

Metribuzin *fb* mulch *fb* hoeing resulted in significantly higher dry matter accumulation followed by atrazine *fb* mulch *fb* hoeing. The positive effect of mulch might be due to increase in crop growth parameters like plant height and number of leaves/plant. Mulch also suppressed the weeds for longer growing period and favoured crop growth. The treatments having straw mulch had significantly higher fresh weight of rhizomes. Mulch application had positive effect for increasing above ground bio-mass which was responsible for increasing dry matter accumulation by rhizomes, because more photosynthates were transferred to rhizomes from above ground parts. Swain *et al.* (2007) also reported significantly higher fresh weight of rhizome per plant with application of paddy straw mulch as compared to no mulch. The lower dry matter accumulation and weight of rhizomes/plant was observed where fenoxaprop + metsulfuron-methyl was used indicating its phytotoxic effect.

All treatments were significantly superior to weedy check in increasing fresh rhizome yield. Mulching proved to be an extremely important

Table 4. Effect of treatments on cost of weed control, gross returns, gross returns due to weeds, net return due to weed control and MBCR (mean of two years)

Treatment	Dose (g/ha)	Cost of cultivation (x10^3 `/ha)	Cost of weed control (x10^3 `/ha)	Gross returns (x10^3 `/ha)	Gross return due to weed control (x10^3 `/ha)	Net return due to weed control (x10^3 `/ha)	MBCR
Metribuzin *fb* hoeing	700 g	82.43	6.02	162.50	86.25	80.23	13.33
Metribuzin *fb* fenoxaprop + metsulfuron-methyl	700 g *fb* 67+ 4g	81.07	4.66	96.25	20.00	15.34	3.29
Metribuzin *fb* straw mulch *fb* hoeing	700 g *fb* 10 t/ha	82.21	5.80	350.00	273.75	267.95	46.20
Pendimethalin *fb* hoeing	1000 g	80.76	4.35	188.75	112.50	108.15	24.86
Pendimethalin *fb* fenoxaprop + metsulfuron-methyl	1000 g *fb* 67+ 4 g	78.68	2.27	92.50	16.25	13.98	6.15
Pendimethalin *fb* straw mulch *fb* hoeing	1000 g *fb* 10 t/ha	81.26	4.85	346.25	270.00	265.15	54.67
Atrazine *fb* fenoxaprop + metsulfuron-methyl	750 g *fb* 67 + 4 g	78.59	2.18	81.25	5.00	2.82	1.29
Atrazine *fb* straw mulch *fb* hoeing	750 g *fb* 10 t/ha	81.17	4.76	322.50	246.25	241.49	50.73
Weed free (3 hand weeding)	-	95.91	19.50	208.75	132.50	113.00	5.79
Weedy check	-	76.41	-	76.25	-	-	

Metribuzin/pendimethalin/atrazine applied as pre-emergence, fenoxaprop + metsulfuron-methyl applied as post-emergence, straw mulch applied immediately after spray and hoeings at 25-35 DAP and 45-55 DAP, MBCR: Marginal benefit cost ratio

practice as the treatments constituting the straw mulch treatment *viz*. pendimethalin/metribuzin/ atrazine *fb* mulch *fb* hoeing resulted in significantly higher fresh rhizome yield over other treatments. The superiority of mulch in increasing rhizome yield of turmeric has been documented by Mahey *et al*. in 1986 and Hossain in 2005. Weeds in unweeded check reduced the rhizome yield by 78.2% over metribuzin *fb* mulch *fb* hoeing. Krishnamurthy and Ayyaswamy (2000) have reported 75% reduction in the yield of turmeric due to season long competition with weeds. Atrazine / pendimethalin/ Metribuzin *fb* mulch *fb* hoeing increased fresh rhizome yield by 1.54-1.68 times over weed free (hand weeding thrice).

Economics

Due to higher rhizome yield, gross returns were highest under metribuzin *fb* mulch *fb* hoeing followed by application of pendimethalin/atrazine *fb* mulch *fb* hoeing and weed free. Net returns followed the trend similar to total gross returns. Marginal benefit cost ratio (MBCR) was highest under pendimethalin *fb* mulch *fb* hoeing (54.67) followed by atrazine *fb* mulch *fb* hoeing (50.73), metribuzin *fb* mulch *fb* hoeing (46.2) and pendimethalin *fb* hoeing (24.86). Due to the higher cost of maintaining weed free environment, weed free (hand weeding 3 times) resulted in lower MCBR. Thus, use of herbicides in turmeric was the cheapest alternative to manual weed control.

The findings of present investigation conclusively inferred that weeds in turmeric can be effectively managed with satisfactory yield and profit gain by pre emergence application of metribuzin (700 g/ha), pendimethalin (1000 g/ha) or atrazine (750 g/ ha) *fb* mulch (paddy straw 10 t/ha) and one hoeing.

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Seasonality of emergence of selected annual weeds in coconut garden

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ABSTRACT

A long-term trial was conducted in the coconut plantation at Thrissur, Kerala, India from July 2008 to June 2013. Time series analysis was performed with monthly weed count data to determine seasonality of selected weeds of a coconut garden. A multiplicative model was assumed for the time series and the seasonal index was worked out for each weed species. The results revealed that *Axonopus compressus*, *Biophytum sensitivum* and *Mimosa pudica* dominated during the South West monsoon season while *Curculigo orchioides* and *Desmodium gangeticum* were seen germinating during the North East monsoon period from September– October and were predominant in the field till February. *Hemidesmus indicus* and *M. pudica* were the weed species seen throughout the year. However, their predominance was the field was between November to April and July to November, respectively.

Keywords: Seasonal index, Weed emergence pattern, Soil seed bank, Coconut plantation

Accumulation of weed seeds helps in the buildup of a population in the soil seed bank. Germination of these seeds in portions over a number of years accounts for the persistence of annual weeds in the ecosystem. Weed seeds exhibit distinct seasonal variation in germination which is determined by both intrinsic factors like dormancy and extrinsic factors like moisture content of soil, temperature, light etc. Soil temperature and soil water availability are regulated by weather (Frank 2003)**.** Seeds buried in soil and exposed to natural temperature cycles exhibit seasonal variation in germination. Akobundu (1987) has reported that weed seeds showed periodicity of germination more in response to variation in temperature and soil moisture content than the tillage practices adopted. Information on the seasonality of germination of weed seeds will help to make predictions on their incidence in the succeeding years. Catherine *et al.* (2010) have used a time series estimation of 66 weed species of the Pacific Northwest and northern Rocky Mountain counties to forecast the weed distribution data. However, timing weed seed emergence is a critical factor for the weed and is equally important for the weed managers. The study was undertaken to understand the seasonality of germination of weed seeds from the soil seed bank of a coconut plantation. Data were collected from a long-term trial started in the coconut plantation at the College of Horticulture, Vellanikkara, Thrissur in July 2008. Time series analysis (Anderson 2011) was performed with monthly weed counts registered from July 2008 to June 2013 to determine seasonality of selected weeds of the coconut garden.

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MATERIALS AND METHODS

The germinating weed seedlings were uprooted and counted species-wise at 15 days interval from 5 peg marked regions of 0.25 m^2 area in the field. The observations were taken for five years from July 2008 to June 2013; data were then converted to monthly weed counts. To understand the influence of season on weed emergence, a time series analysis of the data was done with the weed counts taken for 60 months from July 2008 to June 2013. A multiplicative model was assumed for the time series as given by (Johnson *et al*. 1990)

$$Y = T \times S \times C \times I$$

Where, *Y*- weed count in a month, *T*- trend, *S*- seasonal variation, *C*- cyclic variation and *I*- irregular variation.

Seasonality in weeds for each species was estimated as seasonal indices by the method of moving averages as given by Croxton *et al*. 1979. From the monthly weed count data from July 2008 to June 2013, 12 month moving averages were computed. This involves the computation of the arithmetic mean of the weed count of a species from July 2008 to June 2009, August 2008 to July 2009 and so on. These moving averages represent the combined effects of trend (*T*) and cyclic variation (*C*). The original weed count (*Y*) for each species was then expressed as percentage of the moving averages. These percentages include the seasonal and irregular variations.

$$\frac{\text{Seasonal variation (S)}}{\text{Irregular variation (I)}} = \frac{\text{Original weed count (Y)}}{\text{Trend (T) x Cyclic Variation(C)}} \text{ X } 100$$

Irregular variations were then eliminated by averaging the above percentages over the years 2008 to 2013, giving the seasonal variations. The seasonal variations thus obtained were converted to fractions to get the seasonal indices from January to December. Seasonal index expresses the seasonality of occurrence of a weed. The analysis was done using SPSS 17.

RESULTS AND DISCUSSION

During the beginning of the trial, 37 weed species were observed in the field. The species and their density varied with each sampling. This may be due to physiological factors like dormancy, depth at which the propagules are located, environmental conditions *etc*. However, every year maximum species diversity was observed in the field with the beginning of the South West monsoon which starts by early June. Nearly 25 weed species were found to germinate in the field during this period. After 60 months of study and 120 samplings the species which continued to germinate from the soil seed bank were *Hemidesmus indicus, Chromolaena odorata, Borreria latifolia, Phyllanthus niruri, Euphorbia hirta, Synedrella nodiflora, Mitracarpus villosus, Cyperus iria, Sida cordata, Pouzolzia zeylanica, Scoparia dulcis, Triumfetta indica, Axonopus compressus, Biophytum sensitivum, Elephantopus scaber, Ruellia prostrata, Commelina benghalensis, Stachytarpheta indica, Ischaemum indicum, Centrosema pubscens, Brachairia miliformis, Mimosa pudica, Curculigo orchioides* and *Desmodium gangeticum.*

The weed species that were most predominant in most of the sampling units and exhibited seasonality in its occurrence as per the data collected were selected for estimation of seasonal indices. The selected weed species for which seasonal indices were worked out are given in Table 1. A seasonal index value of more than one indicates the predominance of the weed in the particular month. Any value below one indicates low incidence of the weed. A zero value indicates complete absence of the species during the period.

Seasonality exhibited in the germination of weed species is given in Table 1. The presence of the weeds in the field may extend to a further period of two to three months depending on the duration of the species. *H. indicus* is a predominant summer weed. The weeds *S. nodiflora, B. latifolia, A. compressus and B. sensitivum* appear with the first showers in May. The pattern of weed seed germination from the soil seed bank is represented graphically (Fig. 1(a)).

H. indicus is a weed found to germinate throughout the year. The peak germination period of this weed is from November to March, since most of the other weed species do not germinate during this season, it is a predominant weed in upland ecosystem during summer. Both *Sida acuta* and *Synedrella nodiflora* are weeds which start germination from April - May with the receipt of summer showers in the state and continue up to November - December. However, the germination of *Sida acuta* is higher during the period from June- July to September - October. The germination peak of *Synedrella nodiflora* is during August- September and continues

Table 1. Seasonal indices of major weeds of coconut garden

Month	*H. indicus*	*S. acuta*	*S. nodiflora*	*B. latifolia*	*C. orchioides*	*A. compressus*	*B. sensitivum*	*M. pudica*	*D. gangeticum*
January	1.12	0.15	0.00	0.03	0.06	0.00	0.02	0.35	0.04
February	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00
March	1.70	0.00	0.00	0.00	0.00	0.00	0.12	0.07	0.48
April	1.25	0.24	0.00	0.37	0.51	0.00	0.37	0.32	0.35
May	0.38	0.25	1.87	1.98	0.93	2.50	1.13	0.26	1.36
June	0.32	0.98	1.23	1.39	1.03	3.17	0.94	0.67	6.10
July	0.99	3.04	2.51	3.94	4.84	3.60	2.65	1.55	2.17
August	0.74	2.50	2.76	0.75	1.41	1.49	2.88	1.96	0.73
September	0.40	1.36	1.72	0.87	0.71	0.81	1.38	2.58	0.37
October	0.53	2.58	1.24	0.96	1.22	0.21	1.48	2.11	0.00
November	1.37	0.72	0.67	1.62	1.20	0.21	0.76	1.82	0.39
December	1.48	0.17	0.00	0.09	0.08	0.00	0.26	0.17	0.00

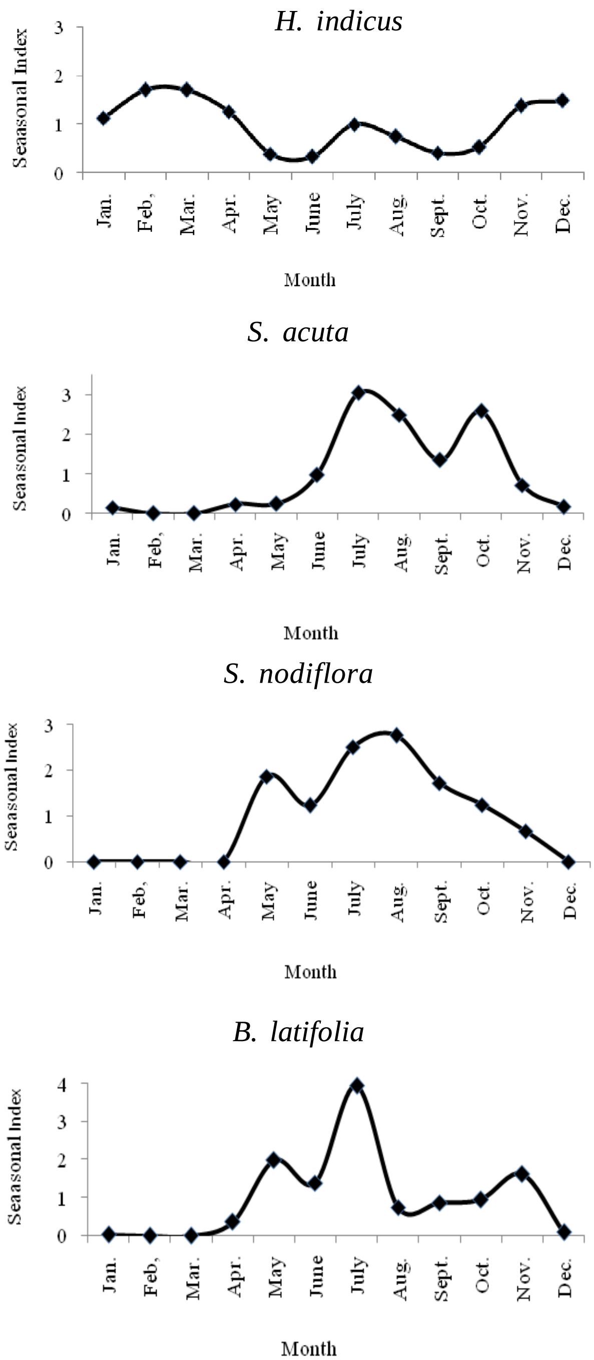

Fig. 1(a). Monthly pattern of emergence of *H. indicus, S. acuta, S. nodiflora* and *B. latifolia*

till November-December. It is one of the main weed species observed during the period from December to February in the state. The seasonality of germination of *Borreria latifolia* revealed that they germinate with the receipt of summer showers in March - April and reaches a peak by the advancement of the South - West monsoon season which starts from May - June in the state. By August, the population declines and a second flush of the weed are seen in September-October with the arrival of the North East monsoon.

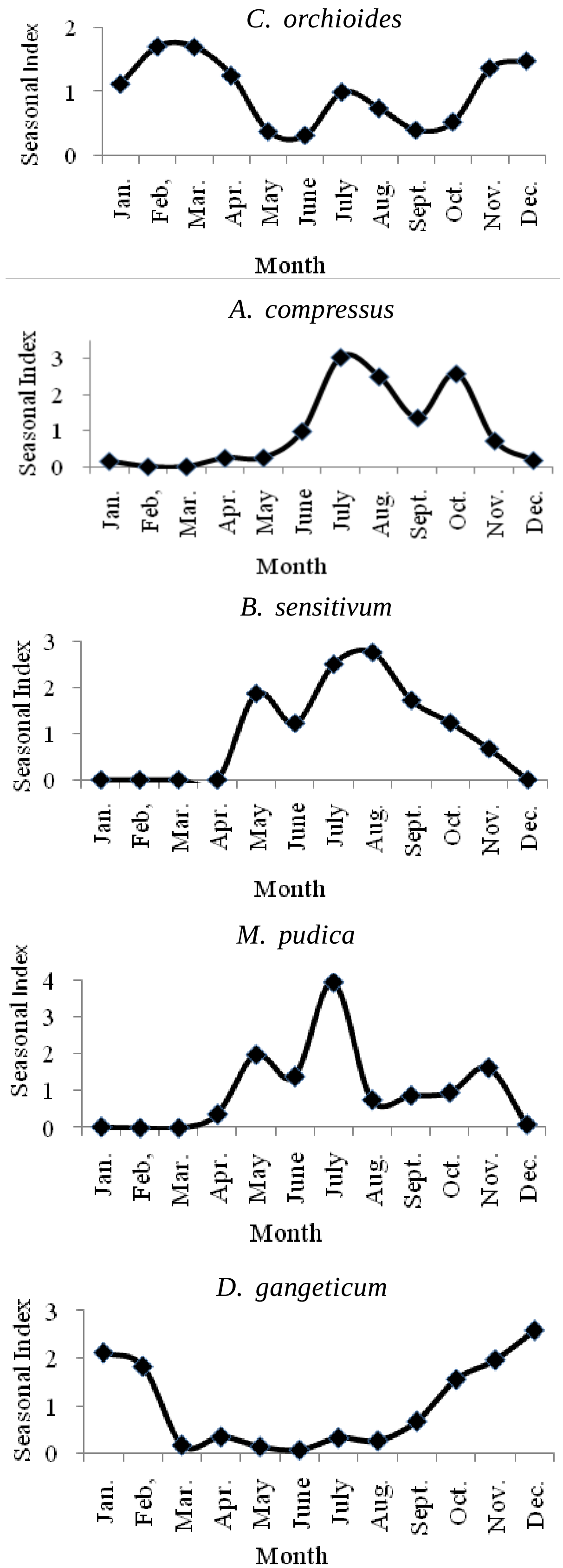

Fig. 1(b). Monthly pattern of emergence of *C. orchioides, A. compressus, B. sensitivum, M. pudica* and *D. gangeticum*

The germination of the weed continues till December after which there is a lull in its germination. However, the weed is observed in the field till February-March. The prevalence of the weed from October to January in Mangalore on sand dunes has been reported by Beena *et al.* 2001. Mangalore has a similar rainfall pattern and climate as Kerala.

The emergence of *C. orchioides* indicates that the weed germinates throughout the year with a lull during the peak summer months of March- April when the moisture availability in the soil is minimum. Though, the weed is seed propagated, the presence of underground tuber may encourage regrowth of shoot with moisture availability. *A. compressus* is a grass weed which germinates with the onset of the South West monsoon in June - July and continues till November with a second peak during the North East monsoon in September - October. The weed is rarely seen during summer. *B. sensitivum* starts germination with the receipt of the first rains in April - May and germinates throughout the rainy season in the state from June - July to October - November, and for the rest of period from December to March - April the weed is rarely seen in the field. *M. pudica* is similar to *B. sensitivum* in its germination pattern but the germinated plants remain in the field for longer time and are prevalent till February - March. However, during peak summer months of March - April the weed is seen only in irrigated situations. Flowering commences about 3 months after germination, and can occur throughout the year in tropical countries (Challa *et al.* 1991). *D. gangeticum* has a prostrate nature and it forms a cover on the soil. It starts germination only by September - October and continues to germinate throughout the summer months till March with minimum moisture availability in the soil.

The pattern of germination of the weeds from the soil seed bank indicated that *Axonopus*, *Biophytum* and *M. pudica* dominated during the South West monsoon season while *C. orchioides* and *D. gangeticum* were seen to germinate during the North East Monsoon period from September – October and are present in the field till the advent of summer season in the state. *H. indicus* and *M. pudica* are weed species seen throughout the year. However, their predominance in the field is between November to April and July to November, respectively (Fig. 1(b)).

Information on the emergence pattern of a weed species in an ecosystem is necessary for devising weed control operations for specific weed flora. Variable weed emergence patterns have many consequences for site-specific weed management. Understanding the causes of differential weed emergence permits more informed decisions, more timely operations, and better management. Seasonal index is a useful parameter to predict the seasonality of weed emergence.

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Molecular characterization and host range studies of indigenous fungus as prospective mycoherbicidal agent of water hyacinth

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ABSTRACT

An indigenous fungal culture, isolated from diseased water hyacinth, in Bolpur, Santiniketan, West Bengal, India, was found to be causing severe blight and dieback disease on water hyacinth, under laboratory and field conditions. It was subjected to morphological and molecular characterization by amplification of 18S RNA gene fragment from genomic DNA using 18S gene universal primers. Subsequently with sequencing, GenBank database comparisons and phylogenetic analysis, the fungus was determined as *Alternaria japonica* Yoshii. Further the pathogen was evaluated for its host specificity to be developed as mycoherbicidal agent against this invasive weed. Host range of *A. japonica* was screened against 48 plant species in 42 genera representing 22 families in pot experiment. Water hyacinth was the only species strongly susceptible to spore suspension (5×10^5 conidia/ml) of *A. japonica*. Minor infection was observed on goosefoot which is not only a weed but also ecologically separated from water hyacinth. Thus, the use of this pathogen in the biological control of water hyacinth would be safe for plants of economic and ecological significance in India. The secondary metabolite produced by *A. japonica* was sprayed on the test plants but phytotoxic symptoms were produced on nine out of 48 plants tested, demonstrating that phytotoxin produced by the fungus is not host specific. Further field tests needs to ascertain its efficacy under more natural conditions.

Key words: *Alternaria japonica*, Biological control, Host specificity, Mycoherbicide, Water hyacinth

Water hyacinth, *(Eichhornia crassipes)*, a native of the tropical South America, is considered to be one of the most serious aquatic weeds (Holms *et al.* 1977). It has spread throughout tropical countries causing widespread problems to millions of users of aquatic bodies and its resources causing severe problems related to its use and management (Gopal 1987). Water hyacinth invasiveness has led to a tremendous negative impact on the social and economic conditions of the aquatic ecosystem, causing a global annual loss of more than US$ 100 million to hydroelectricity generation, irrigation schemes, fisheries, water transport, etc (Shabana 2005).

Various control mechanisms including, manual, mechanical, chemical and biological methods, have been implemented for preventing the invasiveness, or eradication of, water hyacinth by various workers with mixed results (Julien and Orapa 2001, Ray *et al.* 2008). Environmental concerns over the use of chemical herbicides (Ray *et al.* 2008) have drawn interest in biological control of macrophyte. In its native land, water hyacinth is attacked by a large complex of natural enemies including several arthropod agents and fungi (Bennett and Zwölfer 1972, Ray and Hill 2013). But in its range of introduction, in absence of control agents, water hyacinth also flourishes majestically. The biological control agents have provided excellent control of water hyacinth in many locations around the world including India (Center 1994, Coetzee *et al.* 2011).

Biological control of weeds using insects and pathogens has gained considerable importance over last five decades as they are eco- friendly, host specific and effective means of weed control. Among various biological control agents, several phytopathogenic fungi have been found effective against the weed (Charudattan 2001). Various studies have been done to develop these fungi associated with the water hyacinth as potential mycoherbicides (Ray and Hill 2013).

During the present study, a number of indigenous pathogens were isolated from water hyacinth from selected regions of West Bengal (W.B.), India. Among these, a culture of *Alternaria* Nees. (WHK-12), isolated from diseased water hyacinth, in Bolpur, Santiniketan, was observed as a promising mycoherbicidal candidate for biological

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control of water hyacinth during previous studies (unpublished data). Mycoherbicidal potential of several other *Alternaria* species has been reported against water hyacinth from various parts of the world (Nag Raj and Ponnapa 1970, Shabana *et al.* 1997, Pathak and Kannan 2011). *Alternaria* species associated with the weed have also been known to cause severe blight followed by dieback disease to water hyacinth (Nag Raj and Ponnapa 1970, Ray and Hill 2012).

The next step after recovery and screening of potential biocontrol agents is its identification and host specificity test as there is always some risk involved in man's use of new substance or device, be it a drug, pesticide or an electronic device. The isolate was subjected to molecular characterization for identification up to species level. The host range testing schemes have been developed for assessing the safety of non-target plant species against the test pathogen (Wapshere 1974). Thus, an experiment was conducted to determine the host range of this test fungi (WHK-12) by observing the impact of its spore suspension and culture filtrate on 45 plant species in 42 genera representing 22 families.

MATERIALS AND METHODS

Isolation of fungus and culture preparation: The indigenous fungal strain was isolated and purified from the diseased leaves of water hyacinth collected from Bolpur, Santiniketan (Co-ordintes: 23.6700° N, 87.7200° E) in February 2014. The leaves showing disease symptoms were collected and put in large paper envelopes, brought to the laboratory for isolation of pathogens. Back at the laboratory, leaf pieces of about 2 mm^2 was cut from the margins of necrotic or chlorotic lesions on the surface. Pieces were then placed on earlier prepared petri-plates containing potato dextrose agar (PDA) medium and incubated for 3-4 days at 27^{o}C. The fungal species isolated earlier was purified by streak-plate and sub culturing techniques. It was carried out until fresh true monocultures of the fungus were obtained. It was further mass cultured in modified Richard's broth according to Ray (2006) for the present study. The spores were obtained from fungal mat while the toxic filtrate was obtained from the metabolized broth after 21 days of incubation.

Morphological identification of fungus: The fungal strain isolated from infected *E. crassipes*, was morphologically identified by slide culture technique with Lactophenol as mounting medium and observed under Zeiss Axio Scope.A1 Microscope for morphological identification of the genus.

Molecular identification: To confirm the species of the fungi, the isolate was molecularly characterized. Genomic DNA from the fungal isolate mat was extracted by using genomic DNA Isolation Kit (Xcelgen). The DNA stock sample was then quantified using Nanodrop spectrophotometer (Thermo Fisher Scientific NanoDrop™ 1000 spectrophotometer). Purity of DNA was judged on the basis of optical density ratio at 260:280 nm. Concentration of DNA was estimated using the formula.

Concentration of DNA (mg/ml) = OD 260 x 50 x Dilution factor

Agarose 0.8% (w/v) in 0.5X TAE (pH 8.0) buffer was used for submarine gel electrophoresis. Ethidium bromide (1%) was added at 10 µl /100ml. The wells were charged with 5µl of DNA preparations mixed with 1 µl gel loading dye. Electrophoresis was carried out at 80V for 30 min at room temperature. DNA was visualized under UV using UV transilluminator. The DNA concentration and integrity were checked by electrophoresis of the sample on 0.8% agarose gel containing ethidium bromide. After electrophoresis, the agarose gel was photo-documented. 18S RNA gene fragment was amplified from the genomic DNA by PCR (Eppendorf Thermal Cycler), using 18S gene universal primers: 1F and 4R. Details of 18S universal primer sequences were as follows: 1F (CTGGTGCCAGCAGCCGCGGYAA) and 4R (CKRAGGGCATYACWGACCTGTTAT).

Amplified PCR product was then purified using Xcelgen Gel extraction kit, to remove contaminants. To confirm the targeted PCR amplification, 5 µl of PCR product from each tube was mixed with 1 µl of 6X gel loading dye and electrophoresed on 1.2 % agarose gel containing ethidium bromide (1 % solution at 10 ìl/100 ml) at constant 5V/cm for 30 min in 0.5 X TAE buffer. The amplified product was visualized as a single compact band of expected size (Approx 850bp) under UV light and documented by gel documentation system (Biorad). The concentration of the purified DNA was determined and was subjected to automated DNA sequencing BDT v3.1 Cycle sequencing kit on ABI 3730xl Genetic Analyzer. Sequencing was carried out using BigDye® Terminator v3.1 Cycle sequencing kit. After cycling, the extension products were purified and mixed well in 10 µl of Hi-Di formamide. The contents were mixed on shaker for 30 minutes at 300xg. Eluted PCR products were placed in a sample plate and covered with the septa. Sample plate was heated at 95^{o}C for 5 min, snap chilled and loaded into autosampler of the instrument. Consensus sequence of 808 bp of 18S region was generated from forward and reverse sequence data using aligner software. The 18S region sequence generated was then used to carry out BLAST with the nr database of NCBI genbank database (http://www.ncbi.nlm.nih.gov; accessed: 17th Dec 2014). Based on maximum identity score, 15 sequences were selected for preparing the phylogenetic tree, constructed using MEGA 5.

The evolutionary history was inferred using the Neighbor-Joining method. The bootstrap consensus tree inferred from 1000 replicates was taken to represent the evolutionary history of the taxa analysed. Branches corresponding to partitions reproduced in less than 50% bootstrap replicates (BP) are collapsed. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (1000 replicates) are shown next to the branches. The evolutionary distances were computed using the Kimura 2-parameter method and are in the units of the number of base substitutions per site. The analysis involved 16 nucleotide sequences. Codon positions included were 1st+2nd+3rd+Noncoding. All ambiguous positions were removed for each sequence pair. There were a total of 806 positions in the final dataset. Evolutionary analyses were conducted in MEGA5.

Host range studies of test pathogen: The plant species included in the host-range test were selected on the basis of their economic or ecological importance and their relation to the test pathogen or the target plant, water hyacinth. All the test plants taken were at their seedling or early growth stage. They were usually collected from the field during local survey and grown in plastic tubs or cups. All the pots were filled with soil fertilized with farm yard manure and 15-3-12 N:P:K, slow-release fertilizer. The aquatic plants used in the test were grown in similar plastic pots filled with water. For experimentation, plants were kept in the growth chamber conditions at 26 ^{o}C temperature and 75 to 85% relative humidity in plastic pots filled with sterilized soil.

Preparation of spore suspension and phytotoxic culture filtrate: Mass cultivation of the test fungi (WHK-12) was done in modified Richard's broth in ten Erlenmeyer flasks of capacity 1000 ml, each containing 700 ml Richard's broth. These flasks were incubated at 30 ^{o}C in Biological Oxygen Demand (BOD) incubator for 21 days, under condition of 12 hours of alternate day and light. After twenty-one days of incubation, the fungal mat was separated from the liquid metabolized broth, for obtaining spores. The fungal mat was crushed in sterile distilled water and filtered to obtain the spore suspension. Spore suspension (5 x 10^5 spores /ml) was prepared in sterilized distilled water and 0.01% Tween-20 using haemocytometer the metabolized broth was first filtered through eight layers of cheese-cloth then through Whatman No. 1 filter paper to obtain crude culture filtrate to test the phytotoxicity of the secondary metabolite.

Host specificity testing: The test plants were inoculated at the same time during the evening with the spore suspension of the fungi (WHK-12) at concentration 5 x 10^5 spores /ml. They were sprayed until runoff with spore suspension using atomizer. They were covered with transparent polythene bags to create a dew effect for 24 hours and placed in growth racks at 27^{o} C and about 75 to 80% relative humidity. The control plants were sprayed with sterile distilled water and 0.01% tween-20. Another set of similar test plants were sprayed with culture filtrate of the pathogen. All the treatments were replicated thrice. Disease intensity and severity was rated by visual observation at an interval of 24 hours for 30 days. Disease intensity was determined visually on the basis of initiation of disease and increase in disease area seven days after application of the inocula.

RESULTS AND DISCUSSION

Identification and confirmation of species

Morphologically, under microscope, pale brown, simple or branched conidiophores with catenulate conidia at the apex were observed. Section *jponicae* usually contains short to long, simple or occasionally branched primary conidiophores with a single conidiogenous locus (Woudenberg *et al.* 2013). Apical secondary conidiophores were seen to be produced with a single conidiogenous locus. Conidia were porosporous, acropetally developed, dark brown, cylindrical or spindle-shaped, often with cylindrical beaks. Conidia were short, to long-ovoid with transverse and longitudinal septa, conspicuously constricted at most of the transverse septa, in short chains. The species within this section also occur on *Brassicaceae*. Thus the fungal isolate was previously linked to the *A. brassicicola* species-group (Pryor and Gilbertson, 2000, Pryor and Bigelow 2003, Lawrence *et al.* 2013). But this association on being questioned by Hong *et al.* (2005) was later clustered in section *Japonicae* (Woudenberg *et al.* 2013). Further 18S RNA gene fragment was used for characterization and was amplified by PCR from genomic DNA using

18**S** gene universal primers. A single discrete PCR amplicon band of 850 bp was observed when resolved on agarose gel (Fig. 1). Consensus sequence of 808 bp of 18S region was generated (Fig. 2) from forward and reverse sequence data using aligner software. It was then used to carry out BLAST with the nr database of NCBI gene bank database and based on maximum identity score, 15 sequences were selected (Table 1) for preparing the phylogenetic tree, constructed using MEGA 5 (Fig. 3).

The phylogenetic tree is broadly divided into two main clades. The first clade comprises of *Ulocladium botrytis* strain UPSC 3539, *Alternaria cheiranthi* EGS 41-188, *A. alternata* strain HA4087, *A. alternata* strain SRC1lrK2f, *A. maritima* strain CBS 126.60, *A. alternata* isolate AFTOL-ID 1610, *A. alternata* strain FC007, *A. alternata* ATCC 28329, *A. alternata* AA6 and *A. alternata* strain S-f6. While the second clade shows that the closest to our fungal isolate is *A. japonica* strain HDJZZWM- 06 (with 99% identity and 4 BP). Among the same clade the next close ones are *Pleospora herbarum* strain CBS 191.86, *P herbarum*, NS3/NS4 region, *P. herbarum* ATCC 11681 and *P. herbarum* DAOM 150679 respectively. This shows that genetically, *A. japonica* is more closely related to *Pleospora* spp., while among the first clade shows the strains of *A. alternata* and its relatedness with *U. botrytis*. After all these analysis, itt was thus confirmed that the fungal strain isolated, to be similar to *Alternaria japonica* strain HDJZ-ZWM-06 (GenBank Accession Number: GQ354822.1) based on nucleotide homology and phylogenetic analysis.

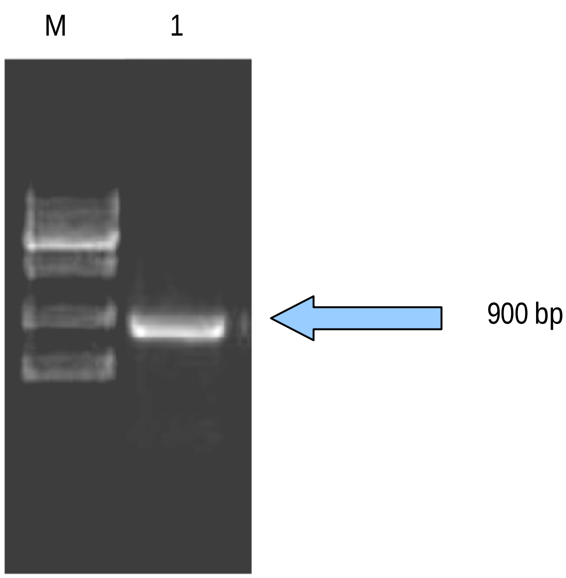

Fig. 1. 1.2% agarose gel image showing single 18S rDNA amplicon of 900 bp after purification by gel extraction. (Lane M: DNA marker (1kb ladder); Lane 1: 18S rDNA amplicon)

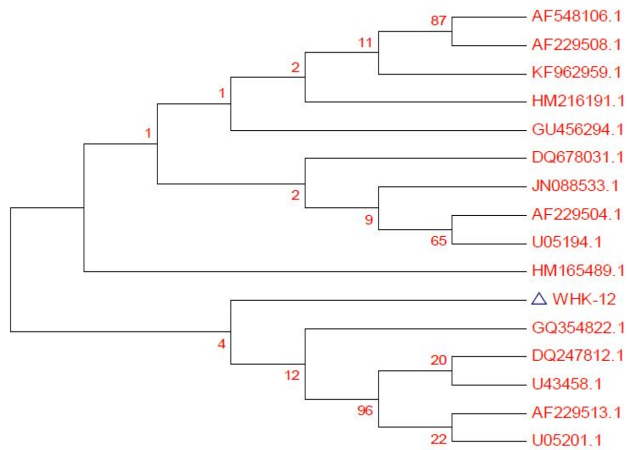

Fig. 3. Phylogenetic tree constructed from 15 closely related sequences, showing similarities between *Alternaria japonica* (WHK-12) and *A. japonica* strain HDJZ-ZWM-06 of Accession Number GQ354822.1. The tree was generated by using the Neighbor-Joining method using MEGA5.

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TAAAGTTGTTGCAGTTAAAAAGCTCGTAGTTGAAACTTGGGCCTGGCTGGCGGGTCCGCCTCACCGCGTGCACTC
GTCCGGCCGGGCCTTCCTTCTGAAGAACCTCATGCCCTTCACTGGGCGTGCTGGGGAATCAGGACTTTTACTTTG
AAAAAATTAGAGTGTTCAAAGCAGGCCTTTGCTCGAATACGTTAGCATGGAATAATAAAATAGGGCGTGCGTTTC
TATTTTGTTGGTTTCTAGAGACGCCGCAATGATTAACAGGAACAGTCGGGGGCATCAGTATTCAGTTGTCAGAGG
TGAAATTCTTGGATTTACTGAAGACTAACTACTGCGAAAGCATTTGCCAAGGATGTTTTCATTAATCAGTGAACG
AAAGTTAGGGGATCGAAGACGATCAGATACCGTCGTAGTCTTAACCGTAAACTATGCCGACTAGGGATCGGGCGA
TGTTCTTTTTCTGACTCGCTCGGCACCTTACGAGAAATCAAAGTTTTTGGGTTCTGGGGGGATTATGGTCGCAAG
GCTGAAACTTAAAGAAATTGACGGAAGGTCACCACCAGGCGTGGAGCCTGCGGCTTAATTTGACTCAACACGGGG
AAACTCACCAGGTCCAGATGAAATAAGGATTGACAGATTGAGAGCTCTTTCTTGATTTTTCAGGTGGTGGTGCAT
GGCCGTTCTTAGTTCGTGGGGTGACTTGTCTGCTTAATTGCGATAACGAGCGAGACCTTACTCTGCTAAATAGCC
AGGCTAACTTTGGTTGGTCGCCGGCTTCTTAGAGAGACTATCAACTCAAGTTGATGGA
```

Fig. 2. Consensus sequence of *Alternaria japonica* (WHK-12)

Table 1. Fifteen sequences with maximum identity score from BLAST report

Accession	Description	Max score	Total score	Query coverage	E value	Max ident
KF962959.1	*Alternaria alternata* strain HA4087	1493	1493	100%	0.0	99%
JN088533.1	*Alternaria alternata* strain FC007	1493	1493	100%	0.0	99%
HM165489.1	*Alternaria alternata* strain S-f6	1493	1493	100%	0.0	99%
GQ354822.1	*Alternaria japonica* strain HDJZ-ZWM-06	1493	1493	100%	0.0	99%
GU456294.1	*Alternaria maritima* strain CBS 126.60	1489	1489	100%	0.0	99%
DQ678031.1	*Alternaria alternata* isolate AFTOL-ID 1610	1489	1489	100%	0.0	99%
AF229504.1	*Alternaria alternata* ATCC 28329	1487	1487	100%	0.0	99%
U05194.1	*Alternaria alternata* AA6	1487	1487	100%	0.0	99%
HM216191.1	*Alternaria alternata* strain SRC1lrK2f	1483	1483	100%	0.0	99%
AF548106.1	*Ulocladium botrytis* strain UPSC 3539	1482	1482	100%	0.0	99%
DQ247812.1	*Pleospora herbarum* strain CBS 191.86	1476	1476	100%	0.0	99%
AF229513.1	*Pleospora herbarum* ATCC 11681	1476	1476	100%	0.0	99%
AF229508.1	*Alternaria cheiranthi* EGS 41-188	1476	1476	100%	0.0	99%
U43458.1	*Pleospora herbarum* NS3/NS4 region	1476	1476	100%	0.0	99%
U05201.1	*Pleospora herbarum* DAOM 150679	1476	1476	100%	0.0	99%

Table 2. Distance matrix of the 15 sequences with maximum identity score from BLAST report

WHK-12	1		0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.002
KF962959.1	2	0.000		0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.002
JN088533.1	3	0.000	0.000		0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.002
HM165489.1	4	0.000	0.000	0.000		0.000	0.000	0.000	0.001	0.001	0.000	0.002
GQ354822.1	5	0.000	0.000	0.000	0.000		0.000	0.000	0.001	0.001	0.000	0.002
GU456294.1	6	0.000	0.000	0.000	0.000	0.000		0.000	0.001	0.001	0.000	0.002
DQ678031.1	7	0.000	0.000	0.000	0.000	0.000	0.000		0.001	0.001	0.000	0.002
AF229504.1	8	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.000	0.001	0.002
U05194.1	9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000		0.001	0.002
HM216191.1	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001		0.002
AF548106.1	11	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.004	0.004	0.002	

Host range of the spore suspension

The present investigation indicates that the indigenous pathogen, A. *japonica* have significantly narrow host range (Table 3). *E. crassipes* and *Chenopodium album* L. (Chenopodiaceae) were the only compatible host plant of *A. japonica* as observed in these studies. None of the other plants were found susceptible to the fungal inoculum. *A. japonica* appears to be a promising biological control agent of water hyacinth. The spore suspension of *A. japonica* also caused appreciable disease on *C. album*. But this does not designate *A. japonica* as a threat as the susceptible plant itself is a noted weed and an ecological difference persists between the aquatic and the land weeds. *A. japonica* has been known to infest Brassicaceae plants including cole crops (Mamgain *et al.* 2013) and cause pod spot of radish (Scott *et al*. 2012). But during the present study none of the plants from Brassicaceae were affected by the pathogen. Thus mycoherbicidal management of water hyacinth seems to have a bright future using the indigenous culture of *A. japonica.*

Host range of the culture filtrate: The culture filtrate of *A. japonica* caused phytotoxic damage to 9 out of 48 plant species tested, *viz*. *Trianthema portulacastrum* L., *Amaranthus viridis* L., *Sinapis alba* L., *Chenopodium album* L., *Spinacia oleracea* L., *Ipomoea aquatic* Forsk, *Hydrilla verticillata* (L. f.) Royle, *Rumex obtusifolia* L., other than *E. crassipes*. Phytotoxic symptoms were produced on several of the plants tested, demonstrating that phytotoxin produced by *A. japonica* is although effective but not host specific. However looking into its damage potential against water hyacinth further intensive studies including proper knowledge of the toxic compounds produced by the fungus is essential. Further using biotechnological approaches (Miller *et al*. 1987) efforts can be directed towards limiting its host range.

Table 3. Host range testing of *A. japonica* on various crops and weed hosts

S.no.	Family	Common name	Vernacular name (in India)	Botanical name	Spore suspension (5×10^5 spores/ml)	Culture filtrate
1.	Aizoaceae	Horse-purslane	Pathar chata	*Trianthema portulacastrum* L.[c]	-	+
2.	Amaranthaceae	Alligator weed	Pani-khutura	*Alternanthera philoxeroides* (Mart.) Griseb. [b c]	-	-
3.		Sessile joyweed	Kantewali santhi	*Alternanthera sessilis* L. [c]	-	-
4.		Amaranth	Chaulai	*Amaranthus viridis* L. [a]	-	+
5.	Apiaceae	Asian pennywort	Brahmi	*Centella asiatica* L. [c]	-	-
6.	Araceae	Water lettuce	-	*Pistia stratiotes* L. [b c]	-	-
7.	Asteraceae	False oxtongue	Kukurbanda	*Blumea lacera* DC [c]	-	-
8.		Chickory	Kasani	*Cichorium intybus* L. [c]	-	-
9.		Parthenium	Gajar ghas	*Parthenium hysterophorus* L. [c]	-	-
10.		Perennial sowthistle	Bhatkataiya	*Sonchus arvensis* L. [c]	-	-
11.		Marigold	Genda	*Tagetes erecta* L. [a]	-	-
12.		Coat buttons	Phulani	*Tridax procumbens* L. [c]	-	-
13.	Brassicaceae[d]	Rai	Sarson	*Brassica campestris* L. *var sarson* [a]	-	-
14.		Radish	Mooli	*Raphanus sativus* L.	-	-
15.		Cauliflower	Phool gobhi	*B. oleracea* L. *var. botrytis* [a]	-	-
16.		Cabbage	Bandha gobhi	*B. oleracea* L. *var. capitata* [a]	-	-
17.		Wild mustard	Safed Rai	*Sinapis alba* L. [c]	-	+
18.	Chenopodiaceae	Goosefoot	Bathua	*Chenopodium album* L. [a c]	+	+
19.		Spinach	Palak	*Spinacia oleracea* L. [a]	-	+
20.	Commelinaceae	Tropical Spiderwort	Kanteri	*Commelina benghalensis* L. [c]	-	-
21.	Convolvulaceae	Bindweed	Hiran chara	*Convolvulus arvensis* L. [c]	-	-
22.		Morning glory	Beshram	*Ipomoea fistulosa* Mart. [c]	-	-
23.		Water spinach	Kalmi sag	*Ipomoea aquatic* Forsk[b c]	-	+
24.	Cyperaceae	Rice foot sedge	Galmotha	*Cyperus iria* L. [c]	-	-
25.	Euphorbiaceae	Asthma weed	Dudhi	*Euphorbia hirta* L. [c]	-	-
26.	Fabaceae					
27.		Gram	Chana	*Cicer arietinum* L. [a]	-	-
28.		Soybean	Soybean	*Glycine max* L. [a]	-	-
29.		Lentil	Masoor	*Lens esculenta* Moench [a]	-	-
30.		Medick	-	*Medicago polymorpha* L. [c]	-	-
31.		Pea	Matar	*Pisum sativum* L. [a]	-	-
32.		Egyptian clove	Barseem	*Trifolium alexandrium* L. [c]	-	-
33.		Mung bean	Moong	*Vigna radiata* L. [a]	-	-
34.	Gramineae	Para grass	-	*Brachiaria mutica* (Forsk.) Stapf. [c]	-	-
35.		Bermuda grass	Dubh	*Cynodon dactylon* L. [c]	-	-
36.		Paddy	Dhan	*Oryza sativa* L. [a]	-	-
37.		Wheat	Gehoon	*Triticum aestivum* L. [a]	-	-
38.		Maize, Corn	Bhutta, Makka	*Zea mays* L. [a]	-	-
39.	Hydrocharitaceae	Hydrilla	-	*Hydrilla verticillata* (L. f.) Royle [b c]	-	+
40.	Lamiaceae	Pignut	Wilayati tulsi	*Hyptis suaveolens* L. Point. [c]	-	-
41.	Lemnaceae	Common duckweed	-	*Lemna minor* L. [b c]	-	-
42.	Linaceae	Linseed	Alsi	*Linum usitatissimum* L. [a]	-	-
43.	Malvaceae	Common wire weed	Kareta	*Sida acuta* Burm. f. [c]	-	-
44.	Polygonaceae	Broad-leaved dock	Jungli palak	*Rumex obtusifolius* L. [c]	-	+
45.	Pontederiaceae	Water hyacinth	Jal kumbhi	*Eichhornia crassipes* (Mart.) Solms	+	+
46.	Solanaceae	Tomato	Tamaatar	*Lycopersicon esculentum* Mill. [a]	-	-
47.	*Verbenaceae*	Wild gooseberry	Pachkotta	*Physalis minima* L. [c]	-	-
		Lantana		*Lantana camara L.* [c]	-	-

[a] Cultivated plant, [b] Plant ecologically related to the test plant, [c] Weed, [d] Plant reported susceptible to cultivars of *A. japonica*, *Spore suspension was sprayed in water containing hydrilla while phytotoxicity was accessed by growing the hydrilla shoot in the culture filtrate., + damage caused, - no damage

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Impact of invasive weeds on soil attributes at invaded sites

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ABSTRACT

Impact on soil chemistry of *Calyptocarpus vialis* Less., (Straggler daisy), *Chromolaena odorata* (L.) King and Robinson (siam weed) and *Parthenium hysterophorus* L. (congress weed) invaded and uninvaded sites were studied during 2014-2015 in selected sites of GKVK, Bengaluru and Mysore district of Karnataka (India). Two soil cores (5 and 10 cm depth, litter discarded) were collected and subjected for analysis of pH, OC, available P K, Zn, Cu, Fe and Mn content. In *C. vialis*, siam weed and congress grass infested sites at surface soil (5 cm depth) and subsoil layer (10 cm depth) pH, C, P and K were less when compared to the uninvaded sites. Soil ions Zn, Cu, Fe and Mn in *C. vialis* and *C. odorata* invaded sites were more at 5 and 10 cm depth. Whereas in *P. hysterophorus* invaded soil, Cu, Fe ions were less at 5 and 10 cm depth and Zn was more at 5 cm and less at 10 cm depth. Mn ion was less at 5 and more at 10 cm depth. Phosphorus was less available at surface layer and more at subsoil layer in all the three weeds infested sites. Whereas, in the uninvaded sites, there was sufficient availability of P. The same is the case for K. Since the form and availability of P and K is highly pH dependant, the low pH had affected the solubility of P and K. A high variability in response to invasion was observed. Results reflected that soil chemistry was disturbed by the presence of *C. vialis, C. odorata* and *P. hysterophorus* to some extent with regard to soil pH, C, P and K contents at 5 and 10 cm depth and micronutrients Zn, Cu, Fe and Mn were increased only in the presence of *C. vialis* and *C. odorata.*

Key words: Invasive weeds, *Calyptocarpus vialis, Chromolaena odorata, Parthenium hysterophorus*

Alien plant invasions are a cause of intense and serious changes in ecosystems around the world (Vitousek 1990, Gusewell *et al.* 2006). But not all invading species are able to alter longer-scale processes. However, it is difficult to generalize about their effects on ecosystem properties, since these vary according to the traits of the invading species, and the properties of the invaded vegetation and habitat. Yet, knowing the inherent functional traits of an exotic invasive plant, could improve understanding of its invasion success and impact, since plant traits affect ecosystem properties such as through impact on indigenous species diversity, soil nutrient competition, loss of production of crops, altering forest fire cycles (Westoby and Wright 2006). The alien invasive species *Calyptocarpus vialis* (straggler daisy), *Chromolaena odorata* (siam weed) and *Parthenium hysterophorus* L. (congress grass) are capable of rapid colonization which are in general more likely to have negative impacts on biodiversity. Since these impacts result from differences in traits between the alien and native species, ultimately soil is the victim which undergoes changes in its constituents suffering severe loss of nutrients.

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C. vialis. has spread extensively in Bengaluru and Mysore districts within a short span of less than one decade. It can be rightly presumed that this invasive weed is going to replace the entire ground flora in a couple of years, unless curative steps are initiated (Rao and Sagar 2010). *C. odorata* and *P. hysterophorus* are the declared invasive alien weeds. Many reports from worldwide on impact of these two weeds on floristic changes, ecological integrity of native habitats, loss of crop yields, effect on forest fire cycles, effects on human and animals are available (Callaway and Ridenour 2004, Pimentel *et al.* 2005, Ortega and Pearson 2005, Rao and Sagar 2012, Kavitha *et al.* 2014,Sushilkumar 2014). Since the negative impact of weeds on soil constituents are seldom discussed, the present study was carried in the quest whether *C. vialis*, *C. odorata* and *P. hysterophorus* affect soil nutrients of the selected sites at different layers of soil?

MATERIALS AND METHODS

Survey of total 5 sites with semi-natural and homogenous vegetation were undertaken. Three sites were invaded by *C. vialis* selected from Botanical Garden, GKVK, Bengaluru and

Chromolaena odorata selected from 'Elachipalya grama' near 'Chennapatna' of Mysore district and *P. hysterophorus* was selected from 'Shambhu-devanapura' near 'Malavalli', Mysore District. Remaining two uninvaded sites were adjacent to the invaded sites although they contained native species. In invaded sites, vegetation structure is profoundly affected by invasion, *with C. vialis*, *C. odorata* and *P. hysterophorus* generally forming pure stands. The sites were having well-established and still expanding populations of test weeds surrounded by native uninvaded vegetation, they were having sufficiently homogeneous soil. The invasion of the weeds in all the sites dates back three decades.

At each site, three 1m^2 plots were marked in invaded patches and two 1m^2 plots were located in adjacent, uninvaded vegetation. The study was carried out from 2014 -2015. In each plot, two soil cores (5 and 10 cm depth, litter discarded) were collected with a soil borer (4 cm in diameter, one core at each corner of the square and one core at the centre of the square) in a zipper polythene bag.

Soil samples from different sites were collected in triplicates to assess the following parameters on each sample: soil pH, organic carbon (C), phosporous (P), potassium (K), magnesium (Mg), zinc (Zn), copper (Cu) and manganese (Mn). Soil analysis were done at the laboratory of Zuari Agro Chemicals Limited, Agricultural Development Laboratory, Puttenahalli, Yelahanka, Bengaluru.

Data collected were subjected to one way ANOVA using SPSS software. The treatment means were separated by using Duncan's multiple range test and least significant difference test (LSD) at P=0.005 probability level (Steel *et al*. 1996).

RESULTS AND DISCUSSION

Soil pH at 10 cm depth was less in *C. odrata* and *C. vialis* invaded sites compared to uninvaded site. Statistically soil pH of *C. vialis* and *C.odorata* invaded and uninvaded were significinantly different (P<0.05) unlike congress grass, where soil pH was almost same as uninvaded soil (Fig.1)

In the soil invaded by straggler daisy C percentage was less at 5 and 10 cm depth than uninvaded site. In *C. odorata* invaded soil, C percentage was more at 5 and equal at 10 cm depth, compared to uninvaded site, respectively. In *P. hysterophorus* invaded site, it was more at 5 cm depth and less at 10 cm depth compared to uninvaded soil. Soil C (%) under stands of *C. vialis*, *C. odorata* and *P. hysterophorus* were significantly different (P<0.05) when compared to uninvaded sites. (Fig. 2).

Phosphorous content in 5 cm depth soil was less and at 10 cm depth, it was almost equal and more in *C. vialis* and *C.odorata* invaded sites, respectively. In *P. hysterophorus* invaded site, P content was less at 5 cm and more at 10 cm depth. Values of P at subsoil layers in *C. odorata* and *P. hysterophorus* invaded sites were significantly different, whereas at surface layer, they formed group which implied that the P values were not significant at 5 cm depth (P>0.05) but *C. odorata* and *P. hysterophorus* were significantly different at 10 cm depth (P<0.05) (Fig. 3).

Potassium availability in 5 and 10 cm depth soil invaded by *C. vialis*, *C. odorata* and *P. hysterophorus* was less compared to uninvaded soils. (Fig.4).

Cu in *C. vialis* and *C. odorata* invaded sites was more at 5 and 10 cm depth and less in *P. hysterophorus* invaded site compared to uninvaded sites (Fig. 5). In *C. vialis* and *C. odorata* invaded sites available Zn was more at 5 and 10 cm depth compared to uninvaded soil. Whereas, in *P. hysterophorus* invaded soil, Zn was more at 5 cm and less at 10 cm depth soil compared to uninvaded soil (Fig. 6). Iron (Fe) in *C. vialis* and *C. odorata* invaded sites was more at 5 and 10 cm depth and less at 10 cm depth in *P. hysterophorus* invaded site. In uninvaded sites Fe was less (Fig.7). Mn in *C. vialis* and *C. odorata* invaded sites at 5 cm depth was more and at 10 cm depth was less. In uninvaded sites Mn content was less (Fig. 8). Impact of invasive plants depends on properties of invaded ecosystem, with site fertility being particularly important. Invasive plant species may increase or decrease nutrient composition in soil (Dassonville *et al*. 2008). At the same time nutrient enrichment has been found to promote plant invasions (Lake and Leishman 2004). In the present study, soil pH of *C. vialis*, siam weed and congress grass infested sites at surface layer (5 cm depth) and subsoil layer (10 cm depth) was less when compared to the uninvaded sites. This may be attributed to the acidic nature of the soil of invaded sites. Soil pH, C, P and K in *C. vialis* invaded site was less at 5 and 10 cm depth. *C. odorata* and *P. hysterophorus* invaded sites whereas in the availability of these nutrients was varying at 10 cm depth which could be attributed to higher concentration of organic matter in the upper layer than in the subsoil layer which in turn is the result of decomposition of more organic matter in the upper layer. The weeds had significant effect on soil nutrients (P<0.05). But, Zn, Cu, Fe and Mn were more in invaded sites by *C. vialis* and *C. odorata* at 5 and 10 cm depth. This indicates the presence of these two weeds have

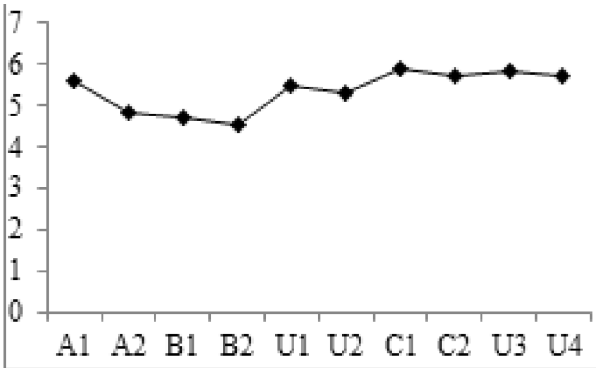

Fig. 1. pH

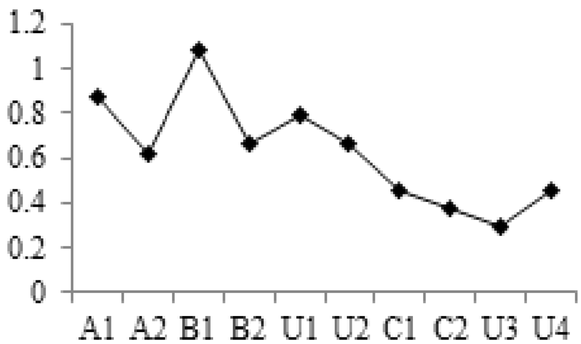

Fig. 2. Org.C %

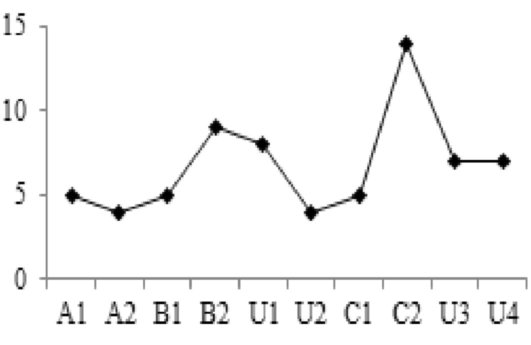

Fig. 3. Available P_2O_5 kg/acre

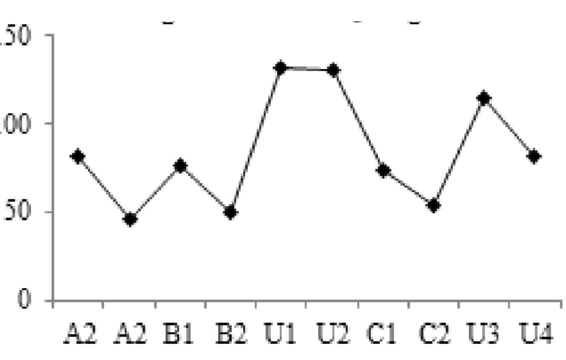

Fig. 4. Available K_2O kg/acre

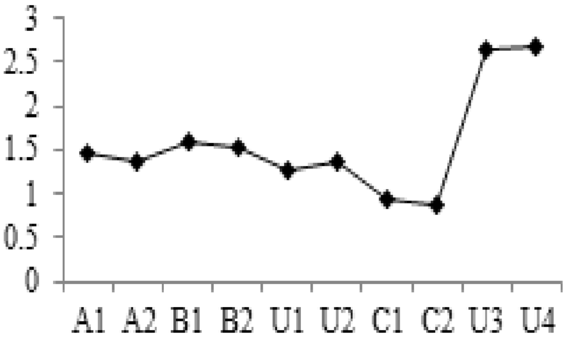

Fig. 5. Cu (ppm)

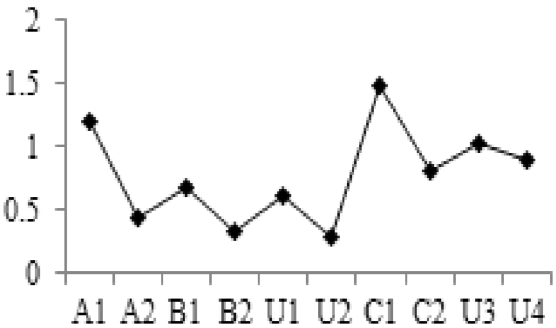

Fig. 6. Zn (ppm)

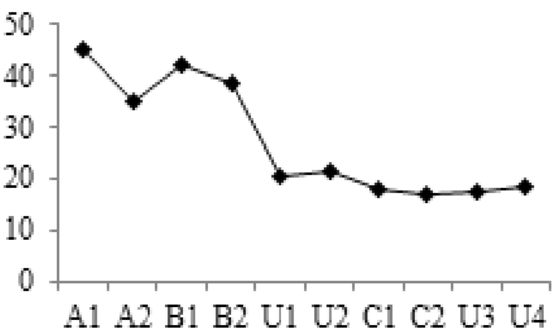

Fig. 7. Fe (ppm)

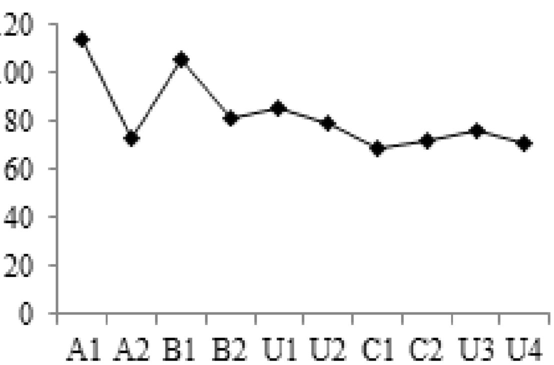

Fig. 8. Mn (ppm)

enriched the availability of ions. Whereas in *P. hysterophorus* invaded site, less availability of Cu, Fe and Mn at surface layer indicated the negative impact of the weed. Less availability of Zn, Cu and Mn at the sub soil (10 cm depth) may be due to soil compaction, reduced air and water circulation and reduced microbial activity. But, P ion was less at surface layer and more at subsoil layer in all the three weeds infested sites. Whereas, in the uninvaded sites available P was sufficient.

The present study revealed that surface layer lacks sufficient P, which supports only herbaceous plants for uptake of P but not shrubby plants. Since the soil is acidic, the cycling of organic matter is slower and ultimately has reduced its availability. Bhowmik *et al*. (2007) and Batish *et al*. (2002c) were of the opinion that in *Parthenium* invaded plots due to allelochemicals and residues from root exudates, the soil might become slightly acidic or neutral. Since the form and availability of P is highly pH dependant, the low pH has affected the solubility of P. The same was the case for K. Though the soil pH was slightly acidic in surface layer, yet all the three weeds have successfully thrived. It is known that acidic soil has less K, P and micronutrients, which are necessary for plant growth.

The test weeds survived and established by forming monocultures in such acidic soil. This implies that they can withstand decreased availability of organic contents and they have expressed high adaptability for acidic soil condition. Recent reviews have concluded that, on an average, alien invasive plants increase nutrient pools and luxes in invaded ecosystems. But, the relationship between soil nutrients and plant invasion is not found uniform. However, in the present study high variability in the response to invasion has been observed. Similar reports are available with (Ehrenfeld 2003, Liao *et al.* 2008). Batish *et al.* (2002c), Bhowmik *et al.* (2007), Manpreet Kaur *et al.* (2014) have found the changes in the above ground vegetation as well as in below ground soil nutrients in the invaded sites. The above interpretations reveal that *C. vialis, C. odorata* and *P. hysterophorous* have no difficulty for their establishment and colonizing in acidic soil. *C. vialis* being herbaceous weed, well utilized the available micronutrients in surface layer resulting in less availability of micronutrients. *C. odorata* and *P. hysterophorous* although being subshrubs, have acted equally in reducing the availability of micronutrients in both surface and sub soil layers of soils.

In recent report, *C. odorata* and *P. hysterophorous* have replaced many native flora and medicinally important plants in Mysore district (Kavitha *et al.* 2014). This effect may be due to synergistic adverse impact of allelochemicals on metabolic, biochemical and enzymological processes of the associated native flora. Furthermore, the changes in vegetation and soil nutrients could lead to ultimate changes in other trophic levels and alter the function of the ecosystem. Over all, it can be said that soil chemistry was disturbed by the presence of *C. vialis, C. odorata* and *P. hysterophorus* to some extent with regard to soil pH, C, P and K contents at 5 and 10 cm depth and micronutrients Zn, Cu, Fe and Mn were increased only in the presence of *C. vialis* and *C. odorata*. Whereas, in the presence of *P. hysterophorus*, these micronutrients were reduced. Varying effects were exhibited by all the three weeds in increasing/decreasing the soil attributes at both the soil layers. However, this conclusion should be tested in edaphic contexts, using much older invading sites. This was beyond the scope of this paper. However, this report provides some clues to mechanisms of the reduction of soil nutrient at surface and subsoil layers by these alien weeds. Therefore, a better understanding of the mechanisms occurring between weeds and soil communities is needed, through which strategies can be developed for reducing direct and indirect negative impacts on soil quality. Simultaneously, research on understanding potential benefits that these invasive alien weeds may provide to either cropping systems or native flora, if carried out, in a way that are beneficial to soil quality and enhanced crop yields.

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Effect of long-term application of herbicides on soil microbial demography in rice-wheat cropping sequence

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ABSTRACT

Increasing reliance of present day intensive agriculture on herbicide use has led to certain concerns about their eco-toxicological effects influencing various microbial populations and associated enzymatic activities, which may serve as indicators of soil quality. The effect of herbicides (cyhalofop butyl, isoproturon, butachlor and clodinafop) on soil microbial population of beneficial and other organisms was assessed over a period after 13 years in a *Rabi* and *Kharif* season. In the present study, herbicide application resulted in transient suppression of population of beneficial microorganisms including fungi. The microbial population regained its number by the time of harvesting of crops

Key words: Beneficial microorganisms, Fungi, Herbicides, Microbial population

Soil health with special reference to biological features maintaining functions of both natural and managed ecosystems, is essential for sustainable agricultural fertility and productivity (Enriqueta-Arias *et al*. 2005). In modern day agriculture, the use of herbicides for combating weeds in crop fields has been increasing steadily. Herbicides form a principal component of weed management in crops and cropping systems in many industrialized and developed countries. These are applied to improve crop yield and quality, and to maximize economic returns. Herbicides are bioactive, toxic substances if applied non-judiciously, which directly or indirectly inûuence soil productivity as well as agro-ecosystem quality such as residual toxicity, health hazards and mammalian toxicity.

During application of herbicides, a large portion of these chemicals accumulate in the top soil layer (0–15 cm), where most of the microbiological activities occur (Alexander 1978). As microorganisms are scavengers in soil and possess physiological variability, they degrade a great variety of chemical substances including the incorporated herbicides in soil (Das and Debnath 2006). Most of the studies till date have been focused on single application for a shorter period or in a single season which may sometimes provide a realistic evaluation of the effects of herbicides on soil microorganisms (Haney *et al.* 2000) but the knowledge about the effect of herbicides on soil enzymatic activities and microbial population over long-term applications has been limited. Therefore, the present study was designed to elucidate the effects of herbicides on soil microbial population after 13 years. This may help to provide a better understanding of the possible responses of soil microorganisms when exposed to different herbicides.

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MATERIALS AND METHODS

A long-term experiment on effect of continuous and rotational use of herbicides in transplanted rice-wheat rotation under All India Coordinated Research Project on Weed Control (AICRP-WC) was initiated in 1999 in Agronomy department, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalay, Palampur. Geographically, the AICRP-WC centre is situated at 32^{o}62 N latitude and 76^{o}32 E longitude at an elevation of 1290.8 meters above mean sea level. This area represents mid hill sub-humid climatic zone of Himachal Pradesh. The mean annual rainfall of about of about 2347.4 mm was received during the last five years at Palampur with the period of June to September being the wettest months of the year.

The soil of the site was clay-loam to silty-clay-loam in texture and taxonomically classified as Alfisols. The surface soil (0-15cm) had a pH range from 5.2 to 6.0 with a medium to high status of organic carbon. The soils were medium in available N and P and high in available potassium content. The studies on effect of herbicide application on soil micro flora and soil activity was assessed after 13 years of cropping in terms of microbial population.

Table 1. Treatment details of experimental long-term effect of continuous and rotational use of herbicides in rice-wheat rotation

Treatment	Rice	Wheat
T1-	Farmer's practice	Farmer's practice
T2-	Butachlor 1.5 kg *fb* 2,4-DEE 1.0 kg/ha (100% N through urea)	Isoproturon 1.0 kg + 2,4-D 0.75 kg/ha
T3-	Butachlor 1.5 kg *fb* 2,4-DEE 1.0 kg/ha (100% N through urea)	Clodinafop 75 g *fb* 2,4-D 0.75 kg/ha soproturon* 1.0 kg + 2,4-D 0.75kg/ha
T4-	Butachlor 1.5 kg *fb* 2,4-DEE 1.0 kg/ha (75% N through urea and 25% N through *Lantana*)	Isoproturon 1.0 kg + 2,4-D 0.75 kg/ha
T5-	Butachlor 1.5 kg *fb* 2,4-DEE 1.0 kg/ha (75% N through urea and 25% N through *Lantana*)	Clodinafop 75 g + 2,4-D 0.75 kg/ha soproturon* 1.0 kg + 2,4-D 0.75 kg/ha
T6-	Cyhalofop-butyl 90 g *fb* 2,4-DEE 1.0 kg, butachlor* 1.5 kg *fb* 2,4-DEE 1.0 kg/ha (100% N through urea)	Isoproturon 1.0 kg + 2,4-D 0.75 kg/ha
T7-	Cyhalofop-butyl 90 g *fb* 2,4-DEE 1.0 kg/ha, butachlor* 1.5 kg *fb* 2,4-DEE 1.0 kg/ha (100% N through urea)	Clodinafop 75 g *fb* 2,4-D 0.75 kg/ha Isoproturon* 1.0 kg + 2,4-D 0.75 kg/ha
T8-	Cyhalofop-butyl 90 g *fb* 2,4-DEE 1.0 kg, butachlor* 1.5 kg *fb* 2,4-DEE 1.0 kg (75% N through urea + 25% N through *Lantana*	Isoproturon 1.0 kg + 2,4-D 0.75 kg/ha
T9-	Cyhalofop-butyl 90 g *fb* 2,4-DEE 1.0 kg, butachlor* 1.5 kg *fb* 2,4-DEE 1.0 kg/ha (75% N through urea + 25% N through *Lantana*)	Clodinafop 75 g *fb* 2,4-D 0.75 kg/ha Isoproturon* 1.0 kg + 2,4-D 0.75 kg/ha

*Herbicides used in rotation

The experiment was initiated in the 1999 with nine treatments (Table 1) replicated three times in randomized block design. The rice and wheat crops grown in year 2012-13 were studied for herbicidal effects on soil microflora population.

Soil samples were collected (0-15 cm depth) from experimental field during wheat crop (2012-13) and rice crop (2013) to assess the total bacterial, fungi and free-living diazotroph populations using serial dilution technique (Agrawal and Hasija 1986). and pour-plate method. After appropriate incubation period, the colonies of microorganisms appearing on plates were counted following standard method (Pramer and Schmidt 1964). Nutrient agar medium (Johnson and Curl 1972) was used for total 2 bacterial count, Pikovskya's medium for phosphate solublising microorganism count, potato dextrose agar medium for fungi and Jensen's N free medium (Jensen 1951) was used for free living diazotrophs count (Wollum 1982).

The population count of microbes namely, bacteria, fungi, *Azotobacter* and phosphorus solubilising micro-organisms was analyzed to evaluate the effect of herbicides on their respective populations by plating soil dilutions. The counts were taken after an incubation period of 48 hours for bacteria, 48–72 hours for fungi, 96 hours for PSM, and one week for *Azotobacter*. The total count of the microorganisms was obtained by multiplying the number of cells per plate by the dilution factor, which was the reciprocal of the dilution.

RESULTS AND DISCUSSION

The effect of herbicides on soil microflora and other soil parameters in the long-term study on effect of continuous and rotational use of herbicides on shift in weed flora in transplanted rice-wheat rotation was analysed at different intervals from 2012-13 in rice-wheat crops. It was revealed that due to the impact of herbicide application, the population of microorganisms was not significantly influenced (Table 2). The herbicide application in wheat crop resulted in lower microbial population in herbicide treated treatments as compared to control. A population reduction of 55.0% of *Azotobacter* was recorded in clodinafop 75 g *fb* 2,4-D 0.75 kg/ha, isoproturon 1.0 kg + 2,4-D 0.75 kg treatment applied at 30 DAS. The population of Phosphate solublising microorganisms reduced to 62.7% on treatment of clodinafop 75 g + 2,4-D 0.75 kg isoproturon 1.0 kg + 2,4-D 0.75 kg/ha. Maximum bacterial reduction (52.1%) was observed with the application of clodinafop 75 g *fb* 2,4-D 0.75 kg isoproturon 1.0 kg + 2,4-D 0.75 kg/ha. Fungal population was not much influenced by application of herbicides and a maximum reduction (17.5%) was observed with the application of clodinafop 75 g/ha fb 2,4-D 0.75 kg, isoproturon* 1.0 kg + 2,4-D 0.75 kg/ha.

The population of total beneficial microorganism *i.e. Azotobacter* and phosphate solublising microorganism and bacterial population was also not influenced significantly in various treatments upon the application of continuous and rotational use of the herbicides in rice (Table 3). The population of

Table 2. Long term effect of continuous use of herbicides on soil microflora in wheat crop

Treatment	*Azotobacter* (×10^4 cfu/g dry soil wt.) *(142.46 ×10^4 cfu/g dry soil wt.)			Phosphate solublising microorganisms (×10^4 cfu/g dry soil wt.) *(87.28 ×10^4 cfu/g dry soil wt.)			Total bacterial population (×10^6cfu/g dry soil wt.) *(77.56 ×10^6 cfu/g dry soil wt.)			Total fungal population (×10^4 cfu/g dry soil wt.) *(66.77 ×10^4 cfu/g dry soil wt.)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T1	101.0	122.6	128.6	47.2	57.0	64.5	43.3	55.2	62.2	58.8	59.6	62.0
T2	80.3	86.5	89.2	34.7	37.9	41.8	39.9	54.6	66.2	60.3	62.2	64.3
T3	66.3	85.6	91.4	38.9	40.3	48.2	40.4	53.1	58.5	55.0	58.6	60.7
T4	76.8	82.5	84.1	33.5	37.8	41.4	42.0	54.2	60.9	60.4	62.5	64.9
T5	65.1	79.1	82.1	32.5	38.5	40.5	42.1	50.1	57.3	56.2	58.3	60.6
T6	77.2	79.3	81.2	34.3	38.6	40.8	40.8	51.5	60.8	62.2	64.8	65.5
T7	67.8	79.0	86.8	36.1	41.4	44.3	37.1	47.8	52.2	59.3	63.5	65.3
T8	68.5	70.6	73.3	33.7	38.2	41.3	44.0	54.9	63.5	58.4	62.1	63.1
T9	64.1	77.6	82.9	32.9	36.6	39.3	39.9	50.3	51.9	59.1	60.7	62.3
LSD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Initial population of microorganisms before herbicide treatment

Table 3. Long term effect of continuous use of herbicides on soil microflora in rice crop

Treatment	*Azotobacter* (×10^4 cfu/g dsw.) *(94.56 ×10^4 cfu/g dsw.)			Phosphate solubilising microorganisms (×10^4 cfu/g dsw) *(84.27 ×10^4cfu/g dsw)			Total bacterial population (×10^6 cfu/g dsw.) (121.28 ×10^6 cfu/g dsw)			Total fungal population (×10^4 cfu/g dsw.) *(46.42 ×10^4 cfu/g dsw)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T1	54.6	68.9	80.3	42.1	50.5	57.5	65.5	78.5	93.2	38.2	40.5	44.3
T2	45.1	54.5	66.5	35.8	39.5	43.9	52.2	61.8	70.4	35.5	35.0	37.3
T3	43.5	48.2	50.5	30.5	35.5	41.1	47.9	56.4	71.1	34.1	33.7	37.9
T4	45.9	55.7	60.1	22.6	25.9	29.8	55.6	68.4	84.1	34.0	37.1	39.9
T5	43.8	53.0	61.9	21.2	26.4	33.9	55.0	67.8	77.3	31.8	32.9	38.2
T6	47.9	55.1	60.2	25.3	31.4	37.1	51.6	58.5	70.6	32.7	34.6	35.9
T7	54.1	60.8	68.4	23.8	28.2	33.9	51.4	58.3	67.7	32.2	34.9	35.8
T8	48.5	55.2	60.2	24.9	29.6	34.5	56.8	69.1	77.3	32.4	33.7	36.0
T9	42.9	48.2	52.7	21.7	26.9	32.1	55.8	66.7	78.0	30.9	32.5	36.7
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*Initial population of microorganisms before herbicide treatment

Azotobacter reduced upto 54.6% after 30 DAS while the population of PSM reduced up to 74.24% and the population reduction of bacteria was observed to be up to 60.5%. Minimum reduction in fungal population was observed as 33.4%. Balasubramanian and Sankaran (2001) also reported initial suppression of soil microflora on herbicide application in different soils. The toxic effect of herbicides normally appear immediately after the application when their concentration in soil is highest. Later on, microorganisms take part in degradation process and herbicide concentration in soil and their toxic effects decrease (Radivojevic *et al*. 2004). The herbicides and their different concentrations affected fungal population but no significant differences were observed on population count at different days after herbicide application both in wheat and rice cropping seasons. No significant interaction effects were observed for the fungal population. The control plots showed highest population of fungi in both the crops. Deshmukh and Srikhande (1974) observed that 2,4-DEE at field application rate did not exert any effect on bacteria, fungi, actinomycetes 40 days after application. Similar effects were also observed in the herbicide treatments in both wheat and rice cropping system in the present experiment wherein the microbial population, 30 days after sowing and immediately after herbicide application, were numerically different compared to control treatment. As it was observed in the current study, herbicides in the soil showed temporary inhibition of *Azotobacter* and Phosphate solublising microorganism as well as bacterial population within the early period of application of herbicides followed by a recovery during the later period in rice and wheat. However, the population of fungi was not much influenced

It can be concluded from the present study that on herbicide application, a temporary suppression in population of beneficial microorganisms occur, but with the passage of time the population again recovers. The decline in inhibition at later stages can be attributed to decrease in herbicide activity in soil due to adsorption and microbial degradation (Saksena and Singh 1984). Microbial adaptation to these chemicals/herbicides or due to their degradation (Latha and Gopal 2010) may also be a possible reason. Besides, it can also be due to microbial multiplication on increased supply of nutrients.

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Short communication

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Weed dynamics and yield of groundnut as influenced by varieties and plant population

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Maintenance of optimum plant population with suitable variety not only reduces weed growth, but also realizes higher yield. Short statured plants with wider plant spacing encourage weed growth in groundnut and *vice versa*. Therefore, the present investigation was carried out to study the influence of varieties and plant populations in early *Kharif* groundnut on weed growth.

A field experiment was conducted during early *Kharif* 2013, in sandy-loam soil of wetland farm of Sri Venkateswara Agricultural College, Tirupati, Andhra Pradesh. The experiment was laid out in a factorial randomized block design and replicated thrice.Four groundnut varieties, *viz. 'Abhaya', 'TAG-24,' 'Dharani'* and *'Kadiri-6'* and four plant populations, *viz*. 3.33, 4.44, 5.00 and 0.67 million/ha were used to study the weed suppressing ability of different varieties at varied plant populations. The soil was low in available nitrogen (225 kg/ha) and phosphorous (23.7 kg/ha); and medium in potassium (264 kg/ha) and low in organic carbon (0.18%). The sowing of groundnut varieties was done on 13 May, 2013. A uniform dose of 20 kg N, 40 kg P_2O_5 and 50 kg K_2O per hectare was applied through urea, single super phosphate and muriate of potash, respectively to all the plots as basal dose. The remaining 10 kg of N was applied as top dressing in the form of urea at 30 DAS. Gypsum was applied in pod zone at 500 kg/ha at 40 DAS to avoid pops. The rest of the package of practices were adopted as per recommendations of the University.

The varieties *'TAG-24,' 'Kadiri-6'* and *'Dharani'* were harvested on 30 August, 2013 and the variety *'Abhaya'* was harvested on 1 September, 2013. The unweeded check plots were also maintained separately for all four varieties at recommended plant population of 0.33 m/ha to observe weed growth and yield. These plots were allowed to remain infested with weeds till harvesting of the crop. Density and dry weight of grasses, sedges and broad-leaved weeds were recorded in the experimental plots and unweeded check plots at the time of harvest. Density and dry weight of weeds were transformed to square root ($\sqrt{X + 0.5}$) transformation to normalize their distribution. The number of filled pods/plant, pod and haulm yields of groundnut were recorded at harvest.

The major weed species that were found in the experimental plots were *Cyperus rotundus* L., among sedges, *Digitaria sanguinalis* L. Scop. among grasses and *Boerhavia erecta* L., *Cleome viscosa* L., *Celosia argentea* L., *Commelina benghalensis* L., *Digera arvensis* L., *Eclipta alba* L. Hassk. and *Trichodesma indicum* R.Br. among broad-leaved weeds.

Effect of varieties and plant population on weed growth

The groundnut cultivars significantly influenced the density and dry weight of weeds associated with the crop. The lowest density and dry weight of all the categories of weeds were significantly lower with groundnut cultivar *'Kadiri-6'* due to its better ground coverage. This cultivar has long statured growth habit with dense foliage which may have suppressed weed growth. The highest density and dry weight of all categories of weeds were associated with groundnut cultivar *'TAG-24*,' due to its short stature that would have resulted in lesser competitive ability allowing more number of weeds to establish. (Table 1). Among the unweeded check plots maintained separately for all the four varieties at recommended plant population of 0.33 m/ha (30 x 10 cm), the groundnut cultivar *'Kadiri-6'* recorded the lowest weed dry weight of 136 g/m^2 followed by *'Abhaya', 'Dharani'* and *'TAG-24'* with 225, 236 and 292 g/m^2, respectively.

The lowest density and dry weight of all the categories of weeds was obtained with the maintenance of plant population of 0.67 m/ha, which was comparable to 0.5 m/ha during early *Kharif*, irrespective of the varieties studied. This might be due to lack of sufficient solar light for germination of

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weed seeds at higher plant populations leading to reduced density and dry weight of the weeds. On the other hand, highest density and dry weight of weeds was obtained with the plant population of 0.33 k m/ ha because of the availability of adequate growth resources and solar light to weeds. The above results are similar with the findings of Senthil Kumar (2009).

Effect of varieties and plant populations on yield and economics

Among the varieties, dry matter production was significantly higher with '*Kadiri-6'* followed by '*Dharani'* and '*Abhaya'* due to better competitive ability of these varieties with weeds that would have suppressed weed growth more efficiently. The highest pod yield was obtained with variety '*Dharani*' which was significantly higher than rest of the varieties due to better partitioning efficiency of photosynthates to pods and weed smothering efficiency which led to increased number of filled pods/plant. The lowest pod yield was registered with '*Abhaya'* due to lower number of filled pods/plant compared to rest of the varieties. The highest haulm yield was obtained with '*Kadiri-6*' due to its long statured growth habit and dense foliage. These findings were in accordance with Soumya *et al.* (2013).

The highest pod yield was obtained with the plant population of 0.50 m/ha followed by 0.33 m/ha with a significant disparity between them. This might be due to maintenance of optimum plant population that led to reduced weed growth which in turn increased the filled pods/plant. The increase in pod yield with plant population of 0.50 m/ha was up to 14.0% as compared to 0.60 m/ha. The highest haulm yield was recorded with plant population of 0.67 m/ha due to maintenance of higher plants/unit area which in turn increased the production of higher dry matter production. The pod yield obtained in unweeded check plots recorded 815, 562, 408 and 313 kg/ha in '*Kadiri-6*,' '*Abhaya,*' '*Dharani'* and '*TAG-24*,' respectively. This clearly indicated that '*Kadiri-6'* recorded higher pod yield than rest of the varieties under unweeded conditions. This might be due to good weed smothering efficiency. The pod yield was significantly lower with '*TAG-24'* in unweeded check. This might be due to its short statured growth habit. The haulm yield in the unweeded check plots followed exactly similar trend with different magnitude as that of the pod yield. The highest benefit-cost ratio was obtained with '*Dharani'*, where as the lowest with '*Abhaya'* due to variation in pod yield. The highest benefit-cost ratio was obtained with plant population of 0.33 m/ha due to reduced seed cost and increased pod yield.

Thus**,** it was concluded that the highest weed suppressing ability was observed with '*Kadiri-6*' as compared to rest of the varieties, however, it recorded lower pod yield. The highestad yield was recorded with groundnut variety '*Dharani'*. The

Table 1. Density and dry matter of weeds, yield and benefit-cost ratio as influenced by varieties and plant populations during *Kharif* groundnut

Treatment	Weed density (no./m^2)				Weed dry weigh (g/m^2)				Dry matter production (t/ha)	Number of filled pods/plant	Pod yield (t/ha)	Haulm yield (t/ha)	Benefit-Cost ratio
	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total					
Varieties													
'Abhaya'	3.34	4.42	3.46	6.45	1.80	2.31	1.86	3.31	7.57	17.8	1.99	5.27	2.07
	(10.6)	(19.0)	(11.5)	(41.2)	(2.7)	(4.8)	(2.9)	(10.5)					
'TAG-24'	4.69	6.65	4.51	9.18	2.49	3.42	2.40	4.75	7.46	26.8	2.86	3.82	2.96
	(21.5)	(42.5)	(19.9)	(83.9)	(5.7)	(11.2)	(5.3)	(22.2)					
'Dharani'	3.64	4.22	3.7	6.61	1.97	2.25	1.99	3.44	7.68	28.8	3.45	5.61	3.22
	(12.7)	(17.3)	(13.2)	(43.2)	(3.4)	(4.6)	(3.5)	(11.4)					
'Kadiri-6'	3.01	3.04	2.37	4.78	1.57	1.58	1.37	2.41	7.95	18.4	2.34	6.15	2.38
	(8.6)	(8.7)	(5.1)	(22.4)	(2.0)	(2.0)	(1.4)	(5.3)					
LSD (P=0.05)	0.465	0.54	0.464	0.496	0.224	0.260	0.214	0.263	0.07	1.20	0.08	0.297	0.081
Plant Population (m/ha)													
0.33 (30 x 10 cm)	4.08	5.86	4.38	8.31	2.11	2.96	2.24	4.14	5.90	27.8	2.75	4.37	3.11
	(16.1)	(33.8)	(18.7)	(68.6)	(3.9)	(8.3)	(4.5)	(16.7)					
0.44 (30 x 7.5 cm)	3.66	4.70	3.93	7.06	2.01	2.54	2.14	3.52	7.39	24.2	2.63	4.78	2.69
	(12.9)	(21.6)	(14.9)	(49.4)	(3.5)	(5.9)	(4.1)	(11.9)					
0.50 (20 x 10 cm)	3.63	4.06	3.04	6.15	1.90	2.10	1.68	3.13	7.81	21.6	2.83	5.44	2.75
	(12.8)	(15.9)	(8.7)	(37.4)	(3.1)	(3.9)	(2.3)	(9.3)					
0.67 (2 0x 7.5 cm)	3.23	3.64	2.69	5.46	1.81	1.97	1.55	2.92	9.54	18.4	2.43	6.26	2.09
	(9.9)	(12.7)	(6.73)	(29.4)	(2.8)	(3.4)	(1.9)	(8.0)					
LSD (P=0.05)	0.465	0.54	0.464	0.496	0.224	0.260	0.214	0.263	0.07	1.20	0.81	0.30	0.081

lowest weed density and dry weight were obtained with the maintenance of plant population of 0.66 m/ha while the highest pod yield was obtained with 0.50 m/ ha in early *Kharif*.

SUMMARY

Groundnut (*Arachis hypogaea* L.) is cultivated in diverse agro-climatic environments characterized by spatial and temporal variation in rainfall, temperature and soils of varying water holding capacity under rainfed as well as irrigated conditions. The productivity of early *Kharif* groundnut is very low due to lack of suitable variety and optimum plant population coupled with heavy weed infestation as the crop is grown under irrigation. Groundnut crop is highly sensitive to weed competition and yield reduction up to 70% have been observed (Americanos 1994). Varieties differ not only in their production potential, but also differ in competitive ability of weeds on account of variation in rapid development of foliage and formation of close canopy during early growth stage (Bussan *et al*. 1997). Different crop geometry also imparts competing ability of crop plants to weeds (Singh and Bhan 2002).

It was concluded that groundnut 'Kadin-6' had the highest weed suppressing ability, whereas the highest pod yield was recorded with variety *Dharani'*. A plant population of 0.66 m/ha was optimum for weed suppression.

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Short communication

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Bio-efficacy of herbicides against weeds in blackgram

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Blackgram [*Vigna mungo* (L.) Hepper] is an important pulse crop in India. It is mostly cultivated during summer as well as in *Kharif* season. It has high nutritive value with high content of proteins, vitamins and minerals. The production of blackgram is not sufficient as against its demand. The national average yield of blackgram has been stagnating around 0.7-0.8 t/ha over the years and it is far behind the research yield. Blackgram being a short duration and initially slow growing, it is heavily infested with many grasses and broad-leaved weeds, which compete with the crop during initial growth stage resulting in reduced seed yield of blackgram. Unchecked weeds have been reported to cause a considerable reduction in the seed yield to the tune of 43.2 to 64.1% during *Kharif* season (Chand *et al*. 2004). The degree of reduction in seed yield of blackgram due to weeds depends upon the density and duration of weed species. Hence, timely removal of weeds using a suitable weed control method is very much crucial to harvest optimum yields of blackgram. Hand weeding is laborious, time consuming, costly and tedious job, furthermore, timely unavailability of labour as well as season continuous rains do not permit timely hand weeding. Looking to situation, use of herbicides offers an alternative for possible effective control of weeds in blackgram. Therefore, an attempt has been made to study the bio-efficacy of different herbicides against weeds of blackgram grown in *Kharif* season.

The present investigation was carried out during *Kharif* season of 2011 at B.A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). The soil of the experimental field was sandy-loam in texture having low available nitrogen, medium available phosphorus and high potassium with pH 8.2. The experiment was laid out in randomized complete block design with four replications. Treatments consisted of pendimethalin 500 g/ha PE *fb* IC + HW at 30 DAS, pendimethalin 1000 g/ha PE, quizalofop-ethyl 38 g/ha POE *fb* IC + HW at 30 DAS, quizalofop-ethyl 50 g/ha POE, imazethapyr 50 g/ha POE *fb* IC + HW at 30 DAS, imazethapyr at 100 g/ha POE, oxyflurofen 100 g/ha PE *fb* IC + HW at 30 DAS, oxyflurofen 200 g/ha PE, fenoxaprop-p-ethyl 50 g/ha POE *fb* IC + HW at 30 DAS, fenoxaprop-p-ethyl 100 g/ha POE, HW at 20 and 40 DAS and weedy check. The blackgram cv. '*T-9*' was sown manually keeping the distance of 45 cm using 20 kg row/ha during fourth week of July, 2011. Entire quantity of nitrogen (20 kg/ha) and phosphorous (40 kg/ha) were applied at the time of sowing. Herbicides were applied with a manually operated knapsack sprayer fitted with flat fan nozzle at a spray volume of 500 l/ha as per treatments. The other package of practices were adopted to raise the crop as per the recommendations. After sowing of the seed immediately a light irrigation was given to the crop for uniform germination, and next day the pre-emergence herbicides were applied. The crop was harvested on third week of October. The observations on number of weeds and dry matter of weeds were taken from randomly selected four spots by using 0.25 m^2 quadrats from net plot area. Weed control efficiency (WCE) was calculated on the basis of formulae suggested by Mani *et al.* (1973). The seed and haulm yield was recorded from the net plot area and subjected to statistical analysis. Net realization and BCR values were also worked out by considering the prevailing market price on the basis of seed and haulm yields.

The predominant weed flora of the experimental field consisted of *Cyperus iria* L., *Digera arvensis* L., *Commelina benghalensis* L., *Eleusine indica* (L), *Digitaria sanguinalis* L., *Dactyloctenium aegyptium* L., *Phyllanthus niruri* L. and *Eargrostis major P. Beauv*.

All the weed management practices caused significant reduction in monocot and dicot weeds and their dry weight recorded at various intervals. Significantly lower density of monocot and dicot weeds were recorded in twice hand weeding done at 20 and 40 DAS, however it was statistically at par with oxyfluorfen 200 g/ha at 25 DAS. Hand weeding

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carried out at 20 and 40 DAS recorded significantly lower density of monocot weeds as compared to sole application of pendimethalin 1000 g/ha, quizalofop-ethyl 50 g/ha, imazethapyr 100 g/ha, fenoxaprop-p-ethyl 100 g/ha, and weedy check. Similar results were also noticed for density of dicot weeds except treatments of imazethapyr 100 g/ha and oxyfluorfen 200 g/ha, both were at par with twice hand weeding treatment at 50 DAS. Further, it was observed that significantly lower dry weight of monocot weeds was recorded under hand weeding carried out at 20 and 40 DAS, which was at par with oxyfluorfen 100 g/ha as PE *fb* IC + HW at 30 DAS and oxyfluorfen 200 g/ha as PE. Similarly, twice hand weeding treatment also recorded significantly lower dry weight of dicot weeds followed by pre-emergence application of pendimethalin 500 g/ha *fb* IC + HW at 30 DAS, post-emergence application of imazethapyr 50 g/ha *fb* IC + HW at 30 DAS, oxyfluorfen 100 g/ha PE *fb* IC + HW at 30 DAS and oxyfluorfen 200 g/ha PE. The lower dry weight of weeds under hand weeding treatment might be due to the lowest density of monocot as well as dicot weeds. These results were in close agreement with those reported by Singh and Shweta (2005) and Mishra and Chandrabhanu (2006).

At 50 DAS, significantly lower dry weight of monocot weeds were observed under hand weeding carried out at 20 and 40 DAS, which was at par with the pre-emergence application of pendimethalin 500 g/ha *fb* IC + HW at 30 DAS, quizalofop-ethyl 38 g/ha as POE *fb* IC + HW at 30 DAS, imazethapyr 50 g/ha as POE *fb* IC + HW at 30 DAS, oxyfluorfen 100 g/ha as PE *fb* IC + HW at 30 DAS and fenoxaprop-p-ethyl 50 g/ha as POE *fb* IC + HW at 30 DAS. At same interval, dry weight of dicot weeds recorded under interculture and hand weeding carried out at 20 and 40 DAS was significantly lower but remained at par with pre-emergence application of pendimethalin 500 g/ha *fb* IC + HW at 30 DAS, quizalofop-ethyl 38 g/ha as POE *fb* IC + HW at 30 DAS, imazethapyr 50 g/ha as POE *fb* IC + HW at 30 DAS, oxyfluorfen 100 g/ha as PE *fb* IC + HW at 30 DAS and fenoxaprop-p-ethyl 50 g/ha as POE *fb* IC + HW at 30 DAS. The lower

Table 1. Density, dry weight of weeds and weed control efficiency as influenced by weed management

Treatment	Monocot weeds				Dicot weeds				Weed control efficiency (WCE %)		
	Density (no./m^2)		Dry weight (g/m^2)		Density (no./m^2)		Dry weight (g/m^2)				
	25 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS	25 DAS	50 DAS	At harvest
Pendimethalin 500 g/ha (PE) *fb* IC + HW 30 DAS	4.09^{e} (16.2)	2.12^{f} (4.0)	3.28^{e}	0.88^{f}	2.74^{ef} (7.0)	2.60^{fg} (6.2)	1.19^{ef}	1.08^{h}	90.1	91.3	59.4
Pendimethalin 1000 g/ha (PE)	4.85^{e} (23.0)	3.28^{e} (10.2)	4.56^{e}	2.24^{e}	5.07^{d} (25.2)	4.74^{d} (22.0)	4.29^{d}	3.81^{d}	80.1	73.2	54.2
Quizalofop-ethyl 38 g/ha (POE) *fb* IC + HW at 30 DAS	7.35^{cd} (53.5)	2.01^{f} (3.5)	10.8^{cd}	0.78^{f}	6.08^{c} (36.5)	2.82^{fg} (7.4)	6.21^{c}	1.82^{h}	62.2	88.5	64.2
Quizalofop-ethyl 50 g/ha (POE)	6.54^{d} (42.2)	4.59^{c} (21.5)	11.6^{d}	4.71^{c}	7.78^{b} (60.0)	6.10^{c} (36.7)	7.10^{c}	6.36^{c}	58.4	51.0	40.8
Imazethapyr 50 g/ha (POE) *fb* IC + HW at 30 DAS	6.73^{d} (44.7)	2.09^{f} (3.9)	9.03^{d}	0.85^{f}	7.60^{b} (57.3)	2.45^{fg} (5.5)	1.45^{ef}	0.95^{h}	76.7	92.0	59.4
Imazethapyr 100 g/ha (POE)	6.84^{d} (46.2)	3.74^{e} (13.5)	9.34^{d}	2.96^{e}	3.61^{e} (12.5)	2.60^{fg} (6.2)	2.13^{e}	1.08^{g}	74.5	82.1	54.6
Oxyfluorfen 100 g/ha (PE) *fb* IC + HW at 30 DAS	6.74^{d} (44.9)	2.10^{f} (3.9)	2.01^{ef}	0.86^{f}	3.23^{e} (9.9)	2.47^{fg} (5.6)	1.19^{ef}	1.21^{h}	91.3	90.8	61.6
Oxyfluorfen 200 g/ha (PE)	3.61^{ef} (12.5)	4.27^{d} (17.7)	2.52^{ef}	3.89^{d}	2.75^{f} (7.1)	2.24^{fg} (4.5)	0.87^{f}	0.77^{g}	92.5	79.3	58.2
Fenoxaprop-p-ethyl 50 g/ha (POE) *fb* IC + HW at 30 DAS	8.38^{b} (69.7)	2.17^{f} (4.2)	14.1^{b}	0.92f	5.68^{cd} (31.7)	2.36^{fg} (5.1)	5.40^{cd}	0.89^{h}	56.7	84.2	62.5
Fenoxaprop-p-ethyl 100 g/ha (POE)	8.03^{bc} (64.0)	5.39^{b} (28.5)	15.5^{bc}	6.24^{b}	7.50^{b} (55.7)	7.95^{b} (62.7)	6.90^{cd}	10.86^{b}	50.2	24.4	48.3
HW at 20 and 40 DAS	1.94^{f} (3.25)	1.66^{f} (2.2)	0.66^{f}	0.49^{f}	1.87^{f} (3.0)	1.65^{g} (2.2)	0.51^{f}	0.39^{h}	97.4	96.1	84.3
Weedy check	12.95^{a} (167.2)	11.54^{a} (132.7)	31.6^{a}	37.17^{a}	8.97^{a} (80.0)	9.47^{a} (89.2)	13.39^{a}	15.44^{a}	-	-	-
LSD (P=0.05)	18.1	17.2	18.1	17.3	15.9	18.0	15.5	9.59	-	-	-

*Figures in the parentheses are original values. All Figures are subjected to transformed values to square root $\sqrt{x + 0.5}$. DAS- Days after sowing, *fb*- followed by, HW: Hand weeding, IC: Interculture

Table 2. Growth, yield attributes and seed yield of blackgram as influenced by weed management

Treatment	No. of plants/m row length	Plant height (cm)		Dry weight of nodule (mg/ plant)	No of branches /plant	Number of pods/ plant	Test weight (g)	Protein content (%)	Seed yield (t/ha)	Haulm yield (t/ha)
		30 DAS	At harvest							
Pendimethalin 500 g/ha (PE) *fb* IC + HW at 30 DAS	8.68	49.1^{ab}	83.5^{abc}	47.0	5.01^{a}	40.0^{ab}	41.6	23.1	1.67^{ab}	3.36^{ab}
Pendimethalin 1000 g/ha (PE)	9.55	45.5^{abc}	91.8^{a}	48.0	4.23b^{c}	31.0^{c}	41.3	22.4	1.19^{de}	2.26^{f}
Quizalofop-ethyl 38 g/ha (POE) *fb* IC + HW at 30 DAS	8.93	48.5^{ab}	87.5^{ab}	44.5	5.14^{a}	39.6^{ab}	37.2	20.8	1.69^{ab}	3.46^{ab}
Quizalofop-ethyl 50 g/ha (POE)	9.23	47.8^{ab}	78.9^{abcd}	45.7	3.90^{c}	28.0^{cd}	38.1	21.9	0.96^{e}	1.55^{g}
Imazethapyr 50 g/ha (POE) *fb* IC + HW at 30 DAS	9.08	44.8^{abc}	82.4^{abc}	46.3	4.82^{ab}	38.6^{ab}	40.7	22.5	1.65^{ab}	3.36^{ab}
Imazethapyr 100 g/ha (POE)	9.23	40.3b^{c}	76.0^{abcd}	47.2	4.38^{abc}	32.4^{c}	39.7	22.7	1.26^{cd}	2.75^{de}
Oxyfluorfen 100 g/ha (PE) *fb* IC + HW 30 DAS	9.48	39.5^{c}	76.9^{abcd}	46.8	4.80^{ab}	38.8^{ab}	40.9	21.5	1575^{bc}	3.09^{cd}
Oxyfluorfen 200 g/ha (PE)	9.33	41.5^{bc}	68.8^{cd}	47.5	4.78^{ab}	31.4^{c}	40.2	22.5	1.46^{bc}	2.52^{ef}
Fenoxaprop- p-ethyl 50 g/ha (POE) *fb* IC + HW at 30 DAS	8.63	50.6^{a}	79.9^{abcd}	45.6	4.82^{ab}	39.3^{ab}	37.3	20.3	1.64^{ab}	3.36^{ab}
Fenoxaprop- p- ethyl 100 g/ha (POE)	9.60	46.3^{abc}	72.1^{bcd}	44.2	3.93^{c}	30.0^{cd}	37.5	20.1	0.97^{e}	1.51^{g}
HW at 20 and 40 DAS	9.75	52.3^{a}	88.5^{a}	48.6	5.05^{a}	43.4^{a}	42.2	23.6	1739^{a}	3.65^{a}
Weedy check	8.55	42.0^{bc}	65.7^{d}	43.2	3.70^{c}	25.5^{d}	37.9	20.3	0.71^{f}	1.21^{h}
LSD (P=0.05)	7.10	10.1	12.1	9.92	9.93	8.73	2.29	3.26	0.12	0.79

dry weight of weeds might be due to prolonged persistence of above herbicides contributing to weed-free condition during crop weed competition period as well as integration with hand weeding at 30 DAS. Similar results were reported by Ramanathan and Chandrashekharan (1998), Rana *et al.* (2008) and Yadav *et al.* (1997). Significantly higher weed dry weight of monocot, dicot and total weeds were recorded under weedy check.

Plant population, dry weight of root nodules, test weight and protein content in seeds were not influenced due to various weed management treatments (Table 2). The treatment, hand weeding carried out at 20 and 40 DAS recorded maximum plant height, number of branches/plant and number of pods/plant followed by pendimethalin 500 g/ha as PE *fb* IC + HW at 30 DAS, quizalofop-ethyl 38 g/ha as POE *fb* IC + HW at 30 DAS, imazethapyr 50 g/ha as POE *fb* IC + HW at 30 DAS, imazethapyr 100 g/ha as POE, oxyfluorfen100 g/ha as PE *fb* IC + HW at 30 DAS, oxyfluorfen 200 g/ha as PE and fenoxaprop-p-ethyl 50 g/ha as POE *fb* IC + HW at 30 DAS. The higher growth and yield attributes under said treatments may be attributed to reduced weed density and lesser weed biomass production. Further, it was observed that significantly higher seed yield (1.74 t/ha) and haulm yield (3.65 t/ha) was recorded under treatment of hand weeding carried out at 20 and 40 DAS and was at par with the treatments of pendimethalin 500 g/ha as PE *fb* IC + HW at 30 DAS, quizalofop-ethyl 38 g/ha as POE *fb* IC + HW at 30 DAS, imazethapyr 50 g/ha as POE *fb* IC + HW at 30 DAS and fenoxaprop-p-ethyl 50 g/ha POE *fb* IC + HW at 30 DAS. Significantly, the lowest seed yield (0.71 t/ha) and haulm yield (1.21 t/ha) was recorded under weedy check, due to higher infestation of weeds causing strong competition of weeds with crop for growth factors. These results were in accordance with the findings reported by Sharma and Yadava (2006) and Rana *et al.* (2008).

SUMMARY

A field experiment was conducted during 2011 at Anand, Gujarat to study the bio-efficacy of different herbicides against weeds of blackgram grown in *Kharif* season. Density and dry weight of weeds were significantly reduced by twice hand weeding carried out at 20 and 40 DAS than that of recorded in other treatments except pre-emergence application of pendimethalin 500 g/ha *fb* IC + HW at 30 DAS, quizalofop-ethyl 38 g /ha as POE *fb* IC + HW at 30 DAS, imazethapyr 50 g/ha as POE *fb* IC + HW at 30 DAS, oxyfluorfen 100 g/ha as PE *fb* IC + HW at 30 DAS) and fenoxaprop-p-ethyl 50 g/ha as

POE *fb* IC + HW at 30 DAS. Twice hand weeding treatment was found superior to other treatments in respect of reducing the density and dry weight of weeds and recording higher seed and haulm yields.

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Short communication

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Yield performance and nutrient uptake as influenced by integrated weed management in clusterbean

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Clusterbean commonly known as '*Guar*' is an important drought hardy leguminous crop which is cultivated mostly in the arid and semi-arid regions of tropical India. This crop is mainly cultivated in the marginal and rainfed areas where inadequate weed management is a major constraint in harnessing its production potential. Being a rainy season crop, it suffers badly due to severe competition by mixed weed flora. Yield reduction due to weed infestation to the tune of 53.7% has been observed (Saxena *et al.* 2004). Although weeds pose problems during entire crop growth period, initial one month of the crop is especially critical. Therefore, weed control needs to be ensured to exploit the yield potential of this crop. Hand weeding is a traditional and effective method but untimely rains, unavailability of labour at peak time and increasing labour cost are the main limitations. Under such situations, the only alternative that needs to be explored is the use of suitable herbicides which may be effective and economical.

A field experiment was conducted on clusterbean during *Kharif*, 2013 at the Instructional Farm, Agricultural Research Station, S.K. Rajasthan Agricultural University, Bikaner. The soil of the experimental field was loamy-sand in texture, alkaline in reaction (pH 8.22), low in organic C (0.08%), available N (78 kg), available P (22 kg) but medium in K (210 kg/ha). Sixteen treatments, *viz.* weedy check, weed-free, pendimethalin 0.75 kg/ha PE, pendimethalin 0.75 kg/ha + hand weeding at 30 DAS, imazethapyr 40 g/ha (25 DAS), imazethapyr 50 g/ha (25 DAS), imazethapyr 60 g/ha (25 DAS), imazethapyr 40 g/ha (25 DAS) + hand weeding at 40 DAS, imazethapyr 50 g/ha (25 DAS) + hand weeding at 40 DAS, imazethapyr 60 g/ha (25 DAS) + hand weeding at 40 DAS, imazethapyr + imazamox 40 g/ha (25 DAS), imazethapyr + imazamox 60 g/ha (25 DAS), imazethapyr + imazamox 80 g/ha (25 DAS), imazethapyr + imazamox 40 g/ha (25 DAS) + hand weeding at 40 DAS, imazethapyr + imazamox 60 g/ha (25 DAS) + hand weeding at 40 DAS and imazethapyr + imazamox 80 g/ha (25 DAS) + hand weeding at 40 DAS were laid out in randomized block design with three replications. Recommended dose of 20 kg N and 40 kg P_2O_5/ha was applied to the crop. Pendimethalin as pre-emergence, imazethapyr and imazethapyr + imazamox as post-emergence were applied as per treatment. Weed-free treatment was achieved by repeated hand weedings. Randomly five plants were selected from each plot and biometric observations of crop and weed parameters were recorded at periodic intervals. Weed density and dry weight were recorded with a quadrate of 0.25 m^2 . Weed control efficiency and weed index were calculated by standard formulae. Economic analysis was done as per the prevailing market price of different outputs and inputs.

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Weed density and dry weight

The experimental field was heavily infested with mixed flora of broad-leaved and grassy weeds, viz. *Amaranthus spinosus* L., *Euphorbia hirta* L., *Aristida depressa* L., *Portulaca oleracea* L., *Digera arvensis* Forsk., *Gisekia poiedious, Cenchrus biflorus* L., *Tribulus terrestris* L., *Aervato mentosa* Forsk., *Corchorus tridense* L., *Eleusine verticillata* L., *Eragrostis tennela* and *Trianthema portulacastrum* L.

All the treatments resulted in significant reduction in weed density and dry weight of weeds over weedy check (Table 1). Weed-free treatment resulted in the lowest weed density and dry weight of weeds. However, imazethapyr at 60 g/ha at 25 DAS as post-emergence in combination with hand weeding recorded significantly least number of weeds (1.47/m^2) and dry weight (1.78 g/m^2) than any other treatment except weed-free. This might be due to control of weeds during early growth stage by application of imazethapyr at 25 DAS and later by hand weeding at 40 DAS. All weed control treatments significantly reduced the density as well as dry weight of weeds over weedy check. The reduction in dry weight of weeds due to pendimethalin 0.75 kg/ha as pre-emergence alone, pendimethalin 0.75 kg/ha as pre-emergence + one hand weeding at 30 DAS, imazethapyr 60 g/ha (25 DAS) + one hand weeding at 40 DAS and imazethapyr + imazemox 80 g/ha (25 DAS) + one hand weeding at 40 DAS was 95.7, 94.7, 98.1 and 94.7% compared to weedy check, respectively.

Effect on crop

Weed-free treatment recorded the highest dry matter production, pods/plant, seeds/pod, seed and straw yield, which were at par with pendimethalin 0.75 kg/ha, imazethapyr 40, 50, 60 g/ha and imazethapyr + imazamox 40, 60, 80 g/ha (Table 1). All herbicides integrated with hand weeding were significantly superior to weedy check. This might be due to minimizing the competition of weeds with main crop for resources, *viz*. space, light, nutrients and moisture with adoption of effective weed control methods. Thus, reduced crop-weed competition resulted in overall improvement in crop growth as reflected by increase in plant height and dry matter accumulation. The results corroborate with the findings of Singh *et al*. (1994) and Yadav *et al*. (2014). The lowest values of growth and yield attributes and yield were recorded in weedy check. Increase in seed yield might be due to the direct influence of various weed management treatments on the suppression of weeds. Thus, crop-weed competition resulted in increased plant height, dry matter accumulation and nutrient uptake by crop. The results corroborate with the findings of Tiwari *et al.* (2014).

All weed management practices significantly enhanced seed yield over weedy check. There was no significant difference between seed yield with all the treatments except weedy check. Weed-free treatment produced the highest seed yield (1.49 t/ha), followed by pendimethalin 0.75 kg/ha + hand weeding 30 DAS (1.45 t/ha), while it was minimum under weedy check (0.77 t/ha).

Economics

Maximum net returns of ` 54,608 /ha were obtained with weed-free treatment, followed by ` 53,277/ha with pendimethalin 0.75 kg/ha alone. Benefit: cost ratio was highest with pendimethalin 0.75 kg/ha alone (3.88), followed by weed-free treatment (3.81).

Nutrient uptake by weeds and crop

All weed control treatments recorded significant increase in N, P and K uptake by the crop compared to weedy check (Table 2). The highest nutrient uptake was obtained with weed-free treatment, which was statistically at par with all other treatments except weedy check. Uptake of N, P and K by weeds followed the trend of weed biomass. It was found that all weed control treatments significantly reduced N, P and K uptake by weeds at harvest. The lowest total

Table 1. Effect of weed control measures on weed growth at harvest, and performance of clusterbean

Treatment	Weed density (no/m^2)	Weed dry weight (g/m^2)	Plant height at maturity (cm)	Pods/ plant	Seed yield (t/ha)	Straw yield (t/ha)	Net returns (x10^3 `/ha)	B:C ratio
Pendimethalin 0.75 kg/ha PE	2.49(5.7)	3.95	112.5	38.0	1.44	3.97	53.28	3.88
Pendimethalin 0.75 kg/ha PE + HW 30 DAS	2.29(4.7)	4.90	112.7	38.7	1.45	4.07	52.35	3.64
Imazethapyr 40 g/ha 25 DAS	4.72(21.7)	17.51	85.1	36.7	1.32	3.60	47.23	3.56
Imazethapyr 50 g/ha 25 DAS	4.54(20.1)	16.72	85.6	38.7	1.33	3.76	47.89	3.59
Imazethapyr 60 g/ha 25 DAS	4.43(19.2)	16.62	86.0	38.8	1.33	3.74	48.05	3.60
Imazethapyr 40 g/ha 25 DAS + HW 40 DAS	1.88(3.05)	2.71	86.6	39.5	1.37	3.79	48.41	3.44
Imazethapyr 50 g/ha 25 DAS + HW 40 DAS	1.66(2.3)	2.18	87.1	39.8	1.38	3.75	48.82	3.47
Imazethapyr 60 g/ha 25 DAS + HW 40 DAS	1.47(1.7)	1.78	87.5	39.1	1.39	3.81	49.29	3.49
Imazethapyr + imazamox 40 g/ha 25 DAS	2.49(5.7)	6.80	93.4	39.4	1.35	3.79	48.99	3.65
Imazethapyr + imazamox 60 g/ha 25 DAS	2.46(5.5)	6.84	93.9	40.0	1.36	3.70	48.99	3.65
Imazethapyr + imazamox 80 g/ha 25 DAS	2.44(5.4)	7.22	94.4	38.7	1.36	3.77	49.24	3.67
Imazethapyr + imazamox 40 g/ha 25 DAS + HW 40 DAS	2.17(4.2)	5.97	93.8	39.1	1.40	3.81	49.96	3.52
Imazethapyr + imazamox 60 g/ha 25 DAS + HW 40 DAS	1.99(3.4)	5.39	94.3	40.0	1.41	3.93	50.44	3.55
Imazethapyr + imazamox 80 g/ha 25 DAS + HW 40 DAS	1.78(2.6)	4.85	94.9	39.0	1.42	3.91	50.76	3.56
Weedy check	10.46(108)	91.94	71.3	28.7	0.77	2.18	21.53	2.28
Weed-free	0.71(0.0)	0.00	115.0	40.2	1.49	4.14	54.61	3.81
LSD (P=0.05)	1.22	5.13	18.67	5.30	0.28	0.65	12.72	0.66

Original figures in parentheses were subjected to square root transformation

Table 2. Effect of weed control measures on gum content, and nutrient uptake (kg/ha) by weeds and clusterbean

Treatment	Gum concentration (%)	Clusterbean			Weeds		
		N	P	K	N	P	K
Pendimethalin 0.75 kg/ha PE	28.6	84.2	16.9	65.5	7.71	1.04	5.19
Pendimethalin 0.75 kg/ha PE + HW 30 DAS	28.6	85.8	17.6	66.5	9.56	1.28	6.52
Imazethapyr 40 g/ha 25 DAS	28.1	71.4	14.7	54.8	34.03	4.48	23.43
Imazethapyr 50 g/ha 25 DAS	28.2	73.1	15.2	56.3	32.51	4.28	22.40
Imazethapyr 60 g/ha 25 DAS	28.3	73.1	15.2	56.2	32.29	4.25	22.17
Imazethapyr 40 g/ha 25 DAS + HW 40 DAS	28.4	76.7	15.9	58.9	5.41	0.74	3.90
Imazethapyr 50 g/ha 25 DAS + HW 40 DAS	28.5	77.4	15.9	59.3	4.39	0.61	3.24
Imazethapyr 60 g/ha 25 DAS + HW 40 DAS	28.0	78.1	16.1	59.9	3.61	0.51	2.73
Imazethapyr + imazamox 40 g/ha 25 DAS	28.3	78.4	16.2	60.2	13.47	1.80	9.95
Imazethapyr + imazamox 60 g/ha 25 DAS	28.4	78.2	16.1	60.0	13.55	1.81	10.02
Imazethapyr + imazamox 80 g/ha 25 DAS	28.5	78.8	16.3	60.5	14.31	1.91	10.62
Imazethapyr + imazamox 40 g/ha 25 DAS + HW 40 DAS	28.4	81.7	16.8	62.8	11.94	1.60	9.13
Imazethapyr + imazamox 60 g/ha 25 DAS + HW 40 DAS	28.5	83.4	17.2	64.0	10.81	1.46	8.39
Imazethapyr + imazamox 80 g/ha 25 DAS + HW 40 DAS	28.6	83.6	17.2	64.1	9.78	1.32	7.74
Weedy check	27.6	41.3	8.6	31.8	180.9	23.74	133.4
Weed-free	28.9	88.2	17.9	70.8	0.00	0.00	0.00
LSD (P=0.05)	NS	7.2	1.8	5.6	7.00	0.92	6.07

uptake by weeds was recorded with weed-free, which was at par with rest of the weed control treatments except imazethapyr 40, 50, 60 g/ha. Reduced nutrient uptake by weeds under the influence of different weed control measures wasalso reported by Gaikwad and Pawar (2003) and Chhodavadia *et al.* (2013). Gum concentration was not influenced by the weed control treatments.

It was concluded that all weed control treatments were equally effective in controlling weeds and improving crop yield of clusterbean. Weed-free recorded maximum yield and net profit, while the highest B:C ratio was achieved with pre-emergence application of pendimethalin 0.75 kg/ha. Post-emergence application of imazethapyr + imazamox 80 g/ha+ hand weeding at 40 DAS was the next best choice for controlling weeds in clusterbean.

SUMMARY

A field experiment was conducted to study the effect of integrated weed management practices on growth, yield, quality of clusterbean and nutrient uptake by crop and weeds at Bikaner during *Kharif* 2013. Higher yield were recorded under weed-free treatment. Weed biomass was reduced significantly by pendimethalin 0.75 kg/ha as pre-emergence as well as imazethapyr and imazethapyr + imazamox as post-emergence. The highest total uptake of N (88.2 kg), P (17.9 kg) and K (70.8 kg/ha) by the crop was recorded under weed-free conditions.

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Short communication

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Integrated weed management for increased yield and quality of isabgol

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Key words: Chemical weed management, Interculturing, Isabgol, IWM

Isabgol (*Plantago ovata* Forsk) is one of the important medicinal plants grown during *rabi* season and introduced into India during Muslim settlement in middle ages. The name is derived from two Persian words "Isab" and "Ghol" meaning horse's ear. This derivation fits well with the shape of the seed which resembles the ear of horse. Seeds of isabgol are mainly valued for their mucilaginous rosy white husk. In addition to medicinal uses, it has a place in dyeing, printing, ice-cream, confectionary and cosmetic industries.

In India, isabgol is cultivated commercially in Gujarat, Rajasthan, Haryana, Punjab, Uttar Pradesh, Madhya Pradesh and Bihar. It is a late *rabi* season cash crop. Due to lower production cost and higher market price, it is known as a low volume but high value crop. Initial slow growth rate of isabgol invites severe weed problem during early stages which is responsible up to 50% yield loss. Managing the weeds by hand weeding, a costly affair, has also reduced yield and quality of produce. Integrated weed management approaches involving physical and chemical weed control techniques can help achieve complete, long-term and effective control of weeds during crop season. Keeping this in view, the present experiment was planned as per the methods below.

The field experiment was conducted at Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushi nagar during *rabi* 2012-13. Twelve treatments of weed control *i.e.* oxyfluorfen 50 g/ha post-emergence at 20 DAS, oxyfluorfen 50 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, oxyfluorfen 75 g/ha post-emergence at 20 DAS, oxyfluorfen 75 g/ha post-emergence at 15 DAS + interculturing followed by hand weeding at 30 DAS, isoproturon 500 g/ha as pre-emergence, oxadiargyl 80 g/ha at 20 DAS, oxadiargyl 80 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, oxadiargyl 100 g/ha at 20 DAS, oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, interculturing followed by hand weeding at 20 and 40 DAS, unweeded and weed-free were evaluated in randomized block design with three replications. The soil was loamy-sand low organic carbon (0.27 %) and available nitrogen (149 kg/ha), medium in available phosphorus (38.9 kg/ha) and high in available potash (287.0 kg/ha) with 7.7 pH. The crop was fertilized with recommended dose of fertilizer *i.e.* 40 kg N and 20 kg P_2O_5/ha in the form of Urea and DAP, respectively in manually opened furrows at 30 cm distance. Half nitrogen in the form of urea was applied at the time of sowing and remaining half N was top-dressed at 30 DAS. Isabgol (variety - *GI 3*) was sown in first week of December, 2012 and crop was harvested in last week of March, 2013. Weeding and interculturing were carried out during crop season for weed management as per treatments. The observations were recorded on growth and yield determinates and yields of isabgol during the crop period. The protein content was evaluated by estimation of nitrogen content in seed by adopting Kjeldhal's method (Jackson 1973) multiplying the nitrogen content to 6.25. The swelling factor was determined as per the method suggested by (Kalyansundram *et al.* 1982). The economics of different treatments was worked out in terms of net returns/ha and benefit cost ratio. Simple correlation coefficient (r) of each character was also calculated.

Effect on growth and yield attributes

It is evident from the data presented in Table 1 that all the growth parameters, yield attributes and yields differed significantly due to integrated weed management treatments. Statistically the higher plant height (36.3 cm) at harvest, number of total (22.4) and effective (15.6) tillers per plant, length of spike (5 cm) and 1000-seed weight (1.88 g) of isabgol were recorded when crop was kept weed free. Weed free

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treatment did not differ significantly with treatments interculturing followed by hand weeding at 20 and 40 DAS, oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS and oxadiargyl 80 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, but was significantly superior over rest of the treatments. The minimum plant height was recorded when no weed management practices were adopted, which may be responsible for severe competition between weeds and crop plants for space and resources *i.e*. light, nutrient, moisture *etc*. Effective control of weeds improved crop growth, checked nutrient depletion by weeds and accelerated more absorption of nutrients by isabgol crop that resulted in taller plants with more number of tillers. Similar results were reported by Patel *et al.* (1996) and Sharma and Jain (2002).

Effect on yield

Isabgol yield is an output of sequential metamorphosis from source to sink. Marked effect on yields of isabgol was recorded due to various integrated weed management practices (Table 2). The maximum seed yield/plant, seed and straw yields/ha was recorded 1.74 g, 1225 and 2930 kg/ha, respectively under weed-free crop condition, which was significantly superior over rest of the treatments except treatment oxadiargyl 80 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS oxadiargyl 80 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS and interculturing followed by hand weeding at 20 and 40 DAS. Performance of interculturing and hand weeding at 20 and 40 DAS did not differ significantly with treatments oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS oxadiargyl 80 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, oxyfluorfen 75 g/ha post-emergence at 15 DAS + interculturing followed by hand weeding at 30 DAS and isoproturon 500 g/ha as pre-emergence. Per cent increase in yield due to treatment interculturing followed by hand weeding at 20 and 40 DAS over unweeded, oxyfluorfen 50 g/ha post-emergence at 20 DAS and oxyfluorfen 75 g/ha post-emergence at 20 DAS was 185.6, 114.2 and 98.9% whereas, it was 151.2, 88.4 and 75.0% due to treatment oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, respectively. Effective removal of weeds throughout the crop growth period by physical and integrated weed control practices provided better space and resources *i.e.*, moisture, nutrients, solar radiation etc., for crop plant which led to higher yields. These findings corroborate the results reported by Patel and Mehta (1986), Patel *et al.* (1996), Sharma and Jain (2002), Kumawat *et al.* (2002) and Sagarka *et al.* (2005) as well as Yadav *et al.* (2005) and Mehariya *et al.* (2007) in case of cumin.

The unweeded crop condition recorded the significantly highest, whereas use of oxyfluorfen 75 g/ha alone as post-emergence recorded the least harvest index. The per cent increase in harvest index due to treatment unweeded was 21.3, 23.5, 29.0, 30.2 and 35.2 with treatments isoproturon 500 g/ha as pre-emergence, oxyfluorfen 75 g/ha post-emergence at 15 DAS + interculturing followed by

Table 1. Effect of different integrated weed management treatments on growth and yield attributes of isabgol

Treatment	Plant height (cm)			Total tillers/ plant	Effective tillers/ plant	Length of spike (cm)	1000-grain weight (g)
	30 DAS	60 DAS	Harvest				
T_1 : Oxyfluorfen 50 g/ha post-emergence at 20 DAS	10.8	25.0	32.1	12.3	10.1	3.4	1.50
T_2 : Oxyfluorfen 50 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS	11.7	26.8	34.0	16.0	12.2	4.4	1.60
T_3 : Oxyfluorfen 75 g/ha post-emergence at 20 DAS	11.0	25.6	32.6	13.0	10.7	3.7	1.55
T_4 : Oxyfluorfen 75 g/ha post-emergence at 15 DAS + interculturing followed by hand weeding at 30 DAS	12.6	28.0	34.7	17.6	13.1	4.5	1.65
T_5 : Isoproturon 500 g/ha as pre-emergence	12.0	27.6	34.3	16.8	13.0	4.4	1.62
T_6 : Oxadiargyl 80 g/ha at 20 DAS	11.2	26.0	33.6	14.3	11.4	4.1	1.58
T_7 : Oxadiargyl 80 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS	12.8	28.5	35.0	18.9	14.0	4.6	1.75
T_8 : Oxadiargyl 100 g/ha at 20 DAS	11.6	26.4	34.3	15.8	12.1	4.2	1.60
T_9 : Oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS	13.2	29.0	35.3	20.4	14.3	4.7	1.80
T_{10} : Interculturing followed by hand weeding at 20 and 40 DAS	13.4	29.9	35.7	21.4	14.9	4.8	1.85
T_{11} : Un weeded	10.7	24.6	27.9	8.67	6.6	2.9	1.00
T_{12} : Weed-free	13.8	30.6	36.3	22.4	15.6	5.0	1.88
LSD (P=0.05)	1.30	2.64	3.17	3.15	2.63	0.83	0.30

Table 2. Effect of different integrated weed management treatments on yield and quality of isabgol

Treatments	Seed yield/ plant (g)	Yields (t/ha)		Harvest index (%)	Swelling factor (ml/g)	Protein content (%)
		Seed	Straw			
T_1: Oxyfluorfen 50 g/ha post-emergence at 20 DAS	0.68	0.51	1.30	28.1	9.3	16.9
T_2: Oxyfluorfen 50 g/ha at 15 DAS + interculturing *fb* hand weeding at 30 DAS	1.02	0.81	1.96	29.2	10.3	17.5
T_3: Oxyfluorfen 75 g/ha post-emergence at 20 DAS	0.73	0.55	1.69	24.5	9.7	17.0
T_4: Oxyfluorfen 75 g/ha post-emergence at 15 DAS + interculturing *fb* hand weeding at 30 DAS	1.41	0.90	2.03	30.8	11.8	17.7
T_5: Isoproturon 500 g/ha as pre-emergence	1.18	0.90	1.96	31.3	10.7	17.6
T_6: Oxadiargyl 80 g/ha at 20 DAS	0.85	0.60	1.82	24.9	10.2	17.3
T_7: Oxadiargyl 80 g/ha at 15 DAS + interculturing *fb* hand weeding at 30 DAS	1.46	0.92	2.64	25.9	12.0	17.8
T_8: Oxadiargyl 100 g/ha at 20 DAS	0.97	0.64	1.92	24.5	10.3	17.4
T_9: Oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS	1.62	0.96	2.73	26.0	12.0	17.9
T_{10}: Interculturing *fb* hand weeding at 20 and 40 DAS	1.65	1.09	2.83	27.8	13.1	18.1
T_{11}: Unweeded	0.30	0.38	0.62	38.0	9.0	16.5
T_{12}: Weed-free	1.74	1.22	2.93	29.5	14.0	18.3
LSD (P=0.05)	0.29	0.19	0.38	3.94	1.00	NS

hand weeding at 30 DAS weede free, oxyfluorfen 50 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS and oxyfluorfen 50 g/ha post-emergence at 20 DAS, respectively. Similar results were also reported by Singh *et al.* (2005), Kulmi and Dubey (2006), Kulmi (2007) in case of isabgol and Yadav *et al.* (2005) in case of cumin.

Effect on quality parameters

Weed free treatment secured maximum swelling factor (14.0 ml/g), which was at par with interculturing followed by hand weeding at 20 and 40 DAS, interculturings and hand weedings at 20 and 40 DAS. It was minimum under unweeded crop condition. On the contrary, various integrated weed control treatments did not exert any significant influence on protein content of seed though the higher value of protein content (18.3%) was recorded under weed free plot. These findings corroborate the results reported by Sagarka *et al.* (2005) and Mehariya *et al.* (2007).

Table 3. Correlation coefficient (r) between seed yield (kg/ha) and other characters

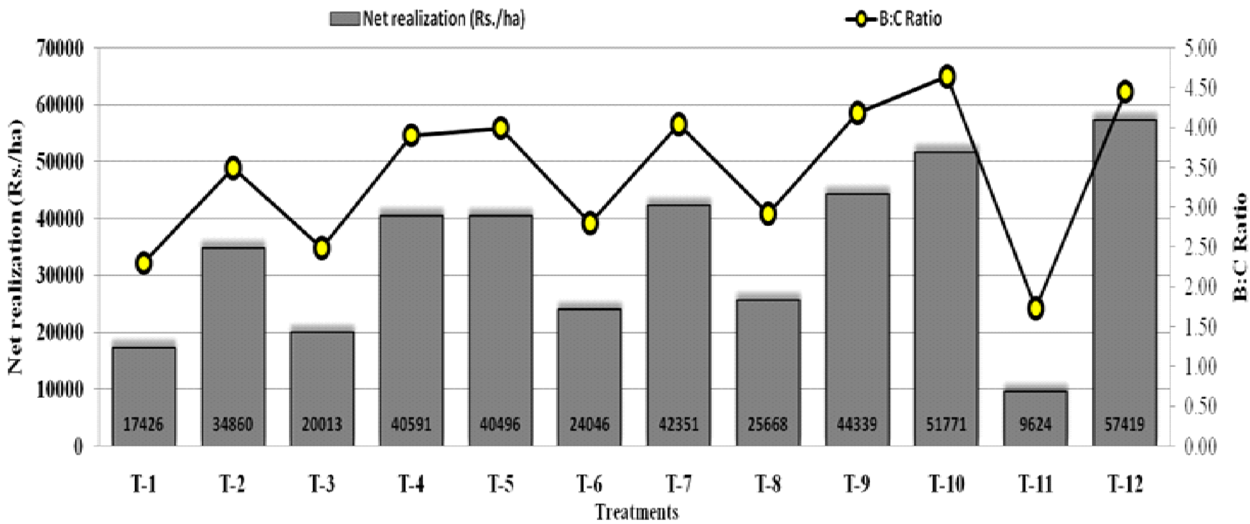
Characters	(r)
Plant height (cm)	0.744
Number of total tillers per plant	0.837
Number of effective tillers per plant	0.788
Length of spike (cm)	0.714
Number of seed per spike	0.532
1000-seed weight (g)	0.425
Seed yield per plant (g)	0.855
Straw yield (kg/ha)	0.808

Note: r value significant at 5 per cent level of probability in all cases.

Effect on economics

Weed free treatment gave the maximum net realization (` 57,419/ha) and was followed by treatments interculturing followed by hand weeding at 20 and 40 DAS (Fig. 1), interculturing and hand weeding at 20 and 40 DAS and oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS and oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS. The highest value of benefit cost ratio, *i.e.* 4.65 was obtained under interculturing and hand weeding at 20 and 40 DAS interculturing followed by hand weeding at 20 and 40 DAS which was closely followed by treatments weed free, oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS and Oxadiargyl 80 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS with BCR values of 4.46, 4.19 and 4.05, respectively. Thus, adoption of interculturing and hand weeding at 20 and 40 DAS was more effective for getting remunerative higher yield.

Yield is a complex quantitative character, which depends on different interrelated characters. These components may show varying degree of association, either favourable or unfavorable. Hence, in order to attain rational improvement in yield, the extent of relationship between the seed yield (kg/ha) and other growth characters as well as yield attributes were studied. It was noticed that growth parameters, yield attributes and straw yield (kg/ha) showed positive significant correlation with seed yield (Table 3).



It can be concluded that effective weed control with higher yields of isabgol under loamy-sand soil of North Gujarat Agro-climatic condition was obtained by performing two interculturings followed by hand weeding at 20 and 40 DAS. During labor scarcity, economically viable production of isabgol can be achieved by adopting integrated weed management practices *i.e.* post-emergence application of oxadiargyl 100 g/ha at 15 DAS with interculturing followed by hand weeding at 30 DAS.

SUMMARY

A field experiment was carried out during *rabi* 2012-13 to study the effect of integrated weed management in isabgol (*Plantago ovata* Forsk). Twelve treatments of weed control *i.e.*, oxyfluorfen 50 g/ha post-emergence at 20 DAS, oxyfluorfen 50 g/haat 15 DAS + interculturing followed by hand weeding at 30 DAS,oxyfluorfen 75 g/ha post-emergence at 20 DAS, oxyfluorfen 75 g/ha post-emergence at 15 DAS + interculturing followed by hand weeding at 30 DAS, isoproturon 500 g/ha as pre-emergence, oxadiargyl 80 g/ha at 20 DAS, oxadiargyl 80 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, oxadiargyl 100 g/ha at 20 DAS, oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS, interculturing followed by hand weeding at 20 and 40 DAS, unweeded and weed free were evaluated in randomized block design with three replications. Results revealed that, crop in weed free condition recorded significantly higher growth parameters, yield attributes, swelling factor (14.0 ml/g), seed (1.22 t/ha) and straw (2.93 t/ha) yields, which were statistically at par to the physical method *i.e.* interculturing followed by two hand weedings at 20 and 40 DAS and integrated weed management practices *i.e.* oxadiargyl 100 g/ha at 15 DAS + interculturing followed by hand weeding at 30 DAS.

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Short communication

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Phyto-sociological attributes of weed flora in major crops of red and lateritic belt of West Bengal

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In agriculture, weeds compete with crop plants for various resources like water, nutrient, sunlight *etc*. Because of their high competitive ability and allelopathic interference, weeds cause an irreversible damage to plants. Crop-weed competition has been established as major deterrent for low crop productivity. The estimation of yield loss due to weeds at the farmer's field with the existing weed management practices followed by the farmers shows that nearly 12% yield loss in potato, 10.5% in wheat, 11% in mustard and 21% in *Kharif* rice in West Bengal occur due to weeds (Anonymous 2008).The red and lateritic belt of West Bengal, India comprising of three main districts, *viz*. Purulia, Bankura and Birbhum has a diverse flora of weeds severely infesting all the crops of the region. In spite of the diversity in crops and weed flora, no detailed floristic and phyto-sociological studies on the weeds in crop fields of this region have been worked out. Therefore, the present investigation on phyto-sociological studies of weed flora in crop fields of red and lateritic belt of West Bengal, India was undertaken.

Red and lateritic belt of West Bengal is situated between 22º 38' N to 24 º 35' N latitude and 85 º 75' E to 88 º 1' E longitudes. Phyto-sociological analysis of weed flora in *Kharif* and *Rabi* season, 2009-10 was conducted in 17 blocks of Purulia and 18 blocks each of Bankura and Birbhum district out of 19, 22 and 19 total blocks present, respectively. For recording observations on the composition of weed flora, a stop was made after every 10-12 km and site for recording observation was selected 4-5 fields away from the main road. Weeds associated with the crops as well as other habitats were identified. The size of the quadrate was taken as 1x1 m. Twenty spots were considered in each village for a particular habitat. Ecological analysis of weed flora was done by traditional quantitative method on the basis of relative frequency, relative density and relative dominance and importance value index (IVI) as per the methods used by Mishra (1968) and Raunkiaer (1934). Accordingly, there were five frequency classes, *i.e*. 'A' class with the species of frequency ranging from 1- 20%; 'B' class 21- 40%; 'C' class 41- 60%; 'D' class 61- 80% and 'E' class 81-100%. Furthermore, the weed community frequency patterns were compared with the normal frequency pattern of Raunkiaer (A>B>C>=D<E). Based on the frequency pattern of the community, the homogeneity and heterogeneity of the vegetation were determined. If the values were high with respect to 'B', 'C' and 'D', then the community is said to be heterogeneous whereas higher values of 'E' indicated the homogeneous nature. Similarity index was calculated using the formula of Sorensen (1948):

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Weed flora in rice

A total of 35 (8 grasses, 22 broad-leaved and 5 sedges), 24 (9 grasses, 10 broad-leaved and 5 sedges) and 45 (11 grasses, 28 broad-leaved and 6 sedges) weed species were observed in Purulia, Bankura and Birbhum districts, respectively (Table 1). *Ludwigia parviflora* was the most frequently distributed weed in transplanted rice field in all the districts. Similar weed flora in transplanted *Kharif* rice was also reported Kiran and Rao (2013).

Weed flora in rapeseed-mustard and wheat

In rapeseed-mustard 16 (4 grasses, 11 broad-leaved and 1 sedges), 9 (3 grasses, 5 broad-leaved and 1 sedges) and 20 (3 grasses, 16 broad-leaved and 1 sedge) weed species were observed in Purulia, Bankura and Birbhum districts, respectively. The wheat field of Purulia and Birbhum districts was infested with 12 (3 grasses, 8 broad-leaved and 1 sedges) and 20 (3 grasses, 14 broad-leaved and 3 sedges) weeds. A total of 13 (3 grasses, 9 broad-leaved and 1 sedge) and 23 (4 grasses, 16 broad-leaved and 3 sedges) weed species were observed in potato field of Bankura and Birbhum districts, respectively. *Ludwigia parviflora* recorded the

Table 1. Weed flora in transplanted *Kharif* rice of Purulia, Bankura and Birbhum districts with their frequency (F) and importance value index (IVI)

S. No.	Species	Purulia		Bankura		Birbhum	
		F (%)	IVI	F (%)	IVI	F (%)	IVI
Grasses							
1	*Cynodon dactylon*	15.26	7.96	13.85	6.76	32.24	16.87
2	*Dactyloctenium aegyptium*	23.42	7.20	10.00	3.57	27.66	10.29
3	*Echinochloa colona*	13.68	5.31	26.92	13.29	20.19	7.88
4	*E. crusgalli*	5.53	2.30	7.69	2.87	2.34	0.92
5	*E. glabrescens*	-	-	10.00	4.56	0.37	0.10
6	*Eleusine indica*	20.26	8.21	27.69	12.88	18.22	7.04
7	*Imperata cylindrica*	7.37	2.60	-	-	1.50	0.49
8	*Paspalum scorbiculatum*	23.16	8.11	20.00	8.05	27.38	10.59
9	*Oryza nivara*	-	-	7.69	2.63	8.50	3.11
10	*Sacciolepis indica*	0.53	0.15	10.77	2.89	5.51	1.59
11	*Setaria glauca*	-	-	-	-	1.31	0.35
Broad-leaved							
1	*Alternanthera philoxeroides*	7.89	3.32	-	-	18.50	7.85
2	*A. sessilis*	-	-	-	-	1.21	0.47
3	*Amaranthus spinosus*	1.84	1.24	-	-	0.37	0.12
4	*A. viridis*	2.37	1.46	-	-	0.37	0.17
5	*Canabis sativa*	1.84	0.59	-	-	0.47	0.15
6	*Centella asiatica*	12.37	4.73	28.46	12.63	5.98	2.49
7	*Colocasia esculenta*	6.05	2.57	-	-	1.03	0.39
8	*Commelina benghalensis*	36.84	18.01	49.23	24.96	40.84	18.58
9	*C. communis*	1.32	0.57	-	-	1.12	0.41
10	*C. nudiflora*	5.26	1.94	-	-	12.71	4.65
11	*Cyanotis axillaris*	-	-	-	-	0.65	0.23
12	*Eclipta alba*	55.53	44.19	28.46	16.48	28.97	23.24
13	*Eichhornia crassipes*	6.84	3.12	2.31	0.85	7.01	2.81
14	*Euphorbia hirta*	1.84	0.77	-	-	3.74	1.22
15	*Gomphrena celosiodes*	4.47	1.56	-	-	2.52	1.00
16	*Hydrolea zeylanica*	15.00	4.50	43.08	15.56	10.47	3.16
17	*Ipomoea aquatica*	3.68	1.09	3.85	1.19	5.51	1.78
18	*Limnocharis flava*	2.37	0.74	-	-	6.64	2.78
19	*Ludwigia parviflora*	77.89	55.21	83.85	61.54	66.26	52.65
20	*Malvastrum coromandelianum*	8.42	2.53	7.69	2.51	4.11	1.58
21	*Marsilea quadrifolia*	63.16	21.06	73.85	28.18	61.78	22.91
22	*Monochoria vaginalis*	-	-	-	-	12.15	3.81
23	*Phyllanthus niruri*	0.26	0.12	0.77	0.26	0.75	0.21
24	*Physalis minima*	0.79	0.45	-	-	1.31	0.44
25	*Polygonum hydropiper*	13.42	5.01	-	-	10.19	3.54
26	*Spilanthes acmella*	-	-	-	-	1.40	0.50
27	*Sphenoclea zeylanica*	-	-	-	-	1.03	0.32
28	*Tridax procumbens*	-	-	-	-	2.43	0.89
Sedges							
1	*Cyperus compressus*	42.63	18.80	0.77	0.50	26.36	10.60
2	*Cyperus difformis*	40.26	15.80	59.23	26.84	33.46	12.59
3	*Cyperus digitatus*	19.21	8.81	11.54	5.56	23.74	10.89
4	*Cyperus iria*	49.21	25.19	60.77	33.15	54.30	26.30
5	*Cyperus rotundus*	-	-	-	-	0.37	0.16
6	*Fimbristylis miliacea*	35.26	14.53	30.00	12.32	50.19	18.75

highest values of frequency, dominance and importance value index in rice field of all the districts which was followed by *Eclipta alba, Cyperus iria, Marsilea quadrifolia, C. compressus, Commelina benghalensis* in Purulia; *C. iria, M. quadrifolia, C. difformis, C. benghalensis* in Bankura, and *C. iria, E. alba, M. quadrifolia, Fimbristylis miliacea* and *C. Benghalensis* in Birbhum district, respectively. Whereas, the dominant weed species in rapeseed-mustard, wheat and potato fields was *Cynodon*

Table 2. Weed flora in potato of Bankura and Birbhum districts with their frequency and importance value index

S. No	Species	Bankura		Birbhum	
		F (%)	IVI	F(%)	IVI
Grasses					
1	*Cynodon dactylon*	29.65	15.86	76.67	42.07
2	*D. aegyptium*	13.37	8.43	8.75	3.02
3	*D. sanguinalis*	-	-	32.92	15.95
4	*E. colona*	5.09	3.07	2.08	0.99
Broad-leaved					
1	*Amaranthus viridis*	10.12	6.48	15.00	6.90
2	*Amaranthus spinosus*	2.06	1.70	-	-
3	*Argemone mexicana*	3.12	2.44	-	-
4	*Asteracantha longifolia*	1.23	0.73	4.17	2.04
5	*Anagallis arvensis*	-	-	21.25	9.89
6	*Blumea lacera*	44.02	54.33	10.00	6.93
7	*C. album*	61.01	56.67	86.67	70.06
8	*C. bonplandianum*	-	-	22.50	11.68
9	*Euphorbia hirta*	32.00	18.24	12.08	4.48
10	*Fumaria parviflora*	-	-	2.50	1.17
11	*G. indicum*	-	-	34.58	14.59
12	*G. celosiodes*	4.12	3.10	8.33	3.36
13	*Phyllanthus niruri*	-	-	4.58	1.62
14	*P. hysterophorus*	-	-	2.50	1.14
15	*Solanum nigrum*	80.02	103.3	7.50	3.08
16	*Sonchus arvensis*	-	-	2.08	0.70
17	*Polygonum plebeium*	-	-	63.75	37.88
18	*Spilanthes acmella*	-	-	14.58	5.92
Sedges					
1	*Cyperus difformis*	-	-	1.67	0.62
2	*Cyperus iria*	-	-	4.58	1.90
3	*Cyperus rotundus*	44.02	25.69	82.08	53.27

dactylon followed by *Echinochloa colona* and *Digitaria sanguinalis* among grasses, and *Cyperus rotundus* among sedges. Among the broad-leaved, the most predominant species was *Chenopodium album* in all the *Rabi* crops of Birbhum, *Anagallis arvensis* in rapeseed-mustard and wheat of Purulia and Bankura, and *Solanum nigrum* in potato field of Bankura district. Other predominant weeds in *Rabi* crops were *Polygonum plebeium, Croton bonplandianum, Blumea lacera, Asteracantha longifolia* and *Euphorbia hirta*.

Weed flora in potato

In potato field, a total of 13 (3 grasses, 9 broad-leaved and 1 sedge) and 23 (4 grasses, 16 broad-leaved and 3 sedges) weed species were observed in Bankura and Birbhum districts, respectively (Table 2). *S. nigrum* in Bankura and *C. Album* in Birbhum district recorded the highest value of density, frequency and dominance, respectively. Similar weed flora in potato was also reported by Pramanick *et al.* (2012).

Frequency classes of weed species

The frequency classes of weed species recorded in the selected crops are presented (Table 3). In rice out of 35, 24 and 45 weed species in Purulia, Bankura and Birbhum, 25, 13 and 33 species were under 'A' category, 5, 5 and 7 species under 'B', 3 each under 'C' and 2 each under 'D' category, respectively for three districts while only one species was found under 'E' category in Bankura district. In rapeseed-mustard 11, 5 and 11 species were under 'A' class frequency, 3, 2 and 3 species under 'B' class, 2 each under 'C' class in Purulia, Bankura and Birbhum districts, respectively.

From the frequency classes and frequency formulae, (Table 4) it is clearly established that most of the weed species encountered in the four crop fields fall under 'A', 'B', 'C' and 'D' frequency classes in rice indicating heterogeneous weed vegetation. Among the *Rabi* crops, wheat of Purulia district showed the homogenous weed vegetation.

Rabi crops in all the districts under study showed higher values of similarity index (Table 5) indicating similar weed flora. However, higher similarity was between rapeseed-mustard and wheat as compared to others.

The knowledge and information regarding phyto-sociological attributes of the weeds of red and lateritic belt of West Bengal may be considered for effective weed management and better crop yield.

Table 3. Frequency classes of weeds in different crops

Frequency classes	Rice			Rapeseed-mustard			Wheat		Potato	
	Purulia	Bankura	Birbhum district	Purulia	Bankura	Birbhum district	Purulia	Birbhum district	Bankura	Birbhum district
A (01-20 %)	25	13	33	11	5	11	3	10	7	15
B (21-40 %)	5	5	7	3	2	3	6	5	2	4
C (41-60 %)	3	3	3	2	2	2	1	2	2	-
D (61-80 %)	2	2	2	-	-	3	2	1	2	2
E (81-100 %)	-	1	-	-	-	1	-	2	-	2
Total	35	24	45	16	9	20	12	20	13	23

Table 4. Frequency formulae

Districts	Rice	Rapeseed-mustard	Wheat	Potato
Purulia	A>B>C>D	A>B>C	A<B>C<D	-
Bankura	A>B>C>D>E	A>B=C	-	A>B=C=D
Birbhum	A>B>C>D	A>B>C<D>E	A>B>C<D>E	A>B>D=E

Table 5. Similarity and dissimilarity Index of weeds under different *Rabi* crops

Districts	Between crops	Similarity index	Dissimilarity index
Purulia	Rapeseed-mustard v/s wheat	0.815	0.185
Bankura	Rapeseed-mustard v/s potato	0.522	0.478
Birbhum	Rapeseed-mustard v/s wheat	0.80	0.20
	Rapeseed-mustard v/s potato	0.727	0.273
	Wheat v/s potato	0.773	0.227

SUMMARY

Phyto-sociological analysis of weed flora in *Kharif* and *Rabi* season of 2009-2010 conducted in Purulia, Bankura and Birbhum districts of West Bengal, India revealed that rice field was infested with 35 (8 grasses, 22 broad-leaved and 5 sedges), 24 (9 grasses, 10 broad-leaved and 5 sedges) and 45 (11 grasses, 28 broad-leaved and 6 sedges) weed species in Purulia, Bankura and Birbhum districts, respectively. In rapeseed-mustard 16 (4 grasses, 11 broad-leaved and 1 sedges), 9 (3 grasses, 5 broad-leaved and 1 sedges) and 20 (3 grasses, 16 broad-leaved and 1 sedge) weed species were observed in Purulia, Bankura and Birbhum districts, respectively. The wheat field of Purulia and Birbhum districts was infested with 12 (3 grasses, 8 broad-leaved and 1 sedges) and 20 (3 grasses, 14 broad-leaved and 3 sedges) weeds. A total of 13 (3 grasses, 9 broad-leaved and 1 sedge) and 23 (4 grasses, 16 broad-leaved and 3 sedges) weed species were observed in potato field of Bankura and Birbhum districts, respectively. *Ludwigia parviflora* recorded the highest values of frequency, dominance and importance value index in rice field of all the districts Whereas, the dominant weed species in rapeseed-mustard, wheat and potato fields was *Cynodon dactylon* followed by *Echinochloa colona* and *Digitaria sanguinalis* among grasses, and *Cyperus rotundus* among sedges.

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Short communication

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Inhibitory potential of "coffee weed" on *Parthenium*

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The chemical exudates from allelopathic plants play a major role in the allelopathy mode of action. Evidence showed that higher plants release a diversity of allelochemicals into the environment, which includes phenolics, alkaloids, long-chain fatty acids terpenoids and flavanoids (Chou 1995). Carrot weed *Parthenium hysterophorus* L. (Asteraceae) is one of the worst weed of agriculture, environment and human health (Knox and Paul 2013, Sushilkumar 2014). It has been estimated to invade about 35 m/ha land in India including crop land, waste land fallow land and forest land, rapidly displacing native and planted pastures (Sushilkumar and Varshney 2010). In Agra district of Uttar Pradesh (UP), it has distributed well comprisng all types of land. In addition to reducing land productivity; the plant causes acute allergic dermatitis and rhinitis in susceptible humans (Tanner and Mattocks1987).

Cassia occidentalis L., more commonly known as"coffee weed", belongs to the family Caesalpiniaceae. *Cassia* plants are well known for containing a group of chemicals with strong laxative effects called anthraquinones. The most widely used species of *Cassia* in herbal medicine is known as senna (*Cassia senna* L. or *C. acutifolia* L.). In nature, *Cassia* competes well with *Parthenium* and inhibits its growth. Therefore, this study was performed to determine the cumulative effects of *C. occidentalis* on the biochemical activities of *Parthenium* and to evaluate the allelopathic potential of this plant in suppressing *Parthenium hysterophorus*.

The experiment was carried out from January, 2013 to December, 2013 at St. John' College, Agra, UP in the research laboratory of Botany Department which is geographically situated at 26° 44' N to 27° 25' N latitude and 77° 26' E to 78° 32' Elongitude at an altitude of 171m msl.

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Preparation of aqueous leachates for bioassay

The upper parts of shoot tips were collected from *C. occidentalis*. 100 g of shoot tips were soaked in 500 ml of double distilled water, each under aseptic conditions for 9 days and placed in conical flasks in a refrigerator at 8 ± 1°C. The aqueous leachates were filtered through three layers of muslin cloth/cheese cloth to remove debris. The filtrate was then re-filtered through one layer of Whatman no. 1 filter paper. Leachates of 100% concentration were prepared and used for bioassay.

Chlorophyll estimation

Chlorophyll content of *Parthenium hysterophorus* was estimated according to Arnon (1949) *Parthenium* leaves (0.40 mg) with 100% of shoot leachates of *Cassia* for 72 hours. After 72 hours, the treated *Parthenium* leaves were placed in black plastic bottles containing 10 ml of 80% acetone and then it was sealed with adhesive tape at its mouth so that acetone may not get evaporated and kept undisturbed in a refrigerator for 5– 6 days at 8 ± 1°C temperature. After 6 days, optical density was recorded by spectrophotometer at different wavelength, *i.e.* 480, 510, 630, 645, 652, and 665 nm.

Estimation of nitrogen

Nitrogen was estimated by following the method of Snell and Snell (1955). 100 mg of *Parthenium* leaves were treated with 100% of shoot leachates of *Cassia* for 72 hours. Then the treated *Parthenium* leaves were placed in 50 ml of conical flask and mixed with 2 ml of concentrated H_2SO_4 and then it was heated on hot plate at 40 °C. When volume reduced to half of the original volume, 1.5 ml of 30% H_2O_2 was added. Then the solution was heated gently at 10 - 20 °C till the clear extract was obtained. The content was then transferred in 100 ml volumetric flask and the volume was made up to the mark with distilled water. After preparation of acid extract of plant material, the nitrogen was estimated.

One ml of prepared acid extract from plant material was taken in 50 ml volumetric flask. To this 10 drops of 10% NaOH and 10 drops of 10% sodium silicate were added and the solution was diluted up to the mark. 1.0 ml of freshly prepared nesseler's reagent was added to the flask, the colour intensity was measured by colorimeter after 15 minutes at transmittance of 420 nm using a reagent blank as reference. With the help of standard curve prepared with 100 ppm NH_4Cl solution the amount of N_2 in the sample was found out.

Protein content

The protein content in plant sample was calculated by multiplying percentage nitrogen content of plant sample by the factor of 6.25. Control received distilled water. The experiment was laid out in correlation with six treatments each comprised of chlorophyll, nitrogen and protein percentage. Using standard procedures of statistical data analysis (including the inbuilt mathematical functions of Microsoft Excel 2007), the effects of *Cassia* on *Parthenium* (before and after treatment) were correlated with the chlorophyll, nitrogen and protein percentage.

It clearly depicted that shoot leachates of *Cassia* inhibited the chlorophyll content of *Parthenium* to the tune of 84.9%, followed by nitrogen and protein in which inhibition was recorded 96.4% and 96.4%, respectively, which was found to be significant.

Of the other flora studied, *C. occidentalis* showed the strongest competitive ability against *Parthenium* (Knox *et al.* 2014).

Maximum significant inhibition in fresh weight and biomass of *Parthenium* was observed in *C. occidentalis* having 6.0 and 3.9 g, respectively followed by *Calotropis procera* in which 7.4 g of fresh weight and 2.6 g of biomass was observed (Knox 2013). In the Indian context, the most efficient plant as biocontrol agent of this weed is undoubtedly *C. sericea* (syn. *C. uniflora*). It releases 'kolines' that interfere with germination and growth rate of only *Parthenium* (Mahadevappa 1999). Lower dose of atrazine supplemented with *C. uniflora* extract was found effective in controlling *P. hysterophorus* (Knox *et al.* 2006). Based on the results of present investigation it can be concluded that *C. occidentalis* was most effective for the management of *Parthenium* weed because *Cassia* could exert allelopathic impact and hinder the biochemistry of *Parthenium*.

SUMMARY

Inhibitory effect of *Cassia occidentalis* L. (CO) on *Parthenium hysterophorus* L. (PH) was assessed under various biochemical parameters like chlorophyll, nitrogen and protein percentage. Chlorophyll content, nitrogen and protein percentage of one month old *Parthenium* plants were observed after treatment with aqueous leachates of the shoots of *C. occidentalis* and compared with control sets treated with distilled water. The allelochemicals released from *Cassia* inhibited the chlorophyll, nitrogen and percentage of *Parthenium* to the tune of 84.9, 96.4 and 96.4%, respectively. The results indicated the possible suppressive effect of allelochemicals present in *C. occidentalis* L. (CO) on *P. hysterophorus*.

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Short communication

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Soil seed bank studies on a riparian habitat invaded by *Parthenium*

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Parthenium weed (*Parthenium hysterophorus* L.) is an annual herb of the Asteraceae family, originating from the tropical Americas and now a weed of global significance in many countries around the world (Adkins and Shabbir 2014). It reduces crop and pasture productivity, reduces native plant community biodiversity and negatively affects human and animal health (Shabbir and Bajwa, 2006). In Pakistan, *Parthenium* weed was first reported from the Gujarat district of Punjab Province in 1980 (Razaq *et al*. 1994) and since then it is rapidly spreading throughout the Province of the Punjab, the Islamabad Capital Territory (ICT) and the Khyber Pukhtunkhwa (KPK) Province (Shabbir *et al*. 2012).

Several aspects contribute to the invasiveness of *Parthenium* weed. These include its very large viable seed production, its large and persistent soil seed banks (Navie *et al*. 2004, Nguyen 2011) the longevity of its seeds when buried (Navie *et al*. 1998), its fast germination and quick flowering time, its ability to flower over a long period of time, its allelopathic interactions with neighboring plants and its ability to adapt to many different environments (Adkins and Shabbir 2014). A single plant of *Parthenium* weed can produce as much as 156,000 seeds (Dhileepan 2012) and result in huge soil seed bank.

Soil seed banks are very important for the regeneration and future composition of plant communities especially for those that are reproduced only by seeds. Variation in the size of soil seed banks may depend upon several factors including the rainfall intensity of the region, the time of year when sampled and the presence or absence of seed predators (McIvor *et al*. 2004, Navie *et al*. 2004). In Australia, Navie *et al.* (2004) determined the size of the viable soil seed bank of *Parthenium* weed invaded pasture where weed seed bank accounted for up to 87% of the total seed bank present. Nguyen (2011) has recently reported that a *Parthenium* weed seed bank still exists at these field sites in the range of 5,000 to 6,000 seed/m^2.

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In Pakistan, there has not been any systematic study on the soil seed bank in in natural areas invaded by *Parthenium* weed. Hence, in this study, we attempted to quantify and compare the soil seed banks of *Parthenium* weed invaded and non-invaded sites along a riparian habitat near the district Lahore.

Two sites were selected along the Lahore branch canal, first site was selected on the basis of its even infestation *Parthenium* weed (*c*. 5-10 weed plants/m^2) while the second site was free of *Parthenium* weed. Both sites were located in riparian area along the canal (extending between the section of EME sector and Izmir Town). The distance between these two sites was approximately 5 km. The annual mean temperature of Lahore is 24.3 ^{o}C and total annual rainfall averages 628.8 mm. The vegetation of the area mainly consists of herbs but few shrubs trees were also present. At each site, three large plots of 5 × 5 m dimensions were selected.

At each site, collection of soil samples from each plot at both sites was made in May 2014. At each site, 5 quadrats (each 1 × 1 m) were thrown randomly within all three larger plots and five soil cores were removed from the individual quadrat (one from each of the four corners and one from the centre of the quadrat), using a brass ring soil corer (7.2 cm diameter and 10 cm deep), and pooled to make a single sample. The samples were placed individually into zip-lock plastic bags, sealed and stored at *ca.* 25 ± 5 °C for between 2 to 3 days while they were being transferred from the field to the glasshouse.

These soil samples were then spread thinly over a 2 cm layer of a sterilized soil contained in shallow trays (20 × 25 × 6 cm; w/l/h) that were distributed randomly on a bench in a glasshouse. All the trays were watered daily to maintain their soil moisture content close to field capacity. The trays were observed regularly for newly emerging seedlings recorded. All identified seedlings were removed while in the cases where identification was not possible, representative individuals were planted into small pots of soil and grown on to maturity, to allow for later taxonomic identification.

Life-history characteristics, such as plant longevity, life form, weed status and origin of all species present were also obtained from the literature. After 4 months, when seedling emergence was almost entirely ceased, the experiment was terminated and a final record of seedling emergence was taken. The data from all samples was used to determine the size of the seed bank and compared between the invaded and non-invaded sites.

A total 28 plant species were found in the soil seed bank community from both invaded and non-invaded sites (Table 1). These species belonged to Poaceae, Asteraceae, Amaranthaceae, Cyperaceae, Malvaceae and 9 other plant families as shown in Table 1. At invaded site, the density of all species in the seed bank was 7,713 seeds/m^2 while it was 6,954 seeds/m^2 at non-invaded site. At invaded site, *Parthenium* weed was represented with the highest seed density (4,438/m^2) followed by *Cynodon dactylon* (650/m^2) and *Calotropis procera* (650/m^2 ; Table 1). At non-invaded site, *Saccharum spontanem* was represented with the highest seed density (1,126/m^2) followed by *Cynodon dactylon* (1,112/m^2) and *Abutilon indicum* (776/m^2 Table 1). It was interesting to note a native grass, *Saccharum spontanem* being the most dominant species of the non-invaded site was altogether absent in the invaded site. *Parthenium* weed was found to be the most dominant and abundant broad-leaved species in the seed bank with 4,438 seeds/m^2 present in soil (Table 1). In Australia, Navie *et al.* (2004) determined the size of the viable soil seed bank of *Parthenium* weed up to 44,700 seed/m^2 in a sandy-loam soil close to a creek. Nguyen (2011) has recently reported that a *Parthenium* weed seed bank still exists at this field site, but now, 10 years later in the range of 5,000 to 6,000 seed/m^2.

More number of plant Families (14) and taxa (25) were represented in *Parthenium* weed-free site as compared to the invaded site where 2 plant families and 8 taxa were absent in soil seed bank (Table 1). Nguyen (2010) found that the diversity of a pasture plant community in Queensland was significantly

Table 1. Comparison of the germinable soil seed bank of a *Parthenium* invaded and non-invaded riparian habitat near Lahore

Plant species	Family	Weed status	Seeds/m^2	
			Invaded sites	Non-invaded site
Abutilon indicum Link. (Sweet)	Malvaceae	Perennial, Shrub	244	776
Cenchrus cilliaris L.	Poaceae	Perennial, Graminoid	110	368
Alternanthera pungens Kunth	Amaranthaceae	Perennial, Forb, Weed	234	198
Calotropis procera (Aiton)	Apocynaceae	Perennial, Shrub	645	46
Convolvulus arvensis L.	Convolvulaceae	Annual, Forb	34	398
Senna occidentalis L. (Link)	Fabaceae	Perennial, Shrub, Weed	398	35
Conyza canadensis (L.) Conq.	Asteraceae	Annual, Forb, Weed	-	27
Cynodon dactylon L.	Poaceae	Perennial, Graminoid	650	1,112
Cyperus rotundus L.	Cyperaceae	Perennial, Graminoid, Weed	88	48
Datura innoxia Mill.	Solanaceae	Annual, Shrub, Weed	-	26
Desmostachya bipinnata (L.) Stapf.	Poaceae	Perennial, Graminoid	-	188
Eleusine indica (L.) Gaertn.	Poaceae	Annual, Graminoid	-	78
Amaranthus viridis L.	Amaranthaceae	Annual, Forb	42	-
Lantana camara L.	Verbenaceae	Perennial, Shrub, Weed	34	-
Malvastrum coromendelianum (Linn.) Garcke.	Malvaceae	Annual, Forb	46	562
Parthenium hysterophorus L.	Asteraceae	Annual, Forb, Weed	4,438	-
Sida cordata	Malvaceae	Perennial, Shrub	-	134
Solanum nigrum L.	Solanaceae	Annual, Forb	48	198
Eragrostis sp.	Poaceae	Annual, Graminoid	-	28
Setaria sp.	Poaceae	Annual, Graminoid	-	188
Cannabis sativa L.	Cannabiaceae	Annual, Shrub	-	26
Heteropogan contortus (L.) P. Beauv.	Poaceae	Perennial, Graminiod	366	882
Saccharum spontanem L.	Poaceae	Perennial, Graminiod	232	1,126
Achyranthes aspera L.	Amaranthaceae	Perennial, Shrub, Weed	46	146
Ipomoea cornea Jace.	Convolvulaceae	perennial, Shrub, Weed	58	28
Tribulis terristris L.	Zygophyllaceae	Annual, Forb, Weed	-	78
Acacia nilotica L.	Fabaceae	Perennial, Tree	-	182
Dalbergia sissoo Roxb.	Fabaceae	Perennial, Tree	-	76
Total			7,713	6,954

reduced by the presence of *Parthenium*, even when the weed was present in relatively low densities (*i.e.* 2 plants/m^2) and this trend was seen in both the above-ground plant community and the soil seed bank.

It was also observed that many grasses (*D. bipinnata, Ellusine indica, Eragrostis* sp. and *Setaria* sp.) were absent in the *Parthenium* invaded site as compared to weed-free site. It was also found that another alien invasive plant, *Lantana camara*, was only found in the *Parthenium* invaded site with a soil seed bank of 34 seeds/m^2 (Table 1). Similarly, the total seed number of other weeds, such as *Senna occidentalis*, *Alternanthera pungens*, *Cyperus rotundus and Ipomoea carnea* present in soil was 61% higher in invaded site as compared to non-invaded site.

The domination by *Parthenium* weed of the seed banks of this site suggests that the weed is having a substantial negative impact on the ecology of these plant communities. This study has demonstrated that *Parthenium* weed can significantly reduce the plant diversity in the below ground species present in the form of seed banks. Many valuable medicinal herbs, adapted to a wide range of environments, are being significantly affected by *Parthenium* weed. Riparian habitats are rich repository of natural herbs used in folk medicines and hence there is now concern for these important biological resources. It is recommended that *Parthenium* weed should be controlled in natural vegetation to protect the native plant populations.

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SUMMARY

Parthenium is an invasive weed in many parts of the world. In Pakistan, this has now become dominant weed in wastelands, forests and other natural areas and is also becoming a problematic weed in other situations such as irrigated and rain-fed cropping systems, pasture lands. In this preliminary study we investigated the impact of this weed on the soil seed bank of a riparian habitat. The impact of *Parthenium* weed upon below ground soil seed bank was assessed in the invaded and non-invaded sites along the canal near district Lahore, Pakistan. In the invaded site, the average number of *Parthenium* weed seeds in the soil was found to be 4,434/m^2. The average numbers of seed/m^2 and species diversity were lowest in the invaded site while it was highest in weed-free sites. A number of important native plant species such as, *Saccharum spontaneum*, *Eleusine indica* and *Solanum nigrum* were found to be declining in the invaded sites. The long-term presence of *Parthenium* weed at these sites poses a serious threat to native plant diversity in these habitats.

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Short communication

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Manually-operated weeders for time saving and weed control in irrigated maize

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Weeds constitute a major component among the bottlenecks for successful crop production. Maize (*Zea mays* L.) is the third most important cereal crop, and no cereal crop on the earth has so much yield potential as that of maize. As the crop is heavily fertilized and sparsely grown, severe weed infestation is experienced, resulting in to a drastic reduction of grain yield (Naidu and Murthy 2014). The traditional weeding operation is arduous, time consuming, back breaking and may not be undertaken at appropriate time due to non-availability of labour during peak period. So, it is not possible to control the weeds timely with the traditional methods like hand weeding. Presently, to substitute manual weeding, more efficient and less energy intensive manually operated weeders have been introduced for weed control in irrigated maize (Mynavathi *et al.* 2009), which are cheaper, more efficient and suitable at farmer's fields to reduce the cost of crop production and improve crop yield to a great extent. In view of the importance of mechanical weed control, a field experiment was conducted during *Kharif* to evaluate the efficiency of manually operated weeders in irrigated maize.

A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore to evaluate the efficiency of different manually operated weeders in maize. The soil of the experimental field was sandy-clay-loam in texture, low in available N (137.2 kg/ha) and phosphorus (9.0 kg/ha) and high in potassium (704.0 kg/ha). Maize variety '*Co-1*' was sown in June at a spacing of 60 x 20 cm. The crop was raised with all recommended package of practices. The treatments consisted of four mechanical weedings with manually operated weeders, *viz.* crescent hoe twice at 25 and 45 DAS, multi-tyne weeder twice at 25 and 45 DAS, wheel-hoe twice at 25 and 45 DAS and rotary peg weeder twice at 25 and 45 DAS. The above treatments were compared with hand weeding twice at 25 and 45 DAS, atrazine 0.5 kg/ha as a pre-emergence + one hand weeding at 45 DAS and unweeded control. The experiment was laid out in randomized block design with three replications. Atrazine 50 per cent WP at 0.05 kg/ha was sprayed using knapsack sprayer fitted with fan type WFN 40 nozzel after 3 days of sowing as pre-emergence. The weeds and yield data of maize were recorded along with other parameters related to mechanical weeders for time saving on weeding operation and weed control efficiency. Weeders were tested using standard test procedures as specified by Regional Network for Agricultural Machinery-RNAM 1983. The mechanical weeders were then evaluated against conventional and chemical weed control methods.

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Effect on weed control efficiency

The major weed species present in the experimental field were *Echinochloa colona* (44.9%), *Digitaria longiflora* (5.3%), *Dactyloctenium aegyptium* (3.1%), *Cyperus rotundus* (4.5%) and the annual broad-leaved weeds constituted 39.6% of the total weed population comprising of *Parthenium hysterophorus* (27.7%), *Digera arvensis* (4.4%) and *Trianthema portulacastrum* (3.6%).

Weed control efficiency (WCE) indicates the magnitude of effective reduction of weed dry weight by weed control treatments over weedy check. This was highly influenced by different weed control treatments. The efficiency of treatments on control of weeds in terms of dry weight in comparison to control plot was worked out (Table 1). At 25 DAS, higher weed control efficiency of 52.2% was obtained in pre-emergence application of atrazine 0.5 kg/ ha on 3 DAS followed by one hand weeding at 45 DAS. At 45 DAS, hand weeding twice recorded higher WCE of 94.9% followed by pre-emergence application of atrazine 0.5 kg/ha on 3 DAS followed by hand weeding on 45 DAS (94.6 %). However, the difference between hand weeding twice, atrazine 0.5 kg/ha on 3 DAS followed by hand weeding PE on 45 DAS and wheel-hoe weeding twice (94.6%) was negligible.

There was a general reduction in weed control efficiency at harvest stage. Among the mechanical weeders, the higher weed control efficiency (34.2%) was reported in wheel-hoe weeding twice. The lower weed control efficiency was obtained in crescent-hoe weeding twice at all the stages. Among the mechanical weeders, wheel-hoe weeding twice produced higher weed control efficiency. (43.1, 94.6 and 34.2% at 25, 45 DAS and at harvest, respectively).

At 25 DAS, all the weed control treatments recorded more than 35% WCE. Pre-emergence application of atrazine 0.5 kg/ha on 3 DAS followed by one hand weeding at 45 DAS recorded higher WCE of 52.2%, followed by hand weeding twice and wheel hoe weeding twice (43.1%). More reduction of weed dry weight by reducing the weed density in these treatments resulted in higher WCE. At 45 DAS, hand weeding twice recorded higher WCE (94.9%), followed by atrazine 0.5 kg/ha PE on 3 DAS followed by one hand weeding on 45 DAS (94.6%), due to the complete removal of weeds by hand weeding. High weed control efficiency (90.7%) in atrazine applied plots was observed. Higher WCE of the treatments and low depletion of nutrients by weeds promoted the yield components of maize.

Time taken for weeding

At 25 DAS, time taken for weeding ranged from 71.4 to 256 hr/ha. The typical work rate for hand hoe is 32 mandays/ha (256 man hours/ha). The operation of rotary-peg-weeder along with rows required 20.8 man days/ha, whereas wheel hoe required, 10.9 man days/ha. The maximum number of mandays/ha required for weeding was recorded with hand weeding twice (Table 2).

At 45 DAS, number of man days required to complete the weeding operation was less compared to 25 DAS (Table 2). Time taken for weeding ranged from 35.1 to 144.0 hr/ha. Pre-emergence application of atrazine 0.5 kg/ha at 3 DAS followed by one hand weeding at 45 DAS required 18 mandays/ha, whereas hand weeding twice required 13 mandays/ha. Among the mechanical weeders, wheel hoe required only 5.4 mandays/ha. Among the mechanical weeders, the maximum number of labourers per hectare was required for rotary peg weeder (9.8 mandays/ha). The maximum number of man days was recorded with pre-emergence application of atrazine 0.5 kg/ha at 3 DAS followed by one hand weeding at 45 DAS (18 mandays/ha) followed by hand weeding twice at 45 DAS.

The increase in crop yield was recorded higher in pre-emergence application of atrazine 0.5 kg/ha at 3 DAS followed by one hand weeding at 45 DAS (173.7%) over control (Table 1). It clearly indicated the importance of weeding. Increase in yield was reported as a result of putting in human labour hours, which ranged from 71.4 to 256 hr/ha at 25 DAS. Wheel-hoe and multi-tyne weeder recorded higher yields of 4.8 and 4.6 t/ha, respectively, the corresponding time utilization for weeding by these devices was low (*i.e.*) 71.4 and 83.3 hr/ha, respectively at 25 DAS and 35.71 and 43.4 hr/ha, respectively at 45 DAS. Hand weeding required 256 man hours/ ha at 25 DAS and 104 man hours/ ha at 45 DAS. These findings corroborate with the finding of Yadav and Pund (2007). This shows that weeding is a labour intensive and tiresome operation.

Wheel-hoe utilized lower time probably due to rotational movement of the front wheel, which helps in ease of operation causing less fatigue to the operator and also recorded at yield of 4.8 t/ha which was 154% increase over control. Further, this hoe reported maximum area coverage (Table 2) with minimum cost of operation (` 714.3/ha) which as

Table 1. Effect of different weed control treatments on weed control efficiency, grain yield and economics in irrigated maize

Treatment	Weed control efficiency (%)			Grain yield (t/ha)	B:C ratio
	25 DAS	45 DAS	At harvest		
Weeding with crescent-hoe (25 and 45 DAS)	36.3	67.5	18.4	4.0	2.08
Weeding with multiweeder (25 and 45 DAS)	40.9	93.4	21.0	4.6	2.39
Weeding with wheel-hoe (25 and 45 DAS)	43.1	94.6	34.2	4.8	2.60
Weeding with rotary peg-weeder (25 and 45 DAS)	36.3	83.4	19.7	4.3	2.18
Hand weeding twice (25 and 45 DAS)	43.1	94.9	52.6	5.2	2.40
Atrazine 0.5 kg/ha as pre-emergence + HW at 45 DAS	52.2	94.6	72.3	5.4	2.87
Unweeded control	-	-	-	3.1	1.95
LSD (P=0.05)	0.51	0.72	0.68	0.45	0.21

Table 2. Effect of different weed control treatments on time taken for weeding at 25 and 45 DAS in irrigated maize

Treatment	25 DAS				45 DAS			
	Time taken		Manual weeding in intra rows (Mandays/ha)	Total time taken for weeding (Mandays/ha)	Time taken		Manual weeding in intra rows (Mandays/ha)	Total time taken for weeding (Mandays/ha)
	Hr/ha	Man days/ha			Hr/ha	Man days/ha		
Weeding with Crescent-hoe (25 and 45 DAS)	111.1	13.8	5.0	18.8	50.0	6.2	2.0	8.2
Weeding with Multiweeder (25 and 45 DAS)	83.3	10.4	4.0	14.2	43.4	5.4	3.0	8.4
Weeding with Wheel-hoe (25 and 45 DAS)	71.4	8.9	2.0	10.9	35.1	4.4	1.0	5.4
Weeding with Rotary peg-weeder (25 and 45 DAS)	142.9	17.8	3.0	20.8	58.8	7.3	2.5	9.8
Hand weeding twice (25 and 45 DAS)	256.0	32.0	-	32.0	104.0	13.0	-	13.0
Atrazine 0.5 kg/ha as pre-emergence + HW at 45 DAS	-	-	-	-	144.0	18.0	-	18.0
LSD (P=0.05)	12.53	2.24	0.12	0.92	15.6	0.44	0.66	0.25

such seems to be the most promising weeding tool for those areas where labour is costly and not easily available. This finding is in accordance with Singhal (1998) that wheel-hoe can cover about 0.2 ha/day during weeding operation.

Wheel-hoe covered more area at both the stages of crop growth in comparison to the remaining weeders. The time taken to complete the weeding operation decreased in wheel-hoe weeding twice (71.4 and 35.7 hr/ha at 25 and 45 DAS, respectively) with the increased width (20 cm) of blades.

The usage of manually operated weeders reduced the cost spent on weeding resulted in least cost of cultivation. Experimental results, conducted by Singh and Sahay (2001) confirmed the above findings.

The results of this study indicated that the use of wheel-hoe not only proved economical (4.8 t/ha of grain and B: C ratio of 2.6) but also useful for completing the weeding operation at a lesser time.

SUMMARY

A field experiment was conducted to evaluate the weed control efficiency and time saving on weeding operation of different manually operated weeders in irrigated maize. Among the manually operated weeders evaluated, wheel hoe registered an yield increase of 154% over control, took less time (71.4 hr/ha), covered maximum area with minimum cost of operation (` 714.3/ ha) and also required less number of mandays to complete the weeding operation (5.46 man days/ha). Among the mechanical weeders, the highest grain yield of 4.8 t/ha was recorded with wheel hoe weeding twice on 25 and 45 DAS and on par with pre-emergence application of atrazine 0.5 kg/ha on 3 DAS followed by one hand weeding on 45 DAS.

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Short communication

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Leaching behaviour of atrazine and metribuzin in different soil types

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Key words: Atrazine, Leaching behaviour, Metribuzin, Soil type

Maize and sugarcane are among the major crops cultivated in Salem district, Tamil Nadu. Major yield reduction under irrigated and rainfed ecosystem is due to severe infestation of weeds. To overcome this weed menace, farmers are using pre-emergence herbicides namely atrazine and metribuzin. Hence, persistence and mobility of these herbicides in different soil types needs to be studied in depth for better weed control efficiency and reducing the soil residual toxicity. Study on leaching potential would also helpful in assessing the efficacy of herbicides since the maximum weed seed bank deposition would be more in top soil surface (0-5 cm) and if the herbicides leach below this point then there is possibility of reduction in weed control efficiency.

To study the leaching behavior of atrazin and metribuzin under different soil texture, a soil column study was conducted. Surface soil samples (red sandy soil and clayey soil) which were not even treated with atrazine and metribuzin,were collected from 0-15 cm top soil layer at Tapioca and Castor Research Station (TCRS), Yethapur, Tamil Nadu. The collected soil samples were air dried and sieved of 1 mm. PVC pipe of 10.5 cm internal diameter was used for the study and were cut in to two equal halves of 60 cm length and joined together using adhesive tapes. The muslin cloth was tied at one end and processed soil was gently packed (approximately 6 kg) in PVC columns of 60 cm length. One day before the herbicide application (on 14.5.2014), 500 ml of water was added from the top to precondition the soil and allowed to drain naturally. The calculated quantity of test herbicides was applied by diluting with 10 ml of water in the respective PVC columns as detailed below on next day (15.5.2014). Atrazine and metribuzin were applied in recommended and double the recommended dose by calculating the surface area of the PVC pipe ðr ^{2} = 3.14 x 5.25^2 =86.67 cm^2. Then the atrazine was applied in soil columns at recommended dose (500 g/ha (A_1) (sorghum, pearlmillet and maize); 1.0 kg/ha (A_2) (sugarcane); double the recommended dose (A_3, 2.0 kg/ha) and meribuzin recommended dose (M_1 250 g/ha) and (M_2, 500 g/ha). One day after herbicide application, 200 ml of water was added daily in two splits by 9.00 am and 5.00 pm for 7 days continuously. To avoid disturbances on the soil surface while adding water, a thin film of sand layer was added above the herbicide applied surface. After 7 DAHA (days after herbicide application), adhesive tape was cut in to two equal halves using sharp knife. The herbicide activity was determined at different depths through bioassay test using blackgram as a sensitive plant.

Then the soil columns were separated into different layers from 0 -5, 5 -10, 10 -15, 15-20, 20-30,30-40,40-50 and 50-60 cm and filled individually in the water proof polythene bags at different soil depths and different doses of herbicide were applied separately as per the treatments. Bioassay test was conducted to study the leaching behavior of herbicides in different soil depths by sowing blackgram seeds at the end of 7 DAHA (days after herbicide application) (23.5.2014) in different soil depths, and watered daily.

Bio-assay test of herbicides

(A_1)· At recommended dose in sorghum, pearlmillet and maize, germination of blackgram seedlings was delayed in top 0– 5 and 5 -10 cm at 3 DAS (26.5.2014) compared to other deep layers. At 7 DAS; chlorotic patches were observed in all the seedlings raised from 0- 40 cm depths This showed that at recommended dose, atrazine traces are found in 0- 40 cm and atrazine could leach maximum up to 40 cm.

(A_2)· At recommended dose in sugarcane, germination of seedlings was delayed in top 0 – 5 cm and 5-10 cm at 3 DAS compared to other deeper layers. At 7 DAS, chlorotic patches were observed in all the seedlings raised from 0- 40 cm depths. This showed that atrazine traces are found in 0 –50 cm and atrazine could leach maximum up to 50 cm depth.

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Table 1. Bio- assay test of atrazine and metribuzin in clayey soil type

Soil depths (cm)	Seedlings germinated (no.)	Shoot length (cm)	Root length (cm)	Seedlings germinated (no.)	Shoot length (cm)	Root length (cm)
	Atrazine applied at 1.0 kg/ha			Metribuzin applied		
0 - 5	10	14.2	2.1	Root and shoot length could not be measured proportionately. Root length varied from 6 cm to 12 cm and shoot length were in the range of 9 - 10 cm. Leaf tip was burnt and chlorotic symptoms observed up to a soil depth of 0 - 25 cm.		
5 - 10	10	12.5	2.0			
10 - 15	9	15.7	2.5			
15 - 20	9	15.7	2.1			
20 - 25	10	15.8	2.3			
25 - 30	10	14.7	1.5			
30 - 35	9	15.7	1.0			
35 - 40	8	15.7	1.4			
40 - 45	7	7.4	1.8			
45 - 50	9	9.0	1.5			
50 - 55	7	6.6	1.5			

(A_3). At double the recommended dose, similar trend as A_2 was observed. This showed that atrazine traces are found in 0– 50 cm and atrazine could leach up to a maximum depth of 40 cm.

(M_1). Under normal dose of metribuzin, normal germination was observed in all the depths. However, at 7 DAS chlorotic symptoms was observed in all the depths, which showed that metribuzin could leach up to a depth of 60 cm and even more deeper layers in red soil type.

(M_2). Under double the recommended dose of metribuzin, normal germination was observed. However, at 7 DAS, chlorotic symptoms was observed in all the depths, which showed that metribuzin could leach up to a depth of 60 cm and even more deeper layers.

In control, germination was uneven at 3 DAS. However, on 7 DAS all the seedlings were observed without any chlorotic patches even with uneven germination. This showed that chlorotic patches occured due to traces of tested herbicide.

It was concluded that in red soils, atrazine traces were observed up to 0 - 40 cm soil layers in 500 kg/ha; up to 50 cm in 1.0 kg/ha and 2.0 kg/ha. Mertribuzin at recommended dose (250 g/ha) and double the recommended dose (500 g/ha) can leach up to a depth of 60 cm soil depth in red soil type.

Bio-assay test of herbicides in clayey soil type

No chlorotic symptoms and delayed germination was observed in seedlings emerged at depths up to 35 cm in clayey soil type. Germination was delayed only in 30 - 40, 40 -50 and 50 - 60 cm in atrazine applied plot. This might be due to poor soaking of water at deeper depths. Gowda *et al*. (1993) reported that mobility of pendimethalin in the 0-5 cm layer was greater than 5-10 cm depth and very little movement occurred at 10-15 cm depth. Sondhia (2007) reported that approximately 80% of pendimethalin was found distributed in 0-12 cm depth due to slow mobility.

SUMMARY

A laboratory soil column experiment was conducted to study the leaching behavior of atrazine and metribuzin in red sandy soil and clayey soil type of TCRS, Yethapur. In atrazine applied plot, chlorotic patches were observed in all the seedlings raised from 0 - 40 cm depths (0 – 5, 5–10,10-15, 15-20, 20 -30 and 30- 40 cm. Chlorosis was not observed in the seedlings raised in the soil depths of 40 - 50 cm and 50 -60 cm.This showed that atrazine traces are found in a depth of 0-40 cm. Application of metribuzin showed chlorosis in all the depths and also showed tip burning in blackgram. From this study, it can be recommended that metribuzin should not be applied in red sandy soil and clayey loam soil (loose soil texture) as this would result in poor weed control efficiency since they are subjected to leaching in deeper layers.

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Short communication

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Density, survival and seed production potential of important weeds of lateritic belt of West Bengal

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Knowledge of weed flora, population and distribution is prerequisite to formulate economic and effective weed management strategy. Composition and density of weed infestation in crops can be predicted from the composition of soil seed bank. Composition of soil seed bank depends on the seed production potential of the weeds and their seed shattering. Each and every flowering plant completes its lifecycle producing seeds for maintaining its generation. These seeds become deposited in the soil after shattering and enrich the soil seed bank year after year. Weeds emerge in huge numbers at the initial growth stage of crop and decrease in number at harvest due to inter - or intra - specific competition and crop management practices. There is insufficient recorded information on seed production potential of important weeds in crop fields of lateritic belt of West Bengal. However, some information on weeds is available in terms of taxonomical aspects (Mukhopadhyay 1968, De and Mukhopadhyay 1984). The current study, therefore, was carried out to have an idea about the density of important weeds at initial growth stage of crop, their survival per cent (%) and seed production potential at harvest under different cropping systems.

The study was conducted at the districts Bankura (22°36.86 - 23°39.21 N latitude and 86° 36.66' - 87° 46.25' E longitude), Western and North–Western part of Birbhum (23° 35.29' - 24° 10.58' N latitude and 87° 5.00' - 87° 37.50' E longitude) and Western part of Burdwan (23° 14.58' - 23° 56.25' N latitude and 86° 45.09'- 87° 37.25' E longitude) representing lateritic belt of West Bengal during *Rabi*, pre-*Kharif* and *Kharif* seasons of 2011-12 and 2012-13. The climate was sub-topical and semi-arid with hot dry summer and short bracing winter. The annual rainfall was 1300–1350 mm most of which is received during June to October. The soil was light textured, porous, slightly acidic and low in organic matter.

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Major cropping systems followed were rice – rice, rice – wheat/mustard/vegetables, rice – potato – sesame/vegetables. Weed management practices followed were two hand weeding or herbicide and one hand weeding in rice; hoeing and weeding in mustard, wheat, vegetables and sesame.

Weed count was done twice by least count quadrate method suggested by Misra (1968) and Raju (1997) using 1 x 1 m quadrate in 10 sampling units (quadrates) for each crop. First count was taken at 20 – 25 days after sowing/transplanting of the crop before taking any weed management measure for documenting the density (no./m^2) of important species. Second count was taken at harvest of crop for documenting weed survival (%) and extent of production of seeds by them. Weeds of large, medium and small sizes were collected randomly in 1 m^2 quadrate in each crop. Average number of plants/m^2, fruits/plant, seeds/fruit and total number of seeds produced/plant were calculated by usual method and ultimately seed rain (number of seeds deposited/m^2 area) of important species was computed.

Weeds and crops

A total of 24 weed species under 22 genera and 14 families were studied under different cropping systems in relation to their initial population (density), survival per cent and seed rain at harvest of crops (rice, wheat, mustard, sesame, tomato, brinjal, cabbage, cauliflower and pumpkin).

Weed density

At early growth stage of *Kharif* rice when soil remains moist, the weed density was recorded highest in *Mollugo stricta* and lowest in *Commelina nudiflora* under rice – rice cropping system. In rice, under rice – wheat/mustard/vegetables cropping system, highest and lowest density were recorded in *Oldenlandia corymbosa* and *Phylanthus fraternus*, respectively. A density of 10 – 20 weeds/m^2 was recorded under 9 species and 5 – 9 weeds/m^2 under 12 species. In winter and pre-*Kharif* seasons, maximum and minimum densities were recorded in *Digitaria sanguinalis* and *Echinochloa colona*, respectively in most of the crops.

Weed survival at harvest of crop

In *Commelina nudiflora*, 100 % survival was recorded in rice under rice – rice cropping system. Considering all the crops and cropping systems, survival per cent was recorded 80 – 89% in *Portulaca oleracea, Cyanotis axillaris, Setaria glauca* and *Echinochloa glabrescens.* Sixty to seventy nine per cent survival was recorded in 9 species, 40 – 59% in 6 species and below 40% in 4 species. Higher survival per cent was noticed in somewhat succulent weeds like *Portulaca oleracea, Cyanotis axillaris, Commelina nudiflora.* Same species in different crops and cropping systems differed in its survival percent.

Fruits, heads and spikelets

In grassy weeds (*Digitaria sanguinaslis, Echinochloa colona, Echinochloa glabrescens, Dactyloctenium aegyptium* and *Setaria glauca*) number of spikelets varied from 58 to 1295, *Echinochloa glabrescens* having highest and *Echinochloa colona* the lowest. Two sedges (*Cyperus iria* and *Fimbristylis miliacea*) possessed 988 and 394 spikelets/plant, respectively. Among 17 broad-leaved weeds, number of fruits/plant varied from 5 to 515, *Chenopodium album* possessed highest and *Cyanotis axillaris* the lowest. Two weed species (*Ageratum conyzoides* and *Eclipta prostrata*) under Asteraceae possessed an average of 32 and 7 heads/ plant, respectively.

Table 1. Density, survival and seed rain of dominant species under lateritic belt of West Bengal

Weed species	Family	Crop	Cropping system	Density (no./m^2)		Survival (%)	Seed rain (no./m^2
				Initial	At harvest		
Cyperus iria	*Cyperaceae*	Rice	Rice – rice	16	7	44	2758
Fimbristylis miliacea				9	4	44	3952
Digitaria sanguinalis	*Poaceae*	Rice	Rice – wheat / mustard / vegetables	11	4	36	504
		Wheat		19	7	37	882
		Sesame	Rice – potato – sesame / vegetables	13	9	69	945
Dactyloctenium aegyptium	*Poaceae*	Rice	Rice – wheat / mustard / vegetables	9	7	78	1127
		Tomato (vegetables)		14	11	79	2464
Echinochloa colona	*Poaceae*	Rice	Rice – rice	6	4	67	1096
		Brinjal (vegetables)	Rice – wheat / mustard / vegetables	5	3	60	174
Echinochloa glabrescens	*Poaceae*	Rice	Rice – rice	9	8	89	10360
Setaria glauca	*Poaceae*	Rice	Rice – wheat / mustard / vegetables	14	12	86	2880
Ageratum conyzoides	*Asteraceae*	Rice	Rice – wheat / mustard / vegetables	6	2	33	3520
Anagallis arvensis	*Primulaceae*	Wheat	Rice – wheat / mustard / vegetables	7	4	57	896
Chenopodium album	*Chenopodiaceae*	Mustard	Rice – wheat / mustard / vegetables	9	7	78	3605
Commelina nudiflora	*Commelinaceae*	Rice	Rice – rice	3	3	100	54
Corton bonplandianum	*Euphorbiaceae*	Sesame	Rice – potato – sesame / vegetables	8	4	50	240
Cynotis axillaris	*Commelinaceae*	Rice	Rice -wheat / mustard / vegetables	12	10	83	150
Eclipta prostrata	*Asteraceae*	Rice	Rice - rice	6	4	67	416
		Mustard	Rice – wheat / mustard / vegetables	9	6	67	1260
		Cauliflower (vegetables)	Rice – wheat / mustard / vegetables	5	3	60	216
		Sesame	Rice – potato – sesame / vegetables	8	6	75	960
Euphorbia hirta	*Euphorbiaceae*	Sesame	Rice – potato – sesame / vegetables	12	4	33	780
Melochia corchorifolia	*Sterculiaceae*	Rice	Rice – wheat / mustard / vegetables	8	6	75	840
Mollugo stricta	*Molluginaceae*	Rice	Rice – rice	32	21	66	2436
Oldenlandia corymbosa	*Rubiaceae*	Rice	Rice – wheat / mustard / vegetables	17	7	41	3038
Phyllanthus fraternus	*Euphorbiaceae*	Rice	Rice–wheat / mustard / vegetables	5	3	60	369
Phyllanthus simplex				6	4	67	204
Portulaca oleracea	*Portulacaceae*	Cabbage (vegetables)	Rice – wheat / mustard / vegetables	15	12	80	1824
Solanum nigrum	*Solanaceae*			9	2	22	9176
Spergula arvensis	*Caryophyllaceae*	Mustard	Rice – wheat / mustard / vegetables	18	5	28	40180
Trianthema portulacastrum	*Aizoaceae*	Sesame	Rice – potato – sesame / vegetables	7	4	57	1404
		Pumpkin (vegetables)	Rice – wheat / mustard / vegetables	6	3	50	1008

Seeds

Average number of seeds/fruit varied from 2-74, *Solanum nigram* being highest and *Oldenlandia corymbosa* the lowest. Number of seeds/fruit was recorded 3 in six species, 4 in two species, 8 in two species, 9 in one species, 14 in one species and 28 in one species. Among the weed species under Asteraceae, *Eclipta prostrata* possessed 24 –32 seeds /head depending on the crops and cropping system. *Ageratum conyzoides* possessed 55 seeds/head.

Seed rain

Considering all the crops and cropping systems, highest seed rain was recorded in *Spergula arvensis* followed by *Echinochloa glabrescens, Solanum nigrum, Fimbristylis miliacea, Chenopodium album, Ageratum conyzoides.* Lowest seed rain was recorded in *Commelina nudiflora.* Extent of seed rain differed in the same species *e.g.*, it was higher in *Digitaria* in wheat under rice – wheat/mustard/vegetables as well as in sesame under rice – potato – sesame cropping system than that in rice under rice – wheat/ mustard/ vegetables cropping system. Similarly, it was higher in *Echinochloa colona* in rice under rice – rice cropping system than that in brinjal under rice – wheat/mustard/vegetables cropping system. Higher seed rain depends on the higher survival per cent of the weed and increased production of fruits and seeds at the time of harvest of crop. As *Spergula arvensis* and *Solanum nigrum* possessed higher number of fruits/plant and seeds/fruit, their seed rain were higher. Similarly, higher survival per cent of *Echinochloa glabrescens, Setaria glauca, Dactyloctenium aegyptium, Chenopodium album, Mollugo stricta* resulted in higher seed rain. From the seed rain data of different weed species it can be easily assumed how much seeds are being deposited in a given area per season. This study may be conducted in other agro-climatic regions of West Bengal for generating data on the weeds in developing weed management technologies.

SUMMARY

The study was carried out to document the density, survival and seed production potential as seed rain, through a single value, of important weeds under different cropping systems at the districts Bankura, Birbhum and Burdwan representing lateritic belt of West Bengal during 2011-12 and 2012-13. Twenty four weed species under 22 genera and 14 families were studied in 9 crops. Highest density was recorded in *Mollugo stricta* in rice under rice – rice system, in *Oldenlandia corymbosa* in rice under rice – wheat/mustard/ vegetables system, whereas *Digitaria sanguinalis* recorded highest density in winter and pre-*Kharif* crops. Highest survival per cent was recorded in *Commelina nudiflora* and seed rain in *Spergula arvensis.*

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