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Bio-efficacy of different herbicides for weed control in direct-seeded rice

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ABSTRACT

Field experiment was conducted during *Kharif* 2009 and 2010 to study the bio-efficacy of different herbicides in direct-seeded rice. Weed control treatments comprised of pendimethalin 0.75 kg, butachlor 1.50 kg, thiobencarb 1.50 kg, anilofos 0.375 kg, pretilachlor 0.75 kg, oxadiargyl 0.09 kg and pyrazosulfuron ethyl 0.015 kg/ha as pre-emergence and with sequential application of bispyribac 0.025 kg/ha at 30 DAS; two hand weedings and unweeded control. Significantly lower number of grass weeds was observed with application of pendimethalin as compared with other pre-emergence herbicides. Sequential application of pendimethalin and bispyribac recorded the lowest weed biomass and 100% weed control efficiency. Crop dry matter accumulation, number of tillers, and effective tillers were significantly higher in sequential use of pre- and post-emergence herbicides, resulting in more grain yield and net returns. The maximum grain yield was recorded in two hand weedings, which was at par with follow-up application of bispyribac after pendimethalin, butachlor, thiobencarb and oxadiargyl.

Key words: Direct-seeded rice, Economics, Grain yield, Herbicides, Weed control efficiency

Weeds are the main constraint in direct-seeded rice since the inherent weed control from standing water at crop establishment is lost (Rao *et al.* 2007). In direct-seeded rice, high weed infestation causes grain yield losses up to 90%. Weeds pose a serious threat by competing for nutrients, light, space and moisture just from the time of emergence and throughout the growing season, whereas weed seeds germinate after rice transplanting in transplanted rice and compete with the well-established rice seedlings. A change in crop establishment method from transplanting to direct seeding brings about changes in the weed community; grasses – *Dactyloctenium aegyptium, Digitaria ciliaris, Eragrostis* spp., *Eleusine indica, Acrachne racemosa, Commelina benghale-nsis;* sedges - *Cyperus compressus, Cyperus rotundus* and broad-leaved –*Digera arvensis, Phyllanthus niruri, Amaranthus viridis* and *Trianthema portulacastrum* have also started appearing in rice fields along with *Echinochloa crus-galli, Echinochloa colona, Leptochloa chinensis, Cyperus iria, Cyperus difformis, Eclipta alba, Sphenochloa zeylenica etc*. So, conversion from transplanted to direct-seeded rice results in more competitive weed flora requiring revised weed management approaches for effective control. A weed-free period for the first 25-45 DAS is required to avoid any loss in yield in dry direct-seeded rice (Chauhan and Johnson 2011, Singh *et al*. 2012). Hand weeding operations are laborious, time consuming, uneconomical, difficult and moreover, result in uprooting of some rice seedlings due to difficulty in differentiating grass weeds that mimic rice plants during early growth. Some herbicides found effective in DSR are pendimethalin, cyhalofop-butyl, fenoxaprop-ethyl, propanil, bispyribac-sodium, penoxsulam, carfentrazone-ethyl, bensulfuron, metsulfuron + chlorimuron, azimsulfuron and 2,4-D. In Punjab state, seven pre-emergence herbicides namely pendimethalin, butachlor, thiobencarb, anilofos, pretilachlor, oxadiargyl and pyrazosulfuron-ethyl have been recommended in puddled transplanted rice. Identifying herbicides with wide-spectrum weed control ability for efficient and economical weed management is crucial for improving the potential of direct seeding of rice. Keeping this in view, an experiment was conducted to study the bio-efficacy of different pre- and post-emergence herbicides used in conventional puddled transplanted rice in direct-seeded rice.

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MATERIALS AND METHODS

The field experiment was conducted at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during *Kharif* season of 2009 and 2010. Ludhiana is situated in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangetic Alluvial plains at 30°56' N latitude, 75°52' E longitude and at an altitude of 247 m above mean sea level. The maximum temperature remained above 38° C during summer. The total rainfall of 818 and 627.6 mm were received during 2009 and 2010, respectively. Most of the rainfall was received in vegetative phase from 23rd (at sowing time) to 35th standard meteorological week (80 days after sowing). The soil of the experimental site was loamy sand with normal soil reaction of pH 7.5 and electrical conductivity of 0.16 dS/m. The soil was low in organic C (0.31%) and available N (251.7 kg/ha) and medium in available P (13.5 kg/ha) and K (164.1 kg/ha). The crop was sown with conventional seed-cum-fertilizer drill at 20 cm row to row spacing with seed rate of 35 kg/ha.

Sixteen weed control treatments comprised of pre-emergence application of pendimethalin 0.75 kg, butachlor 1.50 kg, thiobencarb 1.50 kg, anilofos 0.375 kg, pretilachlor 0.75 kg, oxadiargyl 0.09 kg and pyrazosulfuron-ethyl 0.015 kg/ha, and each unlined with sequential application of bispyribac 0.025 kg/ha at 30 days after sowing (DAS), two hand weedings and unweeded control. Pre-emergence herbicides were sprayed in moist field within two days of sowing and bispyribac was sprayed at 30 DAS as follow-up. Pre- and post-emergence herbicides were applied with knapsack sprayer fitted with flat fan nozzle using 375 L/ha of water. Nitrogen (187.5 kg/ha) was applied as broadcast in four equal splits at 2, 4, 7 and 10 weeks after sowing. Phosphorus (30 kg/ha), potassium (30 kg/ha) and zinc sulphate heptahydrate (62.5 kg/ha) were applied at the time of seed-bed preparation by broadcasting. Plant protection measures for insect-pests and diseases were taken to grow healthy crop.

Data on weed population and dry matter, crop growth and yield were recorded. Weed control efficiency and benefit:cost ratio were calculated. Weed data were square-root transformed before statistical analysis. Pooled analysis of two years was done and comparisons were made at 5% level of significance.

RESULTS AND DISCUSSION

Weed population and dry matter

The predominant weed flora of the experimental field were: *Echinochloa crusgalli*, *Echinochloa colona* and *Cyperus iria*, *Cyperus difformis* at 30 DAS prior to post-emergence application of bispyribac. Along with *Echinochloa* spp., other grass weeds like *Digitaria sanguinalis* and *Dactyloctenium aegyptium* were also reported but *Cyperus* spp. was not observed at later stages of observation as most of the rainfall was received during vegetative phase of crop which led to smothering and perishing of weed flora. Pendimethalin treated plots recorded significantly lower number of *Echinochloa* spp. than all other herbicides but have no effect on *Cyperus* spp. (Table 1). Other pre-emergence herbicides, *viz.* butachlor, thiobencarb, anilofos, pretilachlor, oxadiargyl and pyrazosulfuron-ethyl, conventionally used in puddled transplanted rice under Punjab conditions were broadcast in standing water as pre-emergence but in this study, these were applied on moist soil as spray application. Similar results were obtained by Singh *et al.* (2009) that under dry seeding methods, effective weed control was recorded with pre-emergence application of pendimethalin than pretilachlor. Statistically similar number of *Cyperus* spp. was observed with application of all pre-emergence herbicides, resulting in non-significant differences in weed dry matter. But, weed dry matter was at par in pyrazosulfuron-ethyl and unweeded control. One hand weeding done at 25 DAS has significantly lower weed dry matter as compared with other weed control treatments at 30 DAS.

Follow-up application of bispyribac controlled *Echinochloa* spp. and *Cyperus iria* but had no control over *D. sanguinalis* and *D. aegyptium*, however, *D. sanguinalis* and *D. aegyptium* were controlled with

Table 1. Effect of weed control treatments on weed population and dry matter at 30 DAS in direct-seeded rice (mean of two years)

Treatment	*Echinochloa* spp. (no./m^2)	*Cyperus* spp. (no./m^2)	Weed dry matter (g/m^2)
Pendimethalin 0.75 kg/ha	3.2 (10)	6.4 (40)	5.8 (33)
Butachlor 1.50 kg/ha	4.6 (21)	5.5 (30)	6.3 (38)
Thiobencarb 1.50 kg/ha	4.5 (19)	5.7 (32)	6.3 (38)
Anilofos 0.375 kg/ha	4.5 (19)	5.9 (34)	6.7 (45)
Pretilachlor 0.75 kg/ha	5.3 (27)	5.7 (32)	6.4 (41)
Oxadiargyl 0.09 kg/ha	5.1 (25)	5.3 (28)	7.3 (53)
Pyrazosulfuron-ethyl 0.015 kg/ha	6.4 (40)	6.2 (38)	8.9 (79)
Hand weeding at 25 DAS	1.0 (0)	1.0 (0)	1.0 (0)
Unweeded	9.6 (92)	14.5 (210)	9.1 (83)

The data are square root transformed and values in the parentheses are original values.

two hand weeding and pre-emergence application of pendimethalin, was significantly superior to other herbicides and unweeded control (Table 2). This resulted in lowest weed dry matter and 100% weed control efficiency. Walia *et al.* (2008) also reported that pendimethalin application in dry-seeded rice provided effective control of weeds not associated with paddy crop, whereas bispyribac controlled all typical predominant weeds including *Echinochloa* spp. and all *Cyperus* spp. Bispyribac-sodium and other pre-emergence herbicides, butachlor, thiobencarb, anilofos, pretilachlor, oxadiargyl and pyrazosulfuron-ethyl did not control these grass weeds. Similar results were reported by Kumar and Ladha (2011). Follow-up spray of bispyribac after butachlor, thiobencarb, anilofos, pretilachlor, oxadiargyl and pyrazosulfuron-ethyl resulted in significantly lower weed dry matter than alone application of pre-emergence herbicides, resulting in 88% weed control efficiency. Single application of pre-emergence herbicides showed poor weed control efficiency (19.0–24.2%) (Table 2).

Crop growth and yield

Follow-up application of bispyribac 0.025 kg/ha at 30 DAS after pendimethalin 0.75 kg, butachlor 1.50 kg, thiobencarb 1.50 kg, anilofos 0.375 kg, pretilachlor 0.75 kg, oxadiargyl 0.09 kg and pyrazosulfuron-ethyl 0.015 kg/ha registered significantly taller plants as compared with single application of pre-emergence herbicides, resulting in more crop dry matter production and effective tillers (Table 3). Better crop growth in these treatments might be attributed to more availability of nutrients, water, light and space to crop as a result of effective weed control. All weed control treatments recorded significantly more number of effective tillers as compared with unweeded control. Single application of pre-emergence herbicides, *viz*. pendimethalin, butachlor, thiobencarb, anilofos, pretilachlor and oxadiargyl recorded significantly higher number of effective tillers as compared with pyrazosulfuron-ethyl as pre-emergence and unweeded control. Number of grains/panicle was significantly higher in sequential spray of pre- and post-emergence herbicides than single application of pre-emergence herbicides, except pendimethalin, which was at par with unweeded control. The maximum grain yield was recorded in two hand weedings which was at par with sequential application of pendimethalin, butachlor, thiobencarb and oxadiargyl with bispyribac. Follow-up application of bispyribac registered significantly more grain yield as compared with single application of pre-emergence herbicides.

Table 2. Effect of weed control treatments on weeds in direct-seeded rice (mean of two years)

Treatment	Weed count at 60 DAS (no./m^2)				Weed dry matter (g/m^2)		Weed control efficiency at harvest (%)
	Echinochloa spp.	*Cyperus* sp.	*Digitaria sanguinalis*	*Dactyloctenium aegyptium*	60 DAS	At harvest	
Pendimethalin 0.75	3.4 (13)	2.7 (6)	1.0 (0)	1.0 (0)	8.1 (66)	27.3 (759)	30.4
Pendimethalin 0.75 *fb* bispyribac 0.025	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	100.0
Butachlor 1.50	4.0 (19)	2.6 (6)	1.9 (3)	1.8 (2)	10.1 (101)	28.5 (823)	24.2
Butachlor 1.50 *fb* bispyribac 0.025	1.0 (0)	1.0 (0)	1.9 (3)	1.7 (2)	4.2 (18)	11.1 (123)	88.6
Thiobencarb 1.50	4.0 (19)	2.6 (6)	1.9 (3)	1.7 (2)	10.0 (101)	29.3 (865)	20.4
Thiobencarb 1.50 *fb* bispyribac 0.025	1.0 (0)	1.0 (0)	2.0 (3)	1.7 (2)	4.3 (18)	11.2 (126)	88.3
Anilofos 0.375	4.1 (19)	2.8 (7)	1.9 (3)	1.7 (2)	10.0 (101)	29.2 (876)	19.5
Anilofos 0.375 *fb* bispyribac 0.025	1.0 (0)	1.0 (0)	1.9 (3)	1.8 (2)	4.3 (18)	10.9 (121)	88.7
Pretilachlor 0.75	4.2 (20)	2.5 (5)	1.9 (3)	1.8 (2)	9.8 (96)	29.0 (851)	21.9
Pretilachlor 0.75 *fb* bispyribac 0.025	1.0 (0)	1.0 (0)	1.9 (3)	1.7 (2)	4.4 (20)	11.4 (129)	88.0
Oxadiargyl 0.09	4.0 (18)	2.6 (6)	1.9 (3)	1.7 (2)	10.4 (107)	29.1 (855)	21.4
Oxadiargyl 0.09 *fb* bispyribac 0.025	1.0 (0)	1.0 (0)	1.8 (3)	1.7 (2)	4.4 (19)	10.8 (120)	88.8
Pyrazosulfuron-ethyl 0.015	4.3 (21)	2.7 (7)	2.0 (3)	1.8 (2)	10.4 (108)	29.5 (882)	19.0
Pyrazosulfuron-ethyl 0.015 *fb* bispyribac 0.025	1.0 (0)	1.0 (0)	2.0 (3)	2.0 (3)	4.3 (18)	11.2 (126)	88.3
Two hand weeding	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	10.6 (112)	89.4
Unweeded	6.1 (39)	2.8 (7)	2.1 (4)	1.9 (3)	17.2 (294)	32.7 (1077)	-
LSD (P=0.05)	0.3	0.3	0.3	0.4	0.9	2.2	

Data are square root transformed and values in the parentheses are original values

Table 3. Effect of weed control treatments on crop growth, yield attributes, yield and economics of direct-seeded rice (mean of two years)

Treatment	Final plant height (cm)	Crop dry matter accumulation (g/m^2)	Number of effective tillers/m^2	Number of grains/ panicle	Grain yield (t/ha)	B:C
Pendimethalin 0.75 kg/ha	68.9	776.3	147.5	69.2	2.35	0.09
Pendimethalin 0.75 *fb* bispyribac 0.025 kg/ha	84.5	1257.0	291.3	84.8	5.56	1.38
Butachlor 1.50 kg/ha	70.3	732.2	123.8	64.4	1.41	-0.33
Butachlor 1.50 *fb* bispyribac 0.025 kg/ha	85.0	1203.2	243.9	79.3	5.22	1.28
Thiobencarb 1.50 kg/ha	66.7	777.1	141.3	65.3	1.48	-0.30
Thiobencarb 1.50 *fb* bispyribac 0.025 kg/ha	87.0	1236.7	285.8	79.5	5.29	1.31
Anilofos 0.375 kg/ha	68.5	751.8	133.3	63.8	1.44	-0.31
Anilofos 0.375 *fb* bispyribac 0.025 kg/ha	86.7	1206.6	265.4	77.9	4.66	1.05
Pretilachlor 0.75 kg/ha	68.2	704.2	128.7	64.3	1.48	-0.30
Pretilachlor 0.75 *fb* bispyribac 0.025	85.4	1166.7	272.5	79.1	4.65	1.02
Oxadiargyl 0.09 kg/ha	67.0	687.3	135.0	65.0	1.49	-0.29
Oxadiargyl0.09 *fb* bispyribac 0.025 kg/ha	85.5	1199.9	277.4	80.4	5.22	1.28
Pyrazosulfuron-ethyl 0.015 kg/ha	62.9	479.0	60.3	57.7	1.23	-0.42
Pyrazosulfuron-ethyl 0.015 *fb* bispyribac 0.025 kg/ha	86.3	1170.7	235.4	79.4	4.44	0.94
Two hand weeding	87.6	1252.1	295.1	83.0	5.64	1.12
Unweeded	62.5	331.9	38.8	57.1	1.21	-0.31
LSD (P=0.05)	7.3	104.6	40.1	6.6	0.46	

These results are in conformity with the findings of Walia *et al.* (2009) and Mahajan and Timsina (2011). Walia *et al.*(2008) also reported that it is difficult to raise weed-free DSR with the application of only one herbicide. The dry matter of weeds and grain yield has an inverse relationship with r value of -0.98. Amongst the pre-emergence herbicides, only pendimethalin recorded significantly more grain yield as compared to unweeded control. Similar results were obtained by Singh *et al.* (2009) that under dry seeding, higher grain yield was recorded with pre-emergence application of pendimethalin 1.50 kg/ha. The difference in yield might be due to differences in application mode and efficacy of herbicides against weed species.

Economics

Higher B:C ratio was obtained when bispyribac was sprayed as follow-up application after pre-emergence herbicides as compared with single application of pre-emergence herbicides. The highest net profit was realized from sequential application of pendimethalin and bispyribac, followed by sequential application of thiobencarb/butachlor/oxadiargyl and bispyribac (Table 3). Net returns under weedy situation were negative (loss), which revealed that weed control in DSR is an important component. Similarly, except pendimethalin, all other pre-emergence herbicides resulted in negative returns.

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Management of weeds in direct-seeded rice

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ABSTRACT

A field experiment was conducted during the *Kharif* season of 2012 to 2014 for three years at Agricultural Research Station, Vadgaon Maval, Pune, Maharashtra to find out the efficacy of different chemical and mechanical weed control methods and its economics in direct-seeded rice. From the pooled data it was observed that the pre-emergence application of oxyfluorfen 0.150 kg/ha and post-emergence application metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha as weed control measure in direct-seeded rice gave the highest net returns (` 57,063/ha) with higher B:C ratio (2.3) having lower weed index (2.96) and higher weed control efficiency (91.08 %).

Key words: Direct-seeded rice, Economics, Herbicide, Management, Weeds, Yield

Rice (*Oryza sativa* L.) is a major food grain crop of the world and more than half of the population subsists on it. India is the second largest rice producing country in the world. The method of direct seeding escapes the transplanting and puddling operations which is an attractive and sustainable alternative to traditional transplanting of rice. Direct-dry seeding offers faster and easier planting, reduced labour, earlier crop maturity by 7–10 days, and higher tolerance of water deficit, (Balasubramanian and Hill 2002). A major impediment in the successful cultivation of direct-seeded rice (DSR) in tropical countries is heavy infestation of weeds which often range from 50-91% (Paradkar *et al.* 1997) due to simultaneous emergence of weeds and crop and less availability of efficient selective herbicides for control of weeds during initial stages of crop weed competition. However, weeds are the main biological constraints to the production of DSR (Rao *et al.* 2007, Chauhan and Johnson 2010), which may cause 60-80% reduction in grain yield of rice. Hence, present study was carried out to evaluate the efficacy of different chemical and mechanical weed control methods and its economics in direct-seeded rice.

MATERIALS AND METHODS

A field experiment was carried out during *Kharif* 2012, 2013 and 2014 for three years at Agricultural Research Station, Vadgaon Maval, Pune, Maharashtra. The experiment consisted of ten treatments comprising of unweeded check, weed free and weed control methods, *viz*. pre-emergence application of pendimethalin (1.0 kg/ha), oxyfluorfen (0.150 kg/ha), metsulfuron-methyl + chlorimuron-ethyl (0.004 kg/ha, 25 DAS), pendimethalin (1.0 kg/ha) *fb* metsulfuron-methyl + chlorimuron-ethyl (0.004 kg/ha, 25 DAS), oxyfluorfen (0.150 kg/ha) *fb* metsulfuron-methyl + chlorimuron-ethyl (0.004 kg/ha, 25 DAS), pendimethalin (1.0 kg/ha) *fb* 1 hoeing (25-30 DAS) *fb* 1 HW (40-45 DAS), oxyfluorfen (0.150 kg /ha) *fb* 1 hoeing (25-30 DAS) *fb* 1 HW (40-45 DAS), metsulfuron-methyl + chlorimuron-ethyl (0.004 kg/ha, 25 DAS) *fb* 1 HW (40-45 DAS). The experiment was laid out in randomized block design with three replications. The rice variety *'Phule Samruddhi'* was sown at 22.5 cm distance during *Kharif* 2012-2014. All the herbicides were sprayed by using water 500 L/ha with the help of sprayer fitted with flat fan nozzle. The weed samples taken out as per treatment were oven dried for about one week and dry weight was recorded. All the other recommended package of practices except weed control was followed to raise the direct dry seeded crop.

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RESULTS AND DISCUSSION

Effect on weeds

Dominant weed flora consisted of monocots as *Echinochloa colona* and *Cynodon dactylon* among grasses; *Cyperus iria* and *Cyperus difformis* among sedges and *Eclipta alba*, *Portulaca oleracea*, *Celosia argentea* and *Ludwigia parviflora* among.

Various weed parameters like lowest weight of dry matter of weed (g/m^2), weed control efficiency (%) and lower weed index were significantly influenced by different treatment under studies. Significantly lowest weight of dry matter of weed and weed index with highest weed control efficiency were recorded in the weed-free treatment (Table 1 and 2). The second best treatment was pre-

Table 1. Weight of dry matter of weed (g/m²), weed control efficiency (%) and mean weed index of paddy as affected by different treatments for the year 2012-2014 and pooled mean

Treatment	Weight of dry matter of weed (g/m²)				Weed control efficiency (%)				Weed index			
	2012	2013	2014	Pooled	2012	2013	2014	Pooled	2012	2013	2014	Pooled
Pendimethalin PE 1.0 kg/ha	182.1	167.5	126.6	158.8	38.5	34.7	40.9	38.0	41.1	44.5	40.4	42.0
Oxyfluorfen PE 0.150 kg/ha	155.9	149.7	113.0	139.6	47.3	41.5	47.1	45.3	38.5	40.5	38.3	39.1
Metsulfuron-methyl + chlorimuron-ethyl POE 0.004 kg/ha	161.6	147.0	111.0	139.9	45.4	42.5	48.0	45.3	35.6	33.9	34.8	34.8
Pendimethalin PE 1.0 kg/ha + POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha	67.1	61.1	34.7	54.3	77.1	75.7	83.7	78.8	7.1	15.6	18.0	13.5
Oxyfluorfen PE 0.150 kg/ha + POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha	27.4	25.0	15.9	22.8	90.6	90.1	92.5	91.1	2.0	4.3	2.6	3.0
Pendimethalin PE 1.0 kg/ha + one hoeing (25 to 30 DAS) + one hand weeding (40 to 45 DAS)	146.0	132.9	91.1	123.3	50.5	47.7	57.3	51.9	23.5	30.4	29.6	27.8
Oxyfluorfen PE 0.150 kg/ha + one hoeing (25 to 30 DAS) + one hand weeding (40 to 45 DAS)	121.2	110.3	87.7	106.4	59.0	56.8	58.7	58.1	20.5	24.8	26.0	23.8
POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha + one hand weeding (40 to 45 DAS)	126.0	121.0	91.33	112.8	57.3	52.5	57.1	55.6	26.4	27.2	28.9	27.5
Unweeded check	296.9	257.5	215.5	256.6	00.0	0.0	0.0	0.0	74.7	73.1	60.3	69.4
Weed-free	0.00	0.00	0.00	0.00	100.0	100.0	100.0	100.0	00.0	0.0	0.0	0.0
LSD (P=0.05)	25.9	25.9	17.5	20.8	8.3	9.5	7.1	7.6				

PE – Pre-emergence, POE –Post-emergence

Table 2. Mean grain and straw yield (t/ha) of paddy for the year 2012-2014 and pooled mean

Treatment	Grain yield (t/ha)				Straw yield (t/ha)			
	2012	2013	2014	Pooled	2012	2013	2014	Pooled
Pendimethalin PE 1.0 kg/ha	3.11	3.29	3.48	3.29	3.63	3.77	3.88	3.76
Oxyfluorfen PE 0.150 kg/ha	3.26	3.53	3.61	3.46	3.80	4.06	4.02	3.96
Metsulfuron-methyl + chlorimuron-ethyl POE 0.004 kg/ha	3.41	3.92	3.82	3.72	3.98	4.49	4.25	4.24
Pendimethalin PE 1.0 kg/ha + POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha	4.92	5.00	4.80	4.91	5.74	5.75	5.38	5.63
Oxyfluorfen PE 0.150 kg/ha + POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha	5.20	5.69	5.71	5.53	6.07	6.61	6.45	6.38
Pendimethalin PE 1.0 kg /ha + one hoeing (25 to 30 DAS) + one hand weeding (40 to 45 DAS)	4.06	4.13	4.12	4.10	4.73	4.69	4.58	4.67
Oxyfluorfen PE 0.150 kg/ha + one hoeing (25 to 30 DAS) + one hand weeding (40 to 45 DAS)	4.22	4.47	4.34	4.34	4.92	5.12	4.82	4.95
POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha + one hand weeding (40 to 45 DAS)	3.92	4.35	4.16	4.14	4.57	4.99	4.61	4.73
Unweeded check	1.34	1.60	2.33	1.76	1.56	1.80	2.56	1.98
Weed free	5.31	5.95	5.86	5.71	6.20	6.84	6.63	6.55
LSD (P=0.05)	5.43	6.63	7.25	6.02	6.29	7.33	8.13	6.77

PE – Pre-emergence, POE –Post-emergence

emergence application of oxyfluorfen 0.150 kg/ha and post-emergence application of metsulfuron-methyl 10% + chlorimuron-ethyl 0.004 kg/ha having lowest weight of dry matter of weed (22.77 g/m²) with higher weed control efficiency (91.08%) and lower weed index (2.96). The highest weed biomass was recorded in unweeded check. Result were in close conformity with Singh *et al.* (2014)

Effect on crop

Pooled data, revealed that the mean grain and straw yield (t/ha) of paddy were affected significantly by different treatments (Table 3). It was observed that the significant highest grain and straw yield of paddy (5.71 t/ha and 6.55 t/ha, respectively) were obtained in the weed free treatment. It was at par with

Table 3. Economics of paddy as affected by different treatments for the year 2012-2014 and pooled mean

Treatment	Net returns ($x10^3$ `/ha)				B:C ratio			
	2012	2013	2014	Pooled	2012	2013	2014	Pooled
Pendimethalin PE 1.0 kg/ha	13.29	16.25	18.85	16.13	1.2	1.4	1.4	1.3
Oxyfluorfen PE 0.150 kg/ha	15.73	20.43	21.46	19.21	1.4	1.5	1.4	1.4
Metsulfuron-methyl + chlorimuron-ethyl POE 0.004 kg/ha	18.75	27.69	27.34	24.59	1.4	1.7	1.6	1.6
Pendimethalin PE 1.0 kg/ha + POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha	45.12	46.42	44.09	45.21	2.1	2.1	1.9	2.0
Oxyfluorfen PE 0.150 kg/ha + POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha	50.07	58.81	62.31	57.06	2.2	2.4	2.2	2.3
Pendimethalin PE 1.0 kg /ha + one hoeing (25 to 30 DAS) + one hand weeding (40 to 45 DAS)	27.17	28.21	27.47	27.62	1.6	1.6	1.5	1.6
Oxyfluorfen PE 0.150 kg/ha + one hoeing (25 to 30 DAS) + one hand weeding (40 to 45 DAS)	29.91	34.21	32.09	32.07	1.7	1.7	1.6	1.7
POE application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha + one hand weeding (40 to 45 DAS)	25.86	33.26	32.14	30.42	1.6	1.7	1.6	1.6
Unweeded check	17.83	-13.41	-1.21	-10.82	0.6	0.7	1.0	0.8
Weed free	47.21	58.37	57.59	54.39	1.9	2.2	2.0	2.0
LSD (P=0.05)	9.73	11.76	14.37	11.16				

PE – Pre-emergence, POE –Post-emergence

pre-emergence application of oxyfluorfen 0.150 kg/ha and post-emergence application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg /ha having grain yield (5.53 t/ha) and straw yield (6.38 t/ha). Similar result were in close conformity of Abraham *et al.* (2014)

Economics

Pooled data (Table 3), revealed that weed free treatment recorded significantly highest gross returns (` 1,05,931/ha). However, it was at par with the treatment pre-emergence application of oxyfluorfen 0.150 kg/ha and post-emergence application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha (` 1,02,753/ha).

The significantly highest net returns (` 57,063/ha) was obtained in the treatment of pre emergence application of oxyfluorfen 0.150 kg/ha and post-emergence application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha which was at par with the weed free treatment (` 54390/ha).

The highest B: C ratio (2.3) was observed in pre-emergence application of oxyfluorfen 0.150 kg/ha and post-emergence application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg /ha (Table 3).

The gram was dibbled immediately after harvest of experimental paddy plot to observe the effect of different treatments on succeeding crop. The various herbicides applied to the paddy crop did not affect the germination of the succeeding crop gram.

It was concluded that in drilled paddy for effective management of weeds, pre-emergence application of oxyfluorfen 0.150 kg/ha and post-emergence application of metsulfuron-methyl + chlorimuron-ethyl 0.004 kg/ha at 25 days after sowing in 500 liters of water proved effective and economical.

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Crop establishment, fertility and weed management practices in scented hybrid rice

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ABSTRACT

An experiment was conducted during two consecutive rainy seasons at Rajendra Agricultural University, Pusa to study the effect of establishment method, fertility levels and weed management practices on scented hybrid rice. Two crop establishment methods (standard method of transplanting and SRI method of transplanting), three fertilizer levels (80:40:20, 100:60:40, 120:80:60 N, P_2O_5, K_2O kg/ ha) and three weed management practices (weedy check, one hand weeding (HW) at 35 days after transplanting (DAT) and pre-emergence application of pendimethaline at 1 kg/ha were tested in a randomized block design. SRI method of transplanting recorded higher grain yield than the standard method of transplanting. The yield increased with the increase in fertility levels and was maximum with 120:80:60 kg/ha N, P_2O_5 and K_2O/ha. One hand weeding registered higher grain and straw yields. Weed control efficiency was better with one hand weeding at 35 DAT in comparison to pre–emergence application of pendimethalin at 1 kg/ha.

Key words: Establishment method, Fertility level, Hybrid rice, Weed management

Rice is a staple food of our country and critically important for food security. The demand is expected to grow between 2.0 to 2.5% per annum until 2020, requiring continued efforts to increase productivity while ensuring sustainability. The system of rice intensification (SRI) developed in Madagascar over 3 decades ago is a holistic agro-ecological crop management technique seeking alternative to the conventional high-input oriented agriculture, through effective integration of crop-soil-water continuum. Literature. on SRI is full of controversies regarding its high yield enhancement (Sinclair 2004), additional labour requirement (Moser and Barrette 2003) *etc*. However, at the same time SRI has also received support for yield enhancement (Vijaykumar *et al*. 2006, Kabir and Uphoff 2007), input productivity water saving (Satyanarayana *et al*. 2007). Effect of nutrient management and weed management in SRI is an important and under-addressed issue. Hence, for a system as productive as the SRI system, it is imperative to find out nutritional need of the crop for which wide range of fertilizer doses need to be tested. Addition of fertilizer favours the growth of weeds more than that of crop. The problem of weeds is expected to be more acute under SRI system as compared to conventional transplanting. Hence, fertilizer application without adopting suitable weed control measures becomes a wasteful practice. The objective of this experiment was to evaluate the performance of SRI and standard practices of rice cultivation under optimum combinations of establishment methods, fertility levels and weed management practices.

MATERIALS AND METHODS

An experiment was conducted during rainy (*Kharif*) season of 2005 and 2006 at Crop Research Center, Rajendra Agricultural University, Pusa. The soil was sandy loam in texture, low in available N, P, K and soil pH (8.2) was higher than neutral range. The experiment was laid out in a randomized block (factorial) design comprising two establishment methods, *viz*. standard practice of transplanting with 20 x 15 cm spacing and system of rice intensification method of transplanting with 25 x 25 cm spacing; three levels of N, P_2O_5 and K_2O, *viz*. 80:40:20, 100:60:40 and 120:80:60 kg/ha were applied. Three weed management practices, *viz*. weedy check, hand weeding at 35 DAT and application of pendimethalin at 1kg /ha as pre-emergence. The combinations of all the treatments were replicated thrice. In standard practice of transplanting, 25 days old seedling (1 or 2 seedling/hill) and in SRI method of transplanting, 14 days old seedling (1 seedling/hill) were planted. *Pusa RH-10* of 125 days maturity was the test variety.

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SRI transplanted plots were kept moist throughout the vegetative phase with proper irrigation and drainage facilities. However, in standard practice of transplanting 5±2 cm depth of water was maintained during vegetative phase. In both the methods, 2-3 cm of standing water during reproductive phase was maintained. As per the treatment, the entire quantity of phosphorus as di-amonium phosphate (DAP) and potassium as muriate of potash and half dose of nitrogen as urea was applied as basal, the rest nitrogen was applied in equal splits through urea. The observations on weed density and weed dry weight were recorded. The data were analyzed according to randomized block (factorial) design by standard ANOVA at $P<0.05$ level of significance.

RESULTS AND DISCUSSION

Growth and yield attributes

Rice establishment methods, fertility levels and weed management practices had significant effect on most of the growth and yield attributes. The SRI method of crop establishment had taller plants as compared to standard method, but the difference was non-significant. Number of tillers/hill, length of panicles (cm), no. of fertile grain/panicle and 1000-grain weight registered significantly higher values in case of SRI method than standard method of crop establishment. Panicles/m^2 at harvest did not vary due to variation in crop establishment methods. Under wider spacing in case of SRI, the growth potential of the crop is fully expressed. Transplanting young seedling below the age of 15 days *i.e.* prior to start of fourth phyllocron of growth, preserves plant potential for tillering and root growth which is otherwise reduced under conventional method of transplanting. Though the tiller number under individual hill was higher under wider spacing, the total tiller production per unit area was higher under closer spacing (Table 1). Increased tiller production per unit area with decrease plant spacing has also been reported by Siddiqui *et al.* (1999). Numerically more panicles/m^2 was recorded for standard method of crop establishment than the SRI system due to higher plant density. The plants getting wider spacing as in case of SRI method of transplanting had lower below and above ground competition so essential for better grain filling, higher test weight and number of fertile grains/panicle and also for preventing mortality of late formed tillers resulting in higher productive tillers and increased weight of panicles.

The growth and yield attributes except 1000-grain weight, increased significantly with increase in fertility levels; and were more in plots receiving 120:80:60 kg/ha N:P_2O_5: K_2O. The increase in levels of fertilizer improved all growth and yield attributing parameters due to the adequate nutrient availability since early growth stages ensured proper nutrition for enhanced photosynthetic efficiency and accumulation of photosynthates from source to sink with increased level of fertilizer. Chopra and Chopra (2000) also reported no variation in test weight due to N-levels, indicating negligible influence of N on grain filling in medium duration rice.

Weed population, weed dry weight and weed growth rate were found minimum with one hand weeding at 35 DAT which were significantly lower than that of application of pendimethilin as a pre-

Table 1. Growth, yield attributes and yields of rice as affected by establishment method, fertility level and weed management practices

Treatment	Plant height (cm)		Length of panicle (cm)		No. of fertile grain/ panicle		Panicles/m^2 at harvest		1000-grain weight (g)		Grain yield (t/ha)		Straw yield (t/ha)	
	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006	2005	2006
Establishment method														
Standard method (20 x 15 cm)	82.1	82.5	24.2	24.5	97	102	228	299	21.3	21.8	4.89	5.10	6.04	6.28
SRI method (25 x 25 cm)	84.6	85.2	26.2	26.7	103	111	279	291	21.9	22.4	5.19	5.59	6.16	6.54
LSD (P=0.05)	NS	NS	1.09	0.92	3.66	3.94	N5	N5	0.36	0.40	0.27	0.23	NS	0.25
Fertility level														
80:40:20 N,P_2O_5, K_2O	78.0	78.1	22.6	23.2	89	94	248	262	21.4	21.8	4.45	4.71	5.61	5.90
100:60:40 N,P_2O_5, K_2O	84.9	85.7	25.8	26.4	103	100	289	304	21.6	22.2	5.13	5.49	6.29	6.53
120:80:60 N,P_2O_5, K_2O	87.2	87.8	27.1	27.3	110	116	313	320	21.8	22.4	5.48	5.80	6.39	6.79
LSD (P=0.05)	5.3	4.31	1.33	1.13	4.48	4.83	15.5	17.6	NS	NS	0.33	0.29	0.25	0.31
Weed management														
Weedy check	76.6	79.7	23.4	24.2	83	88	236	250	21.2	21.7	4.14	4.41	5.24	5.51
HW at 35 DAT	88.3	87.4	26.2	27.1	112	118	313	329	21.9	22.5	5.59	5.93	6.64	6.96
Pre-emergence pendimethalin	85.2	84.4	26.0	25.5	107	113	301	308	21.7	22.2	5.33	5.68	6.41	6.78
LSD (P=0.05)	5.30	4.31	1.33	1.13	4.48	4.83	15.5	17.6	0.44	0.49	0.33	0.29	0.25	0.31

emergence and weedy check. In case of weed control efficiency, percentage was also higher with hand weeding. However, the application of pendimethelin was also effective to minimize weed population, weed dry weight and weed growth rate than the check but it was significantly lower than that of hand weeding (Table 2).

The grain yield increased linearly with corresponding increase in fertility levels and higher yield was observed in plot treated with 120:80:60 kg/ ha N: P_2O_5: K_2O. The nutrient uptake by plants increase with increase in fertilizer dose (Table 3) which significantly increased the growth and yields attributes and ultimately led to greater assimilation of photosynthates.

Amongst weed management practices, one hand weeding at 35 DAT was found significantly superior, which registered more growth and yield attributes, followed by application of pendimethalin at 1.0 kg/ha during both the years. The pre-emergence application of pendimethalin did not control all the weeds and might have caused phototoxity to emerging seedling, also with the lapse of time, the effectiveness of herbicides mostly decrease and the weeds tends to regenerate which later on hindered the efficiency of production factor resulting in lower values of growth and yield attributes than hand weeding. Whereas, hand weeding resulted in diminished crop weed competition at most critical period of weed interference and thus the weed free environment prevailing during rice growth and development ensured vigorous plants resulting in higher yields. Due to stiff competition from weeds the growth and yield attributes were recorded the least in the weedy check plots.

Table 2. Weed parameters as affected by different treatments

Treatment	Weed population/m^2 at 60 DAT		Weed dry wt. (g/m^2) at 60 DAT		Weed growth rate at 30-60 DAT (g/day)		W.C.E (%) at 60 DAT	
	2005	2006	2005	2006	2005	2006	2005	2006
Establishment method								
M_1-Standard method (20x15cm)	110.3	105. 4	36.7	35.4	0.81	0.84	48.87	42.95
M_2-SRI method (25x25cm)	112.8	107.4	37.3	36.3	0.80	0.80	48.19	43.26
LSD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fertility level								
F_1-80:40:20 N,P_2O_5,K_2O	109.7	104.3	36.3	35.4	0.79	0.78	48.47	42.78
F_2-100:60:40 N,P_2O_5,K_2O	111.4	106.7	37.2	35.8	0.81	0.86	49.15	43.22
F_3-120:80:60 N,P_2O_5,K_2O	113.6	108.1	37.5	36.3	0.81	0.80	47.97	43.32
LSD(P=0.05)	NS	NS	NS	NS	NS	0.05	NS	NS
Weed management								
W_0- Weedy check	207.3	197.6	71.9	69.6	1.85	1.81	-	-
W_1-HWat 35 DAT	37.4	35.8	9.10	8.83	- 0.24	- 0.14	87.34	73.89
W_2- Pre-emergence pendimethalin	90.1	85.7	30.0	29.1	0.81	0.78	58.25	55.43
LSD(P=0.05)	6.16	5.44	2.22	1.85	0.05	0.05	3.66	2.96

Table 3. Nutrient uptake by weeds as affected by different treatments

Treatment	Nutrient uptake by weeds (kg/ha)					
	N		P		K	
	2005	2006	2005	2006	2005	2006
Establishment method						
M_1-Standard method (20 x 15 cm)	12.9	13.4	2.91	2.98	18.3	17.4
M_2-SRI method (25 x 25 cm)	12.7	13.1	2.84	2.90	17.6	17.1
LSD (P=0.05)	NS	0.22	0.06	0.05	0.38	0.29
Fertility level						
F_1-80:40:20 N, P_2O_5, K_2O	13.1	13.4	2.88	2.96	17.9	17.3
F_2-100:60:40 N, P_2O_5, K_2O	13.3	13.3	2.99	3.00	18.3	17.3
F_3-120:80:60 N, P_2O5, K_2O	12.2	12.9	2.74	2.86	17.7	16.9
LSD (P=0.05)	0.31	0.27	0.07	0.06	N5	0.35
Weed management						
W_0-Weedy check	20.2	23.3	4.84	5.23	31.6	30.2
W_1-HW at 35 DAT	5.94	5.98	1.47	1.32	8.19	7.79
W2- Pre-emergence pendimethalin	12.4	10.3	2.30	2.26	14.2	13.6
LSD (P=0.05)	0.31	0.07	0.07	0.06	0.46	0.35

Yield

Crop establishment methods, fertility levels and weed management practices significantly influenced the grain yield during both the years. The crop raised by SRI method produced significantly higher grain yield (5.59 t/ha) than the plots planted under standard method of establishment (4.85 t/ha) and (5.10 t/ha) in 2005 and 2006, respectively. The favourable effect on growth and yield attributes resulted in higher grain yield under SRI method of crop establishment. Sparse planting in SRI avoids the inhibition of root growth that results from crowding and by exposing plants to more light and air, SRI create border effect for the whole field (Satyanarayan *et al.* 2007).

Amongst weed management practices, one hand weeding at 35 DAT registered the highest mean yield followed by pre-emergence application of pendimethalin both of which were significantly superior to weedy check. These results are in conformity with the findings of Agrawal and Sharma (1997) and Sarath and Thilak (2004).

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Weed control in forage oat through conservation agriculture

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ABSTRACT

A field experiment was conducted during *Rabi* season of two consecutive years of 2010-11and 2011-12 to evaluate the efficacy of different tillage practices in combination with various nutrient levels on productivity and quality along with weed control efficiency in forage oat under plateau region of Jharkhand. Variation in tillage and nutrient level significantly influenced the infestation of crop associated weeds, leaf area index, green forage yield, uptakes of calcium as well as, iron and contents of crude protein as well as crude fiber of forage oat. Population density of narrow, broad-leaved weeds and sedges and its biomass under zero tillage were lesser than conventional and minimal tillage. Application of biofertilizers with 75% recommended dose of fertilizer (RDF) remained at par with 100% RDF. However, maximum forage yield with improved quality was recorded under 125% RDF. Zero tillage practiced in forage oat was equally effective as conventional tillage with regards to productivity and quality of forage oat.

Key words: Biofertilizer, Green forage yield, Nutrient, Oat, Tillage, Weed infestation

Weeds are self germinating, nutrient extractor and competitor for light and space during crop growth. It is a major threat not only during rainy season but also during winter. Demand of food grains and fodder is being increased day by day to fulfill the need of human beings and also to bridge the challenge of fodder deficit for animals. India is rearing 15% of the world animal population with fodder production in 7.06% of net cropped area as well as on 3.7% of pasture/grazing land. Availability of fodder per animal is only 18.2 kg which is far below the requirement and keeping the animal half fed. During rainy season, some natural grasses help the farmers to mitigate the shortage of green herbage up to some extent but, its scarcity during lean period (winter) is very common in Jharkhand and other states. Due to shortage of irrigation, farmers are not inclined towards forage production over the field crops of human interest. Green forage oat is a basic fodder of winter.

Farmers are usually reluctant to chemical weed control because of ignorance and prevailing concepts regarding utilization of weeds as fodder, which may be harmful to the animals. Thus, suppression of weed is essential for improving the productivity and quality of herbage produced. Manual weed control is costly while, chemical control leave hazards to the environment. Better management of crop can be done through conservation agriculture. Among the different inputs, application of balanced nutrition in oat is essential for sustainable production. Keeping the facts in view an experiment was conducted to control the weed proliferation with improved productivity and quality of herbage produce through conservation agriculture.

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MATERIALS AND METHODS

A field experiment was carried out during *Rabi* 2010-11 and 2011-12 at the forage field situated at Ranchi Veterinary College campus under Birsa Agricultural University, Ranchi. The soil of field was sandy loam in texture having sand (56.8%), silt (28.0%), clay (15.2%) and water holding capacity 38.68%, pH 6.2, organic carbon 3.8 g/kg, available nitrogen 232 kg/ha, available phosphorus (P_2O_5) 23.25 kg P_2O_5/ha and available potassium (K_2O) 156.41 kg K_2O/ha. The experiment constituted in split plot design with three tillage management *viz.* zero tillage, minimal tillage and conventional tillage assigned in main plot and four nutrient levels, 125, 100, 75% of recommended dose of fertilizer (RDF) and 75% RDF + biofertilizers (PSB + *Azotobacter*) in sub-plot with three replications. The fodder oat cultivar '*Kent*' was sown in the second week of November during both the year by keeping row to row distance 20 cm with recommended seed rate 100 kg/ha under medium land situation. Fertilizers were applied at the time of sowing through urea, DAP and MOP as basal application. Biofertilizers were applied as seed treatment/inoculation in the form of PSB at 500 g/ha and *Azotobacter* at 500 g/ha and further top dressing were carried through urea. The data recorded on growth, yield, weed density and quality of forage oat were tabulated and subjected to analysis by using analysis of variance (ANOVA) and treatment was tested by F-test. The data on weed density and weed biomass were subjected to square root transformation $\sqrt{x+0.5}$ before carrying out analysis of variance and comparison was made on transformed value.

RESULTS AND DISCUSSION

Tillage management

Tillage management significantly influenced the different types of weed population in forage oat. Zero tillage recorded significantly less narrow-weed (60.20/m^2) and broad weed (11.08/m^2) over minimal and conventional tillage, while less sedges under conventional tillage (50.79/m^2). Dry weight of weed (g/m^2) was significantly less under zero tillage (2.86 g/m^2) than minimal tillage (3.96 g/m^2) and conventional tillage (3.07 g/m^2). Total weed population and weed dry weight were in the order of zero tillage < conventional tillage < minimal tillage (Table 1). The difference in weed composition due to different tillage treatments might be due to variable environments, particularly soil physical condition created under different tillage systems (Singh 1992). Tillage not only favors the crops but also favors the germination, and growth of weeds but at deep ploughing with mould board plough or with increased level of tillage operation, weed seeds or its residue get damaged or go well within the soil thus, germination delayed or hampered in comparison to minimal tillage. While without tillage operation as under zero tillage, oat seeds were placed in between the two rows of paddy residue thus, got less congenial condition to germinate and to get less chance of nutrient utilization by weeds, resulted in poor performance of weed under zero tillage. Tillage operation received suitable environment which improved germination of weeds. The minimum population and dry weight of *Phalaris minor* were recorded under zero tillage and maximum under conventional tillage system in wheat cultivation (Sharma *et al*. 2002). The less weed problem under zero tillage may be due to less soil disturbance helping in keeping the weed seeds at deeper depth (Sharma *et al*. 2002). Due to less soil disturbance under zero tillage, weed germination usually remained less as compared to conventional tillage.

Tillage management had significant effect on growth, yield and quality of forage oat and also influenced the weed proliferation. Leaf area index (LAI) of forage oat at both the cuts under different tillage and nutrient management was influenced significantly. Maximum LAI at both the cuts was recorded under conventional tillage (4.49 and 5.70, respectively) which was significantly higher over zero and minimal tillage. Zero tillage recorded significantly higher LAI compared to minimal tillage (Table 2). Leaf area index (LAI), is best parameter to see the capacity of a crop producing dry matter. Leaf area index at first and second cut under conventional tillage were 8.71% and 16.32%, respectively higher over minimal tillage. This was due to increase in number of photosynthetic green area which led to improvement in photo synthetic efficiency. These findings were in close confirmatory with the result of Singh (1992). Leaf area index increased as growth progressed and achieved optimum at the time of second cut.

Tillage and nutrient management had significant effect on green forage yield at each cut. Green forage yield (GFY) under conventional tillage at first cut (10.95 t/ha) and total (35.46 t/ha) was at par with zero tillage while, at both the cuts and total GFY under

Table 1. Effect of tillage and nutrient management on weed flora in forage oat (pooled)

Treatment	Weed population/m^2				Weed dry Weight (g/m^2)
	Narrow-leaf	Broad-leaf	Sedges	Total	
Tillage management					
Zero tillage	7.82 (60.2)	3.46 (11.1)	8.44 (70.5)	11.9 (141.7)	2.86 (7.39)
Minimal tillage	10.34 (106.4)	6.01 (35.8)	10.73 (114.7)	16.1 (257.3)	3.96 (14.83)
Conventional tillage	10.12 (101.7)	4.33 (18.1)	7.17 (50.8)	13.1 (170.8)	3.07 (8.45)
LSD (P=0.05)	0.47	0.47	0.74	0.51	0.15
Nutrient management					
125% RDF	9.84 (98.8)	5.14 (27.3)	9.52 (92.6)	14.8 (213.7)	3.61 (12.2)
100% RDF	9.72 (95.1)	4.78 (22.7)	9.10 (76.3)	13.9 (194.2)	3.33 (10.3)
75% RDF	8.82 (77.6)	4.03 (16.1)	8.29 (69.4)	12.7 (163.1)	3.04 (8.3)
75% RDF + biofertilizer	9.53 (91.2)	4.46 (20.5)	8.65 (76.3)	13.6 (188.5)	3.29 (10.1)
LSD (P=0.05)	0.77	0.56	0.80	0.92	0.26

*****Un parentheses data are square root transformed $(x \pm 0.5)^{-2}$ value.

Table 2. Effect of tillage and nutrient management on leaf area index, green forage yield of forage oat (pooled)

Treatment	Leaf area index		Green forage yield (t/ha)		
	1st cut	2nd cut	1st cut	2nd cut	Total
Tillage management					
Zero tillage	4.29	5.25	10.6	23.5	34.2
Minimal tillage	4.13	4.90	7.74	21.6	29.3
Conventional tillage	4.49	5.70	10.9	24.5	35.4
LSD (P=0.05)	0.07	0.07	0.62	0.88	2.92
Nutrient management					
125% RDF	4.82	5.93	11.5	25.9	37.5
100% RDF	4.33	5.29	10.1	23.6	33.7
75% RDF	3.85	4.65	7.80	20.3	28.1
75% RDF + biofertilizer	4.24	5.27	9.73	22.9	32.7
LSD (P=0.05)	0.44	0.62	1.40	2.65	3.95

conventional tillage was significantly higher to minimal tillage (Table 2). Similarly, zero tillage was also significantly superior over minimal tillage at both the cuts and total.

Under conventional tillage, soil was pulverized well and created congenial conditions for proper root establishment which helped to utilize ample nutrients by crop in presence of sufficient moisture and sun shine hour throughout the growth period resulted in higher production of photosynthates. In other words, green forage yield under minimal tillage were less as compared to both zero and conventional tillage. Minimal tillage neither recorded the benefit of zero tillage in terms of soil health improvement nor the intensification or activities of roots facilitated due to deep ploughing resulted in inefficient utilization of moisture, nutrient and thereby growth and development and finally the crop yield. These finding was also in symmetry with the finding of Kumar *et al.* (2001). Mohammad *et al.* (2006) also reported more GFY and DFY under conventional tillage in oat over zero tillage. Further, more GFY and DFY were recorded at second cut which was due to more photo-synthetically active area *i.e.*, higher LAI resulting in greater production of dry matter per unit area (Patel *et al.* 2010). The photosynthesis effectiveness depends upon favorable environmental condition as the low temperature prevailing immediately after cutting affected the re-growth of crop and increased temperature at later stages decreased the plant height and other yield attributes (Bali *et al.* 1998).

Leaf: stem (LS) ratio under conventional tillage and zero tillage were at par and were significantly superior over minimal tillage. More uptake of iron and calcium were recorded under conventional tillage.

Table 3. Interaction effects of tillage and nutrient management on total green forage yield (t/ha) of fodder oat under medium land condition (pooled)

Tillage management (T)	Nutrient management(N)				Mean
	125% RDF	100% RDF	75% RDF	75% RDF + biofertilizer	
Zero tillage	39.1	35.9	28.3	33.1	34.2
Minimal tillage	32.6	28.4	26.1	30.1	29.3
Conventional	40.8	36.2	29.7	34.8	35.4
Mean	37.5	33.7	28.1	32.7	
	SEm ±		LSD (P=0.05)		
Between N at same T	0.77		2.28		
Between T at same or different N	0.72		3.15		

Crude protein and crude fiber under conventional and zero tillage were at par however, higher crude protein (10.26% at first cut) and crude fiber (27.98 and 29.56%) at both the cuts under conventional tillage were recorded (Table 3). The decrease in L:S ratio might be due to crop age factor and lodging induced leaf senescence. Joshi *et al.* (1997) reported that in general, specific leaf weight increased with age of the crop except a short fall just after first cut. The response of nutrient up to 125% RDF was also observed on leaf: stem ratio at both the cuts. Higher L:S ratio at first cut was recorded at each levels of nutrient management compared to second cut. This was due to more translocation of photosynthates in leafy portion during early stage of growth *i.e.*, from germination to first cut and decreased with the age of crop. Singh *et al.* (1998) and Sharma *et al.* (2001) also noticed the similar results.

Nutrient management

Leaf area index, green forage yield, leaf: stem ratio, uptake of calcium, iron, contents of crude protein, crude fiber and weed proliferation in terms of weed density and its biomass were recorded higher at 125% RDF. The 100% RDF and 75% RDF + biofertilizer remained at par with each other at both the cuts. Different nutrient levels with or without application of biofertilizers significantly affected the yield attributing characters and yield of forage oat. Green forage yield (GFY) at each cuts were significantly enhanced up to higher dose of nutrients and this might be due to improvement in growth and yield attributing characters which were more at 125% RDF. Similarly 75% RDF + biofertilizers was comparable to 100% RDF due to extra benefit of availability of nutrients through microbial activity specially phosphorus as well as nitrogen availability which leads to better yield attributing parameters (Table 4).

Table 4. Effect of tillage and nutrient management on nutrient uptake and crude protein and fiber content in forage oat (pooled)

Treatment	Leaf : stem ratio		Total uptake (kg/ha)		Protein content (%)		Crude fiber content (%)	
	1st cut	2nd cut	Ca	Fe	1st cut	2nd cut	1st cut	2nd cut
Tillage management								
Zero tillage	2.97	1.96	33.4	0.63	10.1	9.54	26.1	27.6
Minimal tillage	2.92	1.82	30.5	0.55	9.69	9.37	24.5	26.1
Conventional tillage	2.99	2.01	35.1	0.68	10.3	9.44	27.9	29.5
LSD (P=0.05)	0.04	0.07	NS	0.32	0.27	0.15	1.92	1.92
Nutrient management								
125% RDF	3.48	2.51	38.2	0.71	10.3	9.86	26.6	28.2
100% RDF	2.83	1.94	33.7	0.61	10.1	9.44	26.3	27.8
75% RDF	2.75	1.35	28.7	0.54	9.54	9.10	25.8	27.4
75% RDF + biofertilizer	2.78	1.93	31.3	0.60	10.1	9.39	26.0	27.5
LSD (P=0.05)	0.35	0.26	2.23	0.03	0.44	0.38	0.15	0.15

Crude protein and crude fiber increased with increased level of nutrients. During second cutting, proportion of leaf and stem decreased and fodder became harder than that of first cut which reduced the protein content. Similar results for quality parameter in forage oat were also reported by Aklilu (2005). Increased nutrient level also improved the growth of weeds and increased weed density and dry weight per unit area. *Azotobactor* and PSB improved the availability of nitrogen and phosphorus in soil. Thus, 75% RDF along with biofertilizers also remained comparable with 100% RDF (Devi *et al.* 2009).

Interaction

Interaction between tillage and nutrient management had significant effect on green forage yield at both the cuts and on total. Total green forage yield under zero, minimal and conventional tillage managements increased with increased level of nitrogen up to 125% RDF. Total GFY under conventional tillage was at par with zero tillage at RDF, while both the treatments were significantly higher over minimal tillage in similar nutrient level. Green forage yield under conventional tillage at 125% RDF (40.8 t/ha) was significantly higher over all the treatment combinations except zero tillage at the same level of nutrient which was 56.42 per cent more than the minimum under minimal tillage at 75% RDF (Table 2). This might be due to congenial condition for growth and development resulted into higher yield.

Based on the findings, it be concluded that zero tillage is as good as conventional tillage with regards to productivity, quality and suppression of weeds.

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Bio-efficacy of ready-mix formulation of clodinafop-propargyl + metsulfuron for control of mixed weed flora in wheat

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ABSTRACT

Field efficacy of ready mix formulation of clodinafop-propargyl + metsulfuron-methyl was evaluated against mixed weed flora in wheat during winter seasons of 2010-11 and 2011-12 at Punjab Agricultural University, Ludhiana. The results indicated that ready-mix of clodinafop+ metsulfuron at 75 g/ha + 0.2% surfactant recorded effective control of grass and broadleaf weeds and recorded similar wheat grain yield to sequential application of clodinafop 60 g/ha and metsulfuron 4 g/ha and weed free without any phytotoxicity symptoms on the crop.

Key words: Clodinafop, Metsulfuron, Ready-mix formulation, Weeds, Wheat

In India, wheat is the second important food crop, being next to rice. Punjab covers 14% of the total wheat area and accounts for 25% of national wheat production. The wheat crop is invaded by grass and broad-leaved weeds which can reduce the grain yield up to 80%. Loss in yield depends upon weed type, density, timing of emergence, wheat density, wheat cultivar and soil and environmental factors (Malik and Singh 1995, Chhokar and Malik 2002). Among grass weeds, *Phalaris minor* and among broad-leaved weeds, *Rumex dentatus*, *Chenopodium album*, *Anagallis arvensis*, *Medicago denticulata, Melilotus alba*, *Fumaria parviflora*, *Coronopus didymus etc*. are of major concern in irrigated wheat under rice–wheat system (Chhokar *et al*. 2006). The farmers end up with applying two herbicides at different timings for the control of grasses and broad-leaved weeds which add to the labour costs and many times the delayed application of any of the herbicides results in poor control of weeds.

Hence, there is a need for compatible herbicide combinations which could control the weeds in a single pass. Already, a few herbicides are there which controls a variety of weeds in wheat, but one or the other weeds escape with the use of these herbicides. Farmers are using different mixtures of herbicides in wheat already at their own. In some cases, the herbicide mixtures, when used at higher doses, cause phytotoxicity in wheat. However, in ready-mix formulations, the different herbicides are mixed in desired concentration to avoid any phytotoxicity on the crop. The use of ready mix formulations are advantageous over sequential applications, due to saving in application timing and cost. Herbicide mixtures, besides providing control of complex weed flora, also helps in managing and delaying the herbicide resistance in weeds (Wruble and Gressel 1994). The field efficacy of ready mix formulation of clodinafop and metsulfuron was evaluated for control of mixed weed flora in wheat.

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MATERIALS AND METHODS

A field experiment was conducted at Punjab Agricultural University Ludhiana during *Rabi* 2010-11 and 2011-12. Fifteen treatments, *viz*. ready-mix formulation of clodinafop-propargyl 15% + metsulfuron-methyl 1% at 45, 60, 75, 90 and 120 g/ha applied with and without 0.2% surfactant, clodinafop 60 g /ha, metsulfuron 4 g/ha + surfactant 0.2%, clodinafop followed by metsulfuron at 60 *fb* 4 g/ha, weed free and unsprayed control, were evaluated in RCBD with three replications. All the herbicides were applied at 35 days after sowing (DAS) with knapsack sprayer having discharge rate of 375 liters water/ha.

The wheat variety '*PBW 550*' was sown in 22.5 cm spaced rows using 100 kg seed/ha on 16.11.2010 and 17.11. 2011 during first and second years, respectively. The crop was fertilized with 125 kg N, 60 kg P_2O_5 and 30 kg K_2O per ha. The nitrogen was applied in the form of urea (46% N), P_2O_5 in form of diammonium phosphate and K_2O in form of muriate of potash (60% K_2O). Entire quantity of phosphorus and potassium and one-half of nitrogen was drilled at the time of sowing. Remaining N was broadcasted with the first irrigation. Data on weed count and dry matter accumulation of weeds was taken, with quadrate measuring 0.5 x 0.5m placed randomly at three spots per plot, at 60 DAS. Weeds were cut from the ground level, dried in sun and then oven dried at 60 °C and then weighed. The weed data were subjected to square root transformation before analysis. The data on panicle length, effective tillers per square metre and grain yield of wheat were recorded at the time of crop harvest.

RESULTS AND DISCUSSION

Effect on weeds

The experimental field was infested with grass weed *Phalaris minor* and few broad-leaved weeds, *viz. Chenopodium album, Anagallis arvensis, Medicago denticulata, Rumex dentatus* and *Coronopus didymus*.

Ready mix formulation of clodinafop + metsulfuron, when applied with surfactant, recorded similar population but lower dry matter of *P. minor* during both the years, as compared to its application without surfactant. However, addition of surfactant in clodinafop + metsulfuron ready mix significantly reduced the population and dry matter accumulation of broad-leaved weeds as compared to without surfactant during both the years. Clodinafop is basically a grass herbicide and provide effective control of grass weeds without the use of external surfactant. Metsulfuron is a broad-leaved herbicide and applied along with surfactant for effective control of weeds. Hence, the control of *P. minor* was similar when the ready-mix of clodinafop and metsulfuron was used even without surfactant while addition of surfactant enhanced the control of broad-leaved weeds. The population and dry matter did not vary among different doses of clodinafop and metsulfuron applied with surfactant, however, the dry matter was remarkably reduced at 75 g/ha which was significantly lower than its lower dose and at par with its higher doses and clodinafop alone (Table 1).

The control of broad-leaved weeds was significantly reduced with the increase in the dose of ready-mix clodinafop and metsulfuron up to 75 g/ha and was at par to use of metsulfuron + surfactant applied alone. The application of ready mix clodinafop and metsulfuron at 75 g/ha recorded the highest weed control efficiency, for grass and broad-leaved weeds and was at par to sequential application of clodinafop and metsulfuron during both the years. Clodinafop alone at 60 g/ha recorded effective control of *P. minor*, however, being only a grass killer it did not control broad-leaved weeds. Metsulfuron alone at 4 g/ha recorded effective control of only broad-leaved weeds, being a broa-leaved weed killer. Ready-mix formulation of clodinafop and metsulfuron did not provide effective control of broad-leaved weeds at all the doses, when applied without surfactant. The ready-mix of clodinafop and metsulfuron when applied with and without surfactant at 45 and 60 g/ha was poor on grass and broa-leaved weeds (Table 1 and 2). Effective control of complex weed flora in wheat with tank-mix or ready-mix formulation of clodinafop + metsulfuron and ready-mix formulation

Table 1. Effect of herbicide treatments on weed density and dry matter of weeds in wheat during *Rabi* 2010-11

Treatment	Dose g/ha	60 DAS				WCE (%)	
		P. minor population (no./m²)	BLW population (no./m²)	Dry weight of *P. minor* (g/m²)	Dry matter of BLW (g/m²)	Grass weeds	Broad-leaved weeds
Clodinafop + metsulfuron	45+3	2.2 (4)	3.0 (8)	4.6 (20)	7.6 (56)	89.5	56.9
Clodinafop + metsulfuron	60+4	2.0 (3)	2.9 (7)	4.5 (19)	6.7 (44)	90.1	66.2
Clodinafop + metsulfuron	75+5	1.9 (3)	2.8 (7)	4.2 (17)	5.5 (29)	91.1	77.7
Clodinafop + metsulfuron	90+6	1.7 (2)	1.8 (2)	4.0 (15)	4.4 (19)	92.1	85.4
Clodinafop + metsulfuron	120+8	2.1 (3)	1.4 (0.8)	3.4 (11)	4.8 (22)	94.2	83.1
Clodinafop + metsulfuron + S	45+3+S	2.1 (3)	2.6 (6)	5.1 (25)	6.0 (34)	86.9	73.8
Clodinafop + metsulfuron + S	60+4+S	1.8 (2.2)	2.0 (3)	3.3 (10)	3.9 (15)	94.8	88.5
Clodinafop + metsulfuron + S	75+5+S	1.6 (2)	1.7 (2)	2.6 (6)	3.3 (10)	96.9	92.3
Clodinafop + metsulfuron + S	90+6+S	1.5 (1)	1.6 (2)	2.8 (7)	3.5 (11)	96.3	91.5
Clodinafop + metsulfuron+ S	120+8+S	1.2 (0.7)	1.5 (1)	2.4 (5)	2.7 (6)	97.4	95.4
Clodinafop *fb* metsulfuron	160 *fb* 4	2.1 (3)	1.8 (2)	3.2 (9)	3.6 (12)	95.3	90.8
Metsulfuron	4	5.2 (26)	2.1 (4)	13.2 (187)	5.0 (24)	2.1	81.5
Clodinafop	160	2.5 (5)	4.2 (17)	3.3 (10)	10.8 (125)	91.1	3.8
Weed free	-	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	100	100
Unweeded control	-	5.3 (28)	4.4 (18)	13.9 (191)	11 (130)	-	-
LSD (P=0.05)		0.5	0.4	0.5	0.5	-	-

Parentheses are original means and data is subjected to square root transformation; S=Surfactant 1250 mL/acre at 64 g/ha has been reported from Haryana (Punia *et al.* 2004, Malik *et al*. 2013). Application of clodinafop + metsulfuron at 75+5 g/ha with surfactant was found to be most effective and provided 97.3% control of grassy weeds and excellent control (96.5%) of broad-leaved weeds were reported by Singh *et al.* (2012).

All the weed control treatments recorded significantly higher wheat grain yield than unsprayed control during both the years. Ready-mix formulation of clodinafop + metsulfuron at 75 g/ha with 0.2% surfactant produced the highest wheat grain yield (5.77 and 5.50 t/ha) during both the years. Its higher dose of 90 and 120 g/ha though controlled weeds effectively (Table 1 and 2) but recorded significant reduction in effective tillers and grain yield (Table 3). The differences in wheat grain yield were reflected in the effective tillers and panicle length under different weed control treatments. Application of clodinafop and metsulfuron alone recorded lower grain yield due to poor control of broad-leaved and grass weeds, respectively. The ready-mix formulation of clodinafop and metsulfuron did not show any phytotoxicity on wheat plants at all the doses tested.

Table 2. Effect of different treatments on weed count and dry matter of weeds during *Rabi* 2011-12

Treatment	Dose g /ha	60 DAS				WCE (%)	
		P. minor (no./m^2)	Broad-leaved weeds (no./m^2)	Dry wt. *P. minor* (g/m^2)	Dry wt. BLW (g/m^2)	Grass weeds	Broad-leaved weeds
Clodinafop + metsulfuron	45+3	3.1 (9)	3.7 (13)	4.3 (17)	6.8 (44)	73.8	33.3
Clodinafop + metsulfuron	60+4	3.2 (9)	3.3 (10)	4.0 (15)	6.0 (35)	76.9	47.0
Clodinafop + metsulfuron	75+5	2.8 (7)	2.9 (7)	3.7 (13)	4.9 (23)	80.0	65.2
Clodinafop + metsulfuron	90+6	2.5 (6)	2.7 (7)	3.3 (10)	3.8 (14)	84.6	78.8
Clodinafop + metsulfuron	120+8	1.7 (2)	1.4 (1)	1.8 (2)	1.7 (2)	96.9	97.0
Clodinafop + metsulfuron + surfactant	45+3+S	3.0 (8)	3.5 (12)	4.2 (17)	6.1 (37)	73.8	43.9
Clodinafop + metsulfuron + surfactant	60+4+S	2.0 (3)	2.4 (5)	2.4 (5)	3.2 (9)	92.3	86.4
Clodinafop + metsulfuron + surfactant	75+5+S	1.5 (1)	1.9 (3)	1.6 (2)	2.0 (3)	95.4	92.4
Clodinafop + metsulfuron + surfactant	90+6+S	1.6 (2)	1.8 (2)	1.8 (3)	2.2 (4)	95.4	93.9
Clodinafop + metsulfuron + surfactant	120+8+S	2.7 (6)	3.1 (8)	1.3 (0.8)	2.8 (7)	98.8	89.4
Clodinafop *fb* metsulfuron	160 *fb* 4	1.8 (2)	1.8 (2)	2.0 (3)	2.4 (5)	96.9	95.5
Metsulfuron	4	4.1 (16)	2.5 (6)	6.0 (35)	3.1 (9)	46.2	86.4
Clodinafop	160	3.4 (11)	4.5 (19)	3.7 (13)	7.8 (54)	80.0	18.2
Weed free	-	1.0 (0)	1.0 (0)	1.0 (0)	1.0 (0)	100	100
Unweeded control	-	3.9 (15)	5.2 (26)	8.1 (65)	8.2 (66)	-	-
LSD (P=0.05)	-	0.5	0.4	0.4	0.4	-	-

Parentheses are original means and data is subjected to square root transformation; S=Surfactant 1250 ml/acre

Table 3. Effect of herbicide on yield and yield components of wheat during 2010-11 and 2011-12

Treatment	Dose g/ha	Panicle length (cm)		Effective tillers (no./m^2)		Grain yield (t/ha)	
		2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Clodinafop + metsulfuron	45+3	10.3	10.7	319.2	334.5	4.09	4.03
Clodinafop + metsulfuron	60+4	10.4	11.1	323.0	346.9	4.49	4.60
Clodinafop + metsulfuron	75+5	10.4	11.2	333.7	350.0	5.10	4.75
Clodinafop + metsulfuron	90+6	10.8	11.2	335.0	350.0	5.21	4.73
Clodinafop + metsulfuron	120+8	10.5	11.1	328.0	348.0	4.84	4.56
Clodinafop + metsulfuron + surfactant	45+3+S	10.9	11.1	335.0	353.0	5.22	5.15
Clodinafop + metsulfuron + surfactant	60+4+S	11.0	11.2	338.1	355.0	5.52	5.22
Clodinafop + metsulfuron + surfactant	75+5+S	11.1	11.3	346.0	357.3	5.77	5.50
Clodinafop + metsulfuron + surfactant	90+6+S	10.8	11.1	335.0	351.5	5.28	4.92
Clodinafop + metsulfuron+ surfactant	120+8+S	10.7	11.1	333.0	351.0	5.06	4.95
Clodinafop *fb* metsulfuron	160 *fb* 4	11.0	10.8	338.0	333.3	5.52	4.18
Metsulfuron	4	10.8	11.2	334.0	351.0	5.23	4.97
Clodinafop	160	10.4	11.2	327.0	354.0	4.72	5.29
Weed free	-	11.0	11.2	338.8	353.0	5.49	5.34
Unweeded control	-	9.3	9.9	284.1	284.5	2.84	3.38
LSD (P=0.05)	-	0.05	0.04	5.9	3.0	0.11	0.11

S-Surfactant 1250 ml/acre

The similar wheat grain yield with ready-mix formulation of clodinafop + metsulfuron at 60 g /ha to sequential application of clodinafop and metsulfuron has been reported earlier by Malik *et al.* 2013. Punia *et al.* 2008 also reported maximum grain yield with the use of clodinafop + metsulfuron + surfactant at 75 + 5 g/ha which were at par with weed free check and ready mixture of sulfosulfuron + metsulfuron and clodinafop + metsulfuron + surfactant at 60 + 4 g/ha but significantly higher than clodinafop and sulfosulfuron alone. Similar results were reported by Singh *et al.* (2012). One post-emergence application of ready-mix formulation of clodinafop + metsulfuron (Vesta) at 75 g/ha along with 0.2% surfactant recorded effective control of grass and broad-leaved weeds in wheat.

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Herbicide and nitrogen application effects on weeds and yield of wheat

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ABSTRACT

A field experiments was conducted during winter seasons of 2010-12 at Banaras Hindu University, Varanasi to study the effect of herbicides, nitrogen rates and it's scheduling on associated weeds, crop growth and yield of wheat. Six weed species were common infesting wheat fields were *Phalaris minor, Cynodon dactylon,* C*henopodium album, Oxalis purpurea, Anagallis arvensis* and *Cyperus rotundus.* Among the herbicidal treatments, post-emergence application (30 DAS) of sulfosulfuron + metsulfuron [32 g/ha] with higher rates 160 kg N/ha and time of application (50% basal + 25% CRI + 25% flowering) performed significantly with respect to reduction in density and biomass of weeds; increased the LAI and SPAD value ultimately enhanced the production of grain yield of wheat. Scheduling of nitrogen (50% basal + 25% CRI + 25% flowering) enhanced the nitrogen uptake efficiency and total nutrient uptake by crop than other scheduling of nitrogen. However, application of herbicide mixtures as a post-emergence (30 DAS) with increased dose of nitrogen applied as 1/2 basal and topdressing 1/4 at CRI and 1/4 at flowering is most effective.

Key words: Herbicide mixture, LAI, N uptake efficiency, SPAD values

Wheat is the most important cereal crop which is badly infested with grassy as well as broad-leaf weeds. Since 1982 isoproturon is most widely used herbicide for management of *Phalaris minor* in wheat, particularly under rice-wheat cropping system (Walia *et al.* 2010). But, its efficacy has declined due to development of resistance in *P. minor* (Singh 2007). However, the sole dependence on herbicide of single mode of action is also not advisable as it has contributed to shift towards difficult to control weeds and rapid evolution of multiple herbicides resistance, which is a threat to wheat production (Singh 2007). Therefore, there is need to use mixture of herbicides in a way to lower the load on environment and improve weed control efficacy without any adverse effect on crop. Nitrogen (N) is the nutrient that most often limits crop production. Among major cereals, wheat requires 1 kg of N to produce 44 kg of wheat (Pathak *et al.* 2003). Generally, more than 50% of the N applied is not assimilated by plants (Dobermann and Cassman 2004). Furthermore, Kim *et al.* (2006) reported that there was often a significant interaction between herbicide and nitrogen, where increased nitrogen found to enhance the performance of herbicide as well as N-scheduling not only influences the crop growth but also influences weed density and biomass also. However, information in this regard is lacking. So, there is a greater need for new formulated herbicides with nitrogen rates and time of application to make out the effect of treatments on growth and yield of wheat.

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MATERIALS AND METHODS

Field study was carried out during winter (*Rabi*) seasons for two consecutive years of 2010-11 and 2011-12 at the Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25°18′ N, 83°03′ E and 128.93 m altitude). The soil of the experimental field was sandy clay loam in texture with slightly alkaline in reaction (pH 7.5) having low organic carbon (0.42%) and available nitrogen (195.3 kg/ha); and medium in available phosphorus (21.8 kg/ha) and potassium (232.2 kg/ha).

It was a factorial experiment conducted in a randomized complete block design and replicated thrice, having three factors. First factor comprised of three herbicides, *viz.* weedy check, sulfosulfuron + metsulfuron (32 g/ha) and carfentrazone (10 g/ha) + fenoxaprop-p-ethyl (100 g/ha), whereas, second and third factors comprised of two nitrogen rates (120 kg N/ha and 160 kg N/ha) and three times of nitrogen application, *viz.* 50% basal + 50% CRI, 50% basal + 25% CRI + 25% flowering and 33.3% basal + 33.3% CRI + 33.3% flowering, respectively. Wheat variety *'PBW 343'* was sown on 26 November, 2010 and 30

November, 2011 with 100 kg seed/ha by keeping row to row spacing of 22.5 cm during both the years of investigations, respectively. Nitrogen applied as per treatment but full amount of P and K were applied at the time of sowing. Herbicides were dissolved in 600 liters water and applied at 30 days after sowing (DAS), using the knapsack sprayer fitted with flat-fan nozzle. Total weed density and biomass of weeds were recorded 60 DAS and at harvest using a quadrant of 0.5 x 0.5 m randomly selected at two places in each plot. Furthermore, all weeds from quadrant were cut at ground level, placed in a paper bag, and dried for 48 h in an oven at 60° C, and then were weighed to determine weed dry biomass. Leaf area index (LAI) is defined as the area of leaves per unit area of soil surface. LAI was quantified with the AccuPAR model LP-80 (Decagon Devices, Inc. instrument, which calculates LAI based on the above and below-canopy PAR measurements. Leaf chlorophyll content was estimated non-destructively by measuring leaf greenness using a portable SPAD (Soil Plant Analysis Development)-502 chlorophyll metre (Minolta Camera Co. Ltd., Japan). Grain yield recorded in kg/plot was finally converted into grain yield kg/ha. Nitrogen uptake efficiency (%) as the ratio of total plant N uptake to N supplies (Ortiz-Monasterio *et al.* 1997). Weed data (density and biomass) were subjected to square-root transformation $\sqrt{x + 0.5}$. Weed control efficiency (WCE) was computed on the basis of total weed density at harvest. All data were put to analysis of variance as described by Gomez and Gomez (1984). The mean assessment was accomplished by least significant difference (LSD) at 5% level of probability.

Nutrient uptake in grain and straw of the crops were calculated in kg/ha in relation to yield per ha by using the following formula:

$$\text{Uptake (kg/ha)} = \frac{\text{Nutrient (\%) in grain/straw x grain/straw yield (kg/ha)}}{100}$$

RESULTS AND DISCUSSION

Effect on density and biomass of weed

Experimental field was infested with weed flora of *Chenopodium album*, *Oxalis purpurea* and *Anagallis arvensis,* among broad-leaf weeds whereas, *Phalaris minor* and *Cynodon dactylon* among grasses. Moreover, among sedges only one species *i.e. Cyperus rotundus* was observed. Herbicidal treatments significantly reduced the density and dry biomass of total weeds than weedy check. Pre-mix formulation of sulfosulfuron + metsulfuron (32 g/ha) proved the most effective herbicides against broad-leaf weeds and annual grasses, and recorded significantly lower density and dry biomass of these weeds than the tank-mixture of carfentrazone (10 g/ha) + fenoxaprop-p-ethyl (100 g/ha), during both the year (Table 1). The highest weed-control efficiency was also recorded under pre-mix formulation (Total) of sulfosulfuron + metsulfuron (32 g/ha) than tank-mixture of carfentrazone (10 g/ha) + fenoxaprop-p-ethyl (100 g/ha). The higher efficacy of sulfosulfuron + metsulfuron (32 g/ha) as compared to tank-mix of carfentrazone (10 g/ha) + fenoxaprop-p-ethyl (100 g/ha can be attributed to its slow degradation in soil; it control weeds throughout crop growth period (Khokhar and Nepalia 2010). While, sulfosulfuron applied in wheat was found to persist even after 150 days after its application in wheat and its residues in the soil caused phytotoxicity to succeeding crop of sorghum (Brar *et al.* 2007). Carfentrazone-ethyl when tank mixed with fenoxaprop produced white speckling on the top wheat leaf, which disappeared within 10-12 days without any effect on yield attributes. The results are in line with the findings of (Singh *et al.* 2011).

Increased dose of nitrogen 160 kg/ha significantly reduced the density and biomass of weeds as compared to lower rates of nitrogen 120 kg/ha. It is worthwhile to mention that critical period of crop weed competition in wheat is between 30-50 DAS (Chaudhary *et al.* 2008). It means those nitrogen rates which provide competitive advantage to crop *vis-à-vis* suppressive effect on weeds up till 50 DAS would have positive influence on crop yield. In line with above-said facts, experimental findings also showed that during the critical period of crop-weed competition, application of higher rates of nitrogen (160 kg N/ha) shift the competitive advantage in favour of crop and also helps in smothering of weed. It appeared that vigorous crop stand and growth due to higher N levels asserted a strong smothering effect on growth and development of weeds (Patel *et al.* 2012).

Out of various N splits, nitrogen applied in three splits (50% basal + 25% CRI + 25% flowering) showed lower density and biomass of weeds, and higher weed control efficiency being at par with two splits (50% basal + 50% CRI) but significantly superior over three equal splits (33.3% basal + 33.3% CRI + 33.3% flowering). This might be due to improved crop growth as compared to other caused smothering effect on weed growth and development. These finding are in conformity to those of Yadav *et al.* (2005).

Table1. Effect of herbicides, rates and time of nitrogen application on total weed density and biomass

Treatment	Total weed density (number/m^2)*				Total weed biomass (g/m^2)*				WCE (%)
	60 DAS		At harvest		60 DAS		At harvest		
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year	Mean
Herbicides									
Sulfosulfuron + metsulfuron (Total) 32 g/ha	7.34c (53.6)	9.03c (81.4)	2.65c (6.75)	4.18c (17.1)	6.63c (43.6)	7.02c (49.2)	3.30c (10.6)	3.58c (12.6)	83.0
Carfentrazone 10 g/ha + fenoxaprop 100 g/ha	8.25b (67.8)	9.91b (98.1)	3.50b (11.9)	5.04b (25.0)	7.44b (55.17)	7.89b (62.2)	4.30b (18.2)	4.61b (21.1)	72.4
Weedy check control	10.3a (106.4)	12.8a (165.8)	6.25a (38.9)	10.2a (103.1)	9.54a (90.87)	10.4a (107.7)	7.66a (58.5)	8.53a (72.7)	-
LSD(P=0.05)	0.33	0.30	0.18	0.14	0.30	0.34	0.21	0.24	
Nitrogen rates									
120 kg/ha	9.08a (83.7)	11.0a (123.2)	4.54a (22.6)	6.77a (52.18)	8.26a (69.3)	8.83a (79.5)	5.49a (33.2)	6.01a (40.2)	45.6
160 kg/ha	8.18b (68.2)	10.2b (107.0)	3.73b (15.8)	6.15b (44.68)	7.48b (57.11)	8.04b (66.6)	4.69b (25.04)	5.13b (30.7)	58.0
LSD (P=0.05)	0.27	0.25	0.15	0.11	0.25	0.28	0.17	0.20	
Time of nitrogen application									
50% basal + 50 % crown root initiation	8.67ab (76.6)	10.6 ab (115.7)	4.09b (18.8)	6.41b (47.6)	7.85ab (62.9)	8.43ab (72.9)	5.05b (28.7)	5.48b (34.3)	52.6
50% basal + 25 % crown root initiation + 25% flowering	8.40 bc (71.9)	10.4 bc (111.0)	3.92 bc (17.4)	6.26c (46.1)	7.63bc (59.6)	8.18bc (68.8)	4.86bc (26.90)	5.31bc (32.6)	55.2
33.3% basal + 33.3% crown root initiation + 33.3% flowering	8.83 a (79.3)	10.7 a (118.5)	4.39a (21.3)	6.72a (51.5)	8.12a (67.12)	8.70a (77.3)	5.36a (31.8)	5.94a (39.4)	47.6
LSD (P=0.05)	0.33	0.30	0.18	0.14	0.30	0.34	0.21	0.24	

*Data subjected to square root ($\sqrt{x+0.5}$) transformation and original data presented in parenthesis, NS- Not NS- not significant, Number followed by same letter are not statistically different at 5% level of significance.

Effect on crop

The highest leaf area index (LAI) and SPAD value was found in the pre-mix application of sulfosulfuron + metsulfuron (32 g/ha) *fb* by tank mix application of carfentrazone (10 g/ha) + fenoxaprop-p-ethyl (100 g/ha) as compared to weedy check during both the year.

Increasing nitrogen rates gradually increased the LAI and SPAD having the significantly highest values at 160 kg N/ha during both the years. However, application of nitrogen as 50% basal + 25% CRI + 25% flowering brought the significantly higher LAI and SPAD followed 50% basal + 50% CRI being at par with 33.3% basal + 33.3% CRI + 33.3% flowering during both the years (Table 2). The increased in leaf area index with higher nitrogen levels might be due to more leaf area on account of more accumulation of assimilates. Ullah *et al.* (2013) reported enhanced leaf area index by applying higher level of nitrogen.

Pre-mixed application of sulfosulfuron + metsulfuron (32 g/ha) had brought about significant increment 37.7 and 39.2% in grain yield over weedy check during first and second years respectively. Tank mix application of carfentrazone (10 g/ha) + fenoxaprop-p-ethyl (100 g/ha) produced 29.1 and 30.6% higher grain yield over weedy check during first and second year, respectively. This was perhaps due to reduced crop weed competition as the effectively suppressed predominant weeds (both on density and biomass) throughout crop growth period.

Enhanced nitrogen application from 120 to 160 kg/ha resulted in significant increase in grain yield during both the years (Table 2). Application of 160 kg N/ha produced significantly 12.8 and 12.8% higher grain yield over 120 kg N/ha during first and second years, respectively. These results were in conformity with the findings of Bhat *et al*. (2006). However, split application of nitrogen also found significantly increased the grain yield of wheat. Three split application of nitrogen 50% basal + 25% CRI + 25% flowering recorded more yield followed by two split application of nitrogen 50% basal + 50% CRI and three equal splits 33.3% basal + 33.3% CRI + 33.3% flowering. Whereas, three split application of nitrogen 50% basal + 25% CRI + 25% flowering were recorded 13.4 and 16.4 percent higher grain yield over 50% basal + 50% CRI during first and second years, respectively.

Table 2. Effect of herbicides, rates and time of nitrogen application on LAI, SPAD value, grain yield and nitrogen uptake efficiency

Treatment	LAI[a]		SPAD value[a]		Grain yield (t/ha)		N uptake efficiency (%)	
	I Year	II Year	I Year	II Year	I Year	II Year	I Year	II Year
Herbicides								
Sulfosulfuron + metsulfuron (Total) (32 g/ha)	3.86a	4.16a	43.3a	44.6a	4.76a	4.85a	83.8a	87.8a
Carfentrazone (10 g/ha) + fenoxaprop (100 g/ha)	3.61b	3.82b	41.6b	42.8b	4.46b	4.55b	75.5b	79.2b
Weedy check control	3.45c	3.53c	40.0c	40.7c	3.46c	3.49c	56.8c	59.0c
LSD (P=0.05)	0.13	0.14	1.50	1.54	0.14	0.14	7.60	7.91
Nitrogen rates								
120 kg/ha	3.39b	3.60b	40.2b	41.6b	3.97b	4.04b	78.1a	81.5a
160 kg/ha	3.90a	4.07a	43.1a	43.9a	4.48a	4.56a	66.0b	69.2b
LSD (P=0.05)	0.10	0.11	1.23	1.26	0.12	0.11	6.21	6.46
Time of nitrogen application								
50% Basal + 50% crown root initiation	3.59b	3.81b	41.2b	42.9b	4.27b	4.34b	74.1b	77.4b
50% Basal + 25% crown root initiation + 25% flowering	3.81a	3.99a	42.8a	43.7a	4.42a	4.50a	83.1a	86.6a
33.3% Basal + 33.3% crown root initiation + 33.3% flowering	3.52bc	3.72bc	40.8bc	41.6bc	3.99c	4.05c	59.0c	62.1c
LSD (P=0.05)	0.13	0.14	1.50	1.54	0.14	0.14	7.60	7.91

observation recorded at 90 DAS; LAI= Leaf area index

Interaction effect

Significant interaction effect of herbicides and nitrogen rate was observed on wheat productivity during both the years (Table 3). Pre-mix application of sulfosulfuron + metsulfuron with higher level of nitrogen 160 kg/ha produced significantly highest grain yield (5045.52 and 5142.97 kg/ha) and as compared to tank-mix of carfentrazone + fenoxaprop-p-ethyl during both the year, respectively. Also nitrogen rate and time of nitrogen application was observed significantly on grain yield during both the year. Application of nitrogen at 160 kg/ha applied as three split (50% basal + 25% CRI + 25% flowering) recorded significantly highest wheat productivity compared to all other combinations except at the same nitrogen level applied as (50% basal + 50% CRI) during both the year.

Effect on nutrient

The difference in the total uptake of N, P and K by the crop under herbicidal treatments was also a function of the total plant biomass production by any particular treatments. Herbicides application brought about significant reduction in N, P and K uptake by weeds and enhanced nutrient uptake by crop. Amongst herbicides, pre-mix application of sulfosulfuron + metsulfuron increased the availability of nutrients by reducing crop weed competition and resulted into more dry matter accumulation in the crop, which ultimately reflected in more nutrient uptake and nitrogen uptake efficiency as compared to weedy check. The results were in close conformity with the finding of and Chopra *et al.* (2008).

The total uptake of N, P and K in wheat grain and straw was increased significantly with an increased nitrogen rates (160 kg/ha) while, significant decline in nitrogen uptake efficiency. The low uptake of these nutrients under lower level of nitrogen may be attributed to less plant biomass (grain and straw). Sinebo *et al.* (2004) also reported that N uptake efficiency was higher at lower rates of N application but drastically decreased with further increases in the rate of the nutrient. Whereas, application of N in three splits *i.e.* 50% basal + 25% CRI + 25% flowering coinciding with crop requirements might have reduced rapid mineralization and losses through different pathways and their by increased nutrient contents in wheat grain and straw. As a result, higher total uptake of N, P and K with an increased plant biomass (grain and straw).

Scheduling of nitrogen indicated that higher N uptake efficiency by the crop when nitrogen was applied in three splits 50% basal + 25% CRI + 25% flowering regardless of the amount of the dose at each time. Thus, compared to the two split N applications at 50% basal + 50% CRI, the three split applications resulted in significantly higher uptake efficiencies. Corroborating these results, Tran and Tremblay (2000) also indicated lower N uptake

Table 3. Effect of herbicides, rates and time of nitrogen application on total nutrient uptake by crop (grain + straw) of wheat

Treatment	Total nutrient uptake by crop (kg/ha)					
	N		P		K	
	I Year	II Year	I Year	II Year	I Year	II Year
Herbicides						
Sulfosulfuron + metsulfuron (Total) (32 g/ha)	115.9a	121.5a	21.3a	22.7a	107.7a	120.3a
Carfentrazone (10 g/ha) + fenoxaprop (100 g/ha)	104.7b	109.9b	19.4b	20.6b	94.9ab	106.8ab
Weedy check control	78.4c	81.5c	14.5c	15.4c	71.0c	78.5c
LSD (P = 0.05)	10.07	10.37	1.53	1.58	14.8	16.2
Nitrogen rates						
120 kg/ha	93.7b	97.8b	17.3b	18.37b	86.46	95.4
160 kg/ha	105.6a	110.7a	19.5a	20.83a	96.10	108.2
LSD (P = 0.05)	8.22	8.47	1.25	1.29	NS	NS
Time of nitrogen application						
50% basal + 50% crown root initiation	102.3b	106.9b	18.8b	20.0b	94.8b	105.6b
50% basal + 25% crown root initiation+ 25% flowering	114.7a	119.6a	20.8a	22.0a	111.2a	123.2a
33.3% basal + 33.3% crown root initiation+ 33.3% flowering	82.1c	86.4c	15.6c	16.7c	67.8c	76.7c
LSD (P=0.05)	10.07	10.4	1.53	1.58	14.8	16.2

Table 4. Interaction effects of herbicides, nitrogen rate and time of nitrogen application on grain yield of wheat

Treatment	Grain yield (t/ha)											
	I year			II year			I year			II year		
	H_1	H_2	H_3	H_1	H_2	H_3	T_1	T_2	T_3	T_1	T_2	T_3
120 kg/ha	3.31	4.48	4.12	3.34	4.57	4.21	4.07	4.23	3.61	4.14	4.30	3.67
160 kg/ha	3.60	5.04	4.81	3.63	5.14	4.90	4.47	4.61	4.37	4.54	4.69	4.44
LSD (P = 0.05)		0.21			0.20			0.25			0.25	

efficiency in the early applications of N fertilizer at planting and tillering compared to applications in the later stage of crop growth.

It was concluded that pre-mix application of sulfosulfuron + metsulfuron (32 g/ha) along with 160 kg N/ha applied at 50 % basal + 25 % CRI + 25 % flowering showed best treatment for control of weeds in wheat.

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Allelopathic potential of canola and sugarbeet to control weeds in chickpea

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ABSTRACT

Filed experiment was done to evaluate the allelopathic potential of sugarbeet and canola residues on weeds of chickpea field. Five treatments, *viz.* 1: Chopped residues of canola, 2: Chopped residues of sugarbeet both were separately incorporated to 25 cm depth soil, 20 days before sowing, 3: Shoot aqueous extract of canola, 4: Shoot aqueous extract of sugarbeet which were separately sprayed at post emergence stage and 5: Without any residues and spraying as control. The weed control treatments reduced the total weed cover, weed density and total dry weigh of weed. The reduction in weed density with canola and sugarbeet residues incorporated with soil were up to 42.7 and 57% respectively, at 45 days after sowing and 41% and 52.4%, respectively, at 90 days after sowing, compared to control. However, post emergence spraying of shoot aqueous extract of canola and sugarbeet, suppressed weed density up to 37.2 and 35.6% at 40 days after sowing and 56.7% and 49.2% at 90 days after sowing respectively, compared to control. Weed control treatments reduced weed cover (%), weed biomass and weeds stem length. Incorporation of canola and sugarbeet residues in soil reduced weed cover (%) by 47.9% and 57.6%, respectively, while spraying of shoot water extract of canola and sugarbeet suppressed weed cover (%) by 31.7% and 42%, respectively at 90 days after sowing. Application of canola residues and spraying shoot aqueous extract of canola increased chickpea yield by 25.4% and 39.5% respectively, while application of sugarbeet residues and shoot aqueous extract of sugarbeet decreased chickpea yield by 22% and 29.8% respectively compared to control. All nutrient elements analyzed in the leaves of weed generally were lower than control for all treatments. Incorporation of crop residue of canola and sugarbeet on weeds were more effective than spraying water extract of these plants.

Key words: Allelopathy, *Beta vulgaris*, Bio-herbicide, *Brassica napus*, Plant residues

The weeds have significant negative effects on agricultural ecosystems (Singh *et al.* 2003), and may decrease crop yield up to as 24% then 16.4% and 11.2% for diseases and insects, respectively (Hegab *et al.* 2008). Since 1980s, dependence on chemical weed controls worldwide has become less ubiquitous because of public concerns over safety, risks for the environment (Dayan *et al.* 1999) and the development of resistance to chemical herbicides by weeds. This necessitated the research for alternative strategies.

Allelopathy is defined as the inhibitory/ stimulatory effect(s) of one plant on other plants through the release of chemical compounds into the surrounding environment (Rice 1984). Allelopathy is characterized by a reduction in plant emergence or growth, reducing their performance in the association (Florentine *et al.* 2006). It provides a relatively cheaper and eco-friendly weed control strategies (Cheema *et al.* 2000).

Various *Brassica* species possess allelopathic potential and suppresses the certain weed species. Allelopathic effects of *Brassica* species are due to glucosinolates (GSLs) that are not biologically active. When the plant tissue is disrupted, the GSLs are hydrolyzed to a number of products. The mean breakdown products are isothiocianates (ITCs) which are phytotoxic (Fenwick *et al.* 1983).

Sugarbeet (*Beta vulgaris* L.) is known to be allelopathic against weeds. The allelopathic activity of sugarbeet has been attributed to phenolic acids and related compounds. Hegab *et al.* (Hegab *et al.* 2008) identified and quantified 8-phenolic compounds (shikimic acid, camphor, hydroxybenzoic, p-coumaric, vanilic acids, coumarin and porotocatechuic acids) in water extract of *Beta vulgaris*. Dadkhah (2012) has demonstrated that sugarbeet allelopathic varietes can be used to reduce weed populations below the threshold level to minimize the applications of herbicides.

The present study was done to develop management practices to reduce the use of agro-chemicals for sustainable agriculture. Therefore, the effects of allelopathic potential of canola and sugarbeet residues on suppression of some weeds of chickpea farm were studied.

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MATERIALS AND METHODS

A field experiment based on a randomized complete blocks design with four replications was carried out in a naturally weeds infested land to investigate the allelopatic effects of canola (*Brassica napus*) and sugarbeet (*Beta vulgaris*) residues on weeds and yield of chickpea (*Cicer arietinum*) at research center of Shirvan Agricultural College (37° 23′ north latitude and 57° 54′ east longitude and altitude of 1060 meters), North Khorasan Province, Iran. Arial parts of canola and sugarbeet were collected from farm of Shirvan Agricultural College, at harvesting stage. Arial parts were spread on a clean plastic sheet in the shade at room temperature for 3 weeks until they were completely dried and chopped into 5 cm pieces and stored until needed. The experimental site was ploughed, followed by a disc-harrow and smoothing with land leveler. Fertilizer was applied prior to planting at the rate of 100 kg/ha ammonium nitrate (33% N) and 80 kg/ha calcium superphosphate (15.5% P_2O_5). Plot size was 9 m^2 (3 × 3 m). Five treatments, *viz.* 1: Chopped residues of canola (1.5 kg/m^2), 2: Chopped residues of sugarbeet (1.5 kg/m^2) both were separately incorporated to 25 cm depth soil uniformly 20 days before sowing, 3: Shoot aqueous extract of canola, 4: Shoot aqueous extract of sugarbeet which were separately sprayed at post-emergence stage (at 7 and 14 days after sowing) and 5: Without any residues and spraying as control. Chickpea seeds were planted on April 25th in 2013. For preparation of aqueous extract, chopped shade dried residues of canola and sugarbeet were separately ground into fine powder (using an electric mill). One hundred gram of ground tissue of each of the tested species was placed in a 2 L Erlenmeyer flask and 1 L distilled water was added and left for 48 h at room temperature. The mixtures were then filtered through a double layer of cheese cloth followed by Whatman No.1 filter paper using a vacuum pump. Water extracts were applied between rows at the rate of 100 ml per square meter twice at 7 and 14 days after sowing (DAS) using a knapsack hand-sprayer fitted with a flat fan nozzle maintaining a pressure of 207 kpa.

Leaves nutrient content (N, P, K, Ca, Mg, Fe and Mn) of two main weeds of chickpea farm (*Solanum nigrum* and *Echinochloa crusgalli*) were determined at 90 DAS. Nitrogen was determined by Micro-kjeldahl. Phosphors by spectrophotometer and K, Ca, Mg, Fe and Mn were determined by atomic absorption spectrometry after mineralization through wet combustion (AOAC 1970).

Data for individual and total weed density and biomass in a unit area was recorded 40 and 90 days after sowing (DAS) using a 0.5 × 0. 5 m quadrat randomly placed at two places in each experimental unit. Weeds were oven dried at 70^0 C for 72 hours for the dry weight. Chickpea crops was harvested and threshed manually in fourth week of August, 2013 from individual treatment plots; grain yield was weighed in kilograms and expressed as kilo gram per hectare (kg/ha).

RESULTS AND DISCUSSION

Statistical analysis of the data showed that there were significant differences among the weed control treatments. Results showed that incorporation of crop residues had greatly affected the total weeds cover, weeds density and weeds dry weight, while post application of water extract of crop showed comparatively lesser controlling ability. There was significant difference on weed cover and weed dry weight between two test spices.

The reduction in weed density with canola and sugarbeet residues incorporation were up to 42.7 and 57.2%, respectively at 45 days after sowing and 41 and 52.6% at 90 days after sowing compared to control (Fig. 1). However, post-emergence spraying of shoot aqueous extract of canola and sugarbeet suppressed weed density up to 37.2 and 35.6% at 45 days after sowing and 56.7 and 49.2% at 90 DAS, respectively, compared to control (Fig. 1).

Weed control treatments also reduced weed cover (%). Incorporation of canola and sugarbeet residues in soil, reduced weed cover by 48 and 58.6% respectively, while spraying water extract of canola and sugarbeet lowered weed cover by 31.6 and 42.5% respectively at 90 DAS (Fig. 2).

Total weeds dry weight decreased significantly by weed control treatments. Incorporation of canola and sugarbeet residues in soil reduced total weeds dry weight by 57.6 and 78.2%, respectively, compared to control. However, spraying water extract of canola and sugarbeet decreased total weeds dry weight by 56.3 and 70.7%, respectively, compared to control at 45 DAS (Fig. 3). The reduction of total weeds dry weight for canola and sugarbeet residues were 82.3 and 90.9% respectively, at 90 DAS (Fig. 3). Such suppressive actions are believed to originate through the release of phytotoxin allelochemicals from incorporated crop residues by leaching or decomposition.

Leaves nutrient elements content of weeds was significantly decreased by treatments compared to control. The N content of *Solanum nigrum* leaves

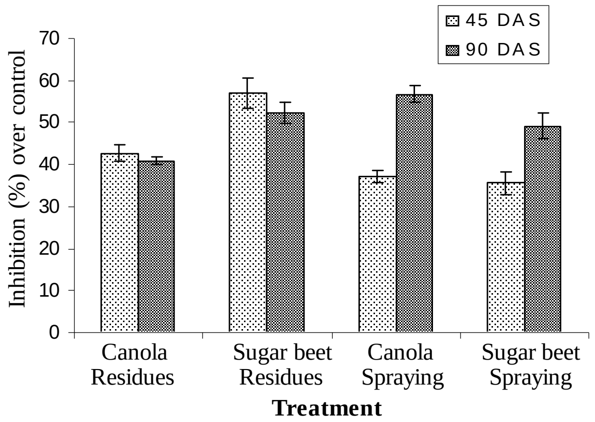

Fig. 1. Inhibitory effects of canola, wheat residues and spraying aqueous extracts of canola and sugarbeet on weed density of chickpea farm (vertical lines are standard deviation of means)

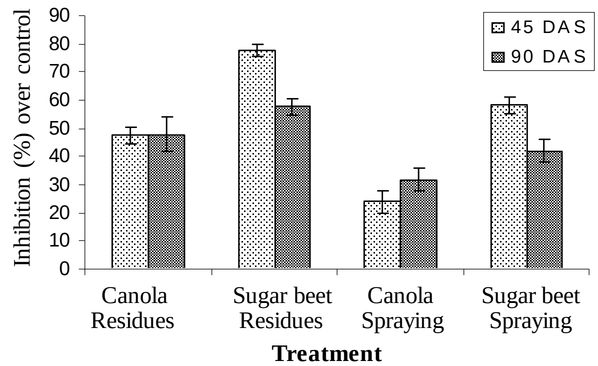

Fig. 2. Inhibitory effects of canola, wheat residues and spraying aqueous extracts of canola and sugarbeet on weed cover of chickpea farm (vertical lines are standard deviation of means)

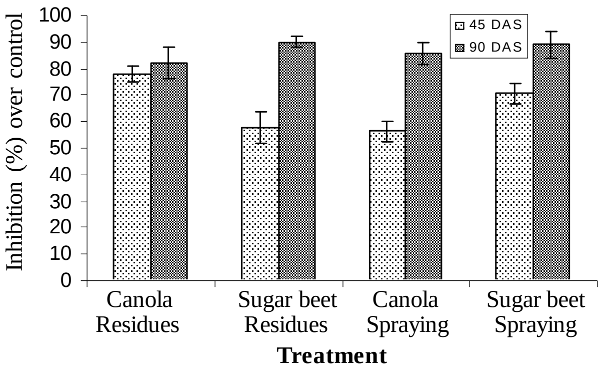

Fig. 3. Inhibitory effects of canola, wheat residues and spraying aqueous extracts of canola and sugarbeet on total weeds dry weight of chickpea farm (vertical lines are standard deviation of means)

decreased from 3.68% (at control) to 1.95% (at canola residues treatment), 1.78 (at sugarbeet residues treatment), 2.48 (at canola extract spraying) and 2.59 (at sugarbeet extract spraying).

Soil incorporated canola residues decreased the P, K. Ca, Mg, Fe and Mn from 0.78% to 0.42%, 2.19% to 1.3%, 2.45% to 1.8%, 0.62% to 0.48%, 95 ppm to 49 ppm and 73 to 50 ppm respectively, compared to control (Table 1).

The nitrogen content of *Echinochloa crusgalli* leaves decreased from 2.83% (at control) to 1.5% (at canola residue treatment), 1.32% (at sugarbeet residue treatment), 1.9% (at canola extract spraying) and 2.1% (at sugarbeet extract spraying) (Table 2). The results showed that soil incorporation of crop residues of canola and sugarbeet were more effective than water extract spraying of these plants.

The results showed that the treatments were more effective on weeds dry weight than weed density. It indicates that growth of weeds was more suppression by phytotoxic effects of test plants than weed seed germination. In other words, inhibition in weeds dry weight was more pronounced than in weed seed germination. Smith (1991) and Ben-Hammouda *et al.* (1995) found that allelochemicals of several species suppressed the seedling growth in target plants more than seed germination.

Some researchers reported that allelochemicals inhibits the physiological processes that leads to reduced growth (Jefferson and Pennacchio 2003, Dadkhah 2012). The effects of allelochemicals on growth of plants may occur through various mechanisms. Like reduced mitotic activity, suppressed hormone activity, reduced rate of nutrients uptake, inhibited photosynthesis and respiration, inhibition of protein formation, reduction in permeability of cell membranes and inhibition of enzyme action (Rice 1984, Wu *et al.* 2000, Xuan *et al.* 2004). Under stress conditions, growth decreases due to decrease in cell number and cell size (De-Herralde *et al.* 1998). A possible reason for reduction in dry matter in weeds under allelochemical stress could be owing to the drastic reduction in uptake and assimilation of mineral nutrients. Akemo *et al.* (2000) reported that reduction in both macro and micronutrients uptake under allelopathy stress could be one of the effective parameters for growth reduction. Another possibility for dry matter reduction may be due to reduction in photosynthetic area or assimilation rate per unit leaf area (Dadkhah 2012). He also reported that dry matter accumulation of *Amaranthus retroflexus* significantly decreased by increasing allelochemical concentration. He mentioned that this reduction accompanied with reduction in leaf area and leaf photosynthesis per unit leaf area.

Table 1. Nutrient elements content of *Solanum nigrum* weed and percentage of reduction at different treatments condition at 90 DAS

Nutrient	Control		Canola residue		Wheat residue		Canola spraying		Wheat spraying	
	Actual	%	Actual	%	Actual	%	Actual	%	Actual	%
N (%)	3.68a	0.0	1.95b	47.01	1.78b	51.63	2.48a	32.61	2.59a	29.62
P (%)	0.78a	0.0	0.42d	46.15	0.53c	32.05	0.61b	21.79	0.53c	32.05
K (%)	2.19a	0.0	1.3c	40.63	1.49c	31.96	1.82b	16.89	1.73b	21.01
Ca (%)	2.45a	0.0	1.8b	26.53	1.89b	22.86	2.31ab	5.714	2.10b	14.29
Mg (%)	0.62a	0.0	0.48b	22.58	0.48b	22.58	0.52b	16.13	0.50b	19.36
Fe (ppm)	95.0a	0.0	49.0c	48.42	56.0c	41.05	67.0b	29.47	59.0bc	37.90
Mn (ppm)	73.0a	0.0	50.0c	31.50	53.0bc	27.40	65.0b	10.95	62.0b	15.07

Each number is the mean of four replications. Numbers followed by the same letter in rows are not significantly (P³0.05) different by Duncan's multiple range test.

Table 2. Nutrient elements content of *Echinochloa crusgalli* weed and percentage of reduction at different treatments condition at 90 DAS

Nutrient	Control		Canola residue		Wheat residue		Canola spraying		Wheat spraying	
	Actual	%	Actual	%	Actual	%	Actual	%	Actual	%
N (%)	2.83a	0.0	1.50c	47.00	1.32c	53.36	1.90b	32.86	2.1b	25.80
P (%)	0.86a	0.0	0.40c	53.49	0.46c	46.51	0.71b	17.44	0.61b	29.07
K (%)	2.00a	0.0	1.15c	42.50	1.23c	38.50	1.72ab	14.00	1.56b	22.22
Ca (%)	2.50a	0.0	1.72b	31.20	1.63b	34.80	2.10ab	16.00	1.82b	27.20
Mg (%)	0.50a	0.0	0.56a	-12.00	0.46ab	8.00	0.40b	20.00	0.39b	22.00
Fe (ppm)	70.0a	0.0	53.0b	24.29	61.0b	12.86	68.00a	2.86	55.0b	21.43
Mn (ppm)	61.0a	0.0	48.0b	21.31	52.0b	14.75	65.00a	-6.56	51.0b	16.39

Each number is the mean of four replications. Numbers followed by the same letter in rows are not significantly different by Duncan's multiple range test.

Incorporation of crop residues of canola and sugarbeet to control weeds were more effective than spraying water extract of these plants. The main reason for this can be attributed to higher concentration of allelochemicals or release gradually of allelochemicals by the residues of test plants that remained in the soil during growth period. Elijarrat and Barcelo (2001) reported that weeds can be controlled better by incorporating plant residues that release a greater fraction of allelochemicals in the soil. Higher concentration of allelochemicals inhibits the amylase activity in wheat seedlings and decreases the protein content in wheat seedlings (Hegab *et al.* 2008). On the other hand, application of sugarbeet residues and sugarbeet water extract had more inhibitory effect on weeds than canola application. Therefore, more inhibitory effects of *Beta vulgaris* might be due to the presence of more active phenolic compounds in it (Dadkhah 2012). Chung *et al.* (2002) demonstrated that p-hydroxybenzoic, p-coumaric acids were the most active compounds in rice hull extract, which inhibited the growth of barnyardgrass. The nature of inhibitory effects of allelochemicals on weed seed germination and weed growth could be attributed to the inhibition in water absorption (Oyun 2006).

The result of this experiment also showed that application of canola treatments increased chickpea yield (Fig. 4). Application of canola residues incorporated in soil and canola extract spraying increased chickpea yield by 25.4 and 39.5% compared to control plants. However, application sugarbeet residues and spraying water extract of sugarbeet decreased chickpea yield by 29.8 and 21%, compared to control. The increased chickpea yield by application canola residues and canola water extract might be due to suppression of weeds, soil and moisture conservation and improved nutrient cycling. While, chickpea yield reduction due to application of sugarbeet could be due to negative effect of sugarbeet allelochemicals on vegetative and reproductive growth of chickpea.

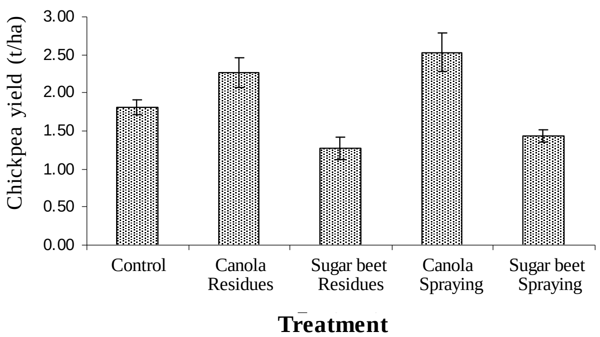

Fig. 4. Effect of different treatments on yield of chickpea. Vertical lines are standard deviation of means

These studies conclude that integrating canola and sugarbeet residues has the potential to suppress weeds germination and growth. These residues can be used as an eco-friendly approach to manage weeds in chickpea fields.

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Weed management effects on yield and economics of blackgram

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ABSTRACT

A field experiment was conducted during the *Kharif* season of 2012 and 2013 to evaluate the effect of weed management practices on weed dry weight, yield attributes, yield and economics of blackgram (*Vigna mungo* L.). All the weed species were controlled effectively by pre-mix herbicides as compared to alone application of pendimethalin as pre-emergance and imazethapyr as post-emergence. The reduction in total dry weight of weeds (6.13g/m^2) and maximum weed control efficiency 95.74% was found significantly higher with weed free treatment over all the weed control treatments except pre-mix herbicide imazethapyr + imazamox at 0.05 kg/ha PoE having 12.20g/m^2 weed dry weight and 91.53% weed control efficiency at 60 DAS stage of crop growth. The significantly higher seed (0.89t/ha) and straw (2.91t/ha) yield was recorded in weed free plot over all the treatments, which was followed by imazethapyr + imazamox (pre-mix) at 0.05 kg/ha as (0.84 and 2.89t/ha) and pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha (0.80 and 2.82 t/ha) treatments. However, the maximum net return of ` 17,135/ha and benefit:cost ratio (2.35) was found with imazethapyr + imazamox (pre-mix) at 0.05 kg/ha followed by pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha (` 16,410 and 2.30) treatment.

Key words: Blackgram, Economics, Pre-mix herbicides, Weed dry weight, Yield

Blackgram is one of the most important pulse crops, which can be grown in tropical and subtropical countries. It is grown during *Kharif* season in India where weed infestation causes considerable loss in yield. The weed causes maximum damage initially 25 to 35 days after sowing (Randhawa *et al.* 2002). The weed infestation during early stages of crop growth ends up in yield reduction up to 43.2-64.1% in blackgram (Rathi *et al.* 2004). Therefore, removal of weeds at appropriate time using a suitable method is essential to obtain high yields of blackgram. In blackgram, weeds could be controlled by hand weeding (Chand *et al.* 2004). However, hand weeding is laborious, time consuming, costly and tedious. Moreover, many times labour is not available at the critical period of weed removal. Furthermore, weather conditions do not permit timely hand weeding due to wet field conditions. Use of herbicides offers an alternative for possible effective control of weeds. Therefore, in the present study, effect of various herbicides was compared with hand weeding and untreated check for evaluating the reduction in weed dry weight and obtaining high yields of blackgram grown during *Kharif* season.

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MATERIALS AND METHODS

The climate of experimental area was dry hot during summer and dry cool in winter season. The temperature varies from 5^{0}C during winter to 47^{0}C in summer season. The soil of the experimental field was sandy-loam in texture, neutral in reaction (pH 7.6) with 0.45% organic carbon content and analyzing low in available N (179 kg/ha), medium P (18.6 kg/ha) and K (298 kg/ha) contents. The topography of experimental field was uniform. Fertility status of experimental site was homogenous. Variations in the growth and yield of crop were mainly due to effect of the treatments tested. The experiment was laid out in randomized block design with three replications having ten treatments, *viz.* pendimethalin at 1.0 kg/ha PE, imazethapyr at 0.050 kg/ha PoE, , imazethapyr at 0.070 kg/ha PoE, pendimethalin + imazethapyr (pre-mix) at 0.80 kg/ha PE, pendimethalin + imazethapyr (pre-mix) at 0.90 kg/ha PE, pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha PE, imazethapyr + imazamox (pre-mix) at 0.04 kg/ha PoE, imazethapyr + imazamox (pre-mix) at 0.05 kg/haPoE, weed free (two hand weedings at 20 and 40 DAS) and weedy check. The quantities of herbicides as per treatments were sprayed by knap-sack sprayer with flat fan nozzle with 600 litre of water. The blackgram variety *'T-9'* was sown at 30 cm apart rows with a seed rate of 18 kg/ha on first fortnight of July and harvested on first week of October during both the experimental years. The crop was fertilized with 20 kg N, 50 kg P_2O_5 and 20 kg K_2O/ha through urea, single super phosphate and murate of potash, respectively.

RESULTS AND DISCUSSION

Effect on weeds

The major weed flora of the experimental field consisted of *Cyperus rotundus, Echinochloa crusgalli, Commelina benghalensis, Phyllanthus niruri* and *Digera arvensis*. All the weed species were effectively controlled by pre-mix herbicides *i.e.*, imazethapyr + imazamox and pendimethalin+ imazethapyr as compared to alone application of pendimethalin as PE and imazethapyr as PoE. Both doses of pre-mix herbicide imazethapyr + imazamox and pendimethalin+ imazethapyr were equally effective as two hand weedings at 20 and 40 days after sowing and they were statistically at par with each other whereas all the weed control treatments were significantly superior to weedy check in respect to reduce the weed population and dry weight of weeds at 60 DAS stage of crop growth. The reduction in total dry weight of weeds was found significantly higher with weed free treatment (6.13 g/m^2) over all the weed control treatments except imazethapyr + imazamox (pre-mix) at 0.05 kg/ha PoE (12.20 g/m^2). The findings were in close agreement with previously reported by Bhandari *et al.* (2004). The maximum weed control efficiency 95.74% was recorded under weed free treatment, which was followed by imazethapyr + imazamox (pre-mix) at 0.05 kg/ha PoE (91.53%) at 60 DAS stage of crop growth.

Effect on crop

All the growth and yield attributes were significantly higher under pre-mix herbicides as PE and PoE application as compared to alone application of these herbicides and at par with weed free plot. The weed free plot was recorded significantly superior in respect of growth and yield attributes as compared to all other treatments. However, among the herbicidal treatments, highest plant height (96.6 cm and 96.2 cm), number of leaves (35.7 and 35.2), Pod length (4.42 and 4.41 cm), number of branches (16.9 and 16.9/plant) and number of pods (65.69 and 57.7/plant) were recorded with imazethapyr + imazamox (pre-mix) at 0.05 kg/ha and pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha, respectively. This was due to better control of both grassy as well as broad leaved weeds during early crop growth period. The minimum values were recorded under

Table 1. Effect of different treatments on weed population, dry weight of weeds and WCE at 60 DAS in blackgram (pooled data of two years)

Treatment	Weed population/m^2					Weed dry weight (g/m^2)			Weed control efficiency (%)
	E. crusgalli	*C. rotundus*	*D. arvensis*	*C. benghal-ensis*	*P. niruri*	Narrow -leaf weed	Broad -leaf weed	Total	
Pendimethalin at 1.0 kg/ha PE	2.44 (5.67)	2.16 (8.66)	2.15 (3.66)	2.41 (5.17)	2.33 (4.67)	35.1	27.3	62.39	56.7
Imazethapyr at 0.050 kg/ha PoE	2.37 (5.16)	2.22 (8.33)	1.89 (2.67)	2.14 (3.66)	1.80 (2.33)	28.4	19.1	47.50	67.1
Imazethapyr at 0.070 kg/ha PoE	1.99 (3.17)	1.99 (7.00)	1.67 (2.00)	1.69 (2.16)	1.64 (1.83)	20.3	15.3	35.64	75.3
Pendimethalin + imazethapyr (pre-mix) at 0.80 kg/ha PE	1.88 (2.67)	1.84 (5.67)	1.71 (2.00)	2.01 (3.17)	1.55 (1.50)	20.7	17.8	38.56	73.3
Pendimethalin + imazethapyr (pre-mix) at 0.90 kg/ha PE	1.70 (2.00)	1.73 (4.83)	1.52 (1.50)	1.87 (2.67)	1.43 (1.17)	14.70	13.3	28.01	80.6
Pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha PE	1.50 (0.83)	1.50 (3.83)	1.31 (0.83)	1.55 (1.50)	1.33 (0.83)	.41	2.1	1.51	5.1
Imazethapyr + imazamox (pre-mix) at 0.04 kg/ha PoE	1.71 (2.00)	1.57 (4.00)	1.41 (1.16)	1.95 (1.50)	1.38 (1.00)	6.2	.94	5.15	2.5
Imazethapyr + imazamox (pre-mix) at 0.05 kg/ha PoE	1.28 (0.67)	1.04 (2.00)	0.71 (0.50)	1.43 (1.17)	1.21 (0.50)	.02	.18	2.20	1.5
Weed free (two hand weeding at 20 and 40 DAS)	1.18 (0.50)	0.87 (1.50)	1.14 (0.33)	1.07 (0.16)	1.07 (0.16)	.55	.58	.13	5.7
Weedy check	4.53 (20.2)	3.46 (31.3)	3.75 (13.8)	3.63 (12.3)	3.19 (6.54)	8.15	15.9	44.2	.00
LSD (P=0.05)	0.47	0.38	0.33	0.79	0.44	2.56	4.41	6.97	-
Transformation	Log x	$\sqrt{x+0.5}$	$\sqrt{x+0.5}$	$\sqrt{x+0.5}$	$\sqrt{x+0.5}$				

PE - pre-emergence

Table 2. Effect of different treatments on growth, yield attributing characters, yield and economics of blackgram (pooled data of two years)

Treatment	Plant height (cm)	No. of branches /plant	No. of pods/ plant	Seed yield (t/ha)	Stover yield (t/ha)	Cost of cultivation ($x10^3$ `/ha)	Net returns ($x10^3$ `/ha)
Pendimethalin at 1.0 kg/ha PE	88.6	13.9	48.8	0.54	2.25	11.65	7.14
Imazethapyr at 0.050 kg/ha PoE	87.8	12.6	49.1	0.33	2.23	11.59	6.86
Imazethapyr at 0.070 kg/ha PoE	90.9	12.9	51.2	0.64	2.34	11.75	10.75
Pendimethalin + imazethapyr (pre-mix) at 0.80 kg/ha PE	93.3	14.3	56.1	0.74	2.62	12.17	13.58
Pendimethalin + imazethapyr (pre-mix) at 0.90 kg/ha PE	95.6	16.1	56.1	0.75	2.69	12.25	14.07
Pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha PE	96.2	16.9	57.7	0.80	2.82	12.34	16.42
Imazethapyr + imazamox (pre-mix) at 0.04 kg/ha PoE	95.3	15.2	59.8	0.82	2.71	11.99	15.06
Imazethapyr + imazamox (pre-mix) at 0.05 kg/ha PoE	96.6	16.9	65.6	0.77	2.89	12.16	17.13
Weed free (two hand weeding at 20 and 40 DAS)	98.1	17.5	68.8	0.89	2.91	14.98	16.31
Weedy check	71.2	8.09	30.2	0.31	1.56	10.92	-0.18
LSD (P=0.05)	4.45	2.46	5.05	0.05	0.12	-	-

weedy check treatment. The significantly higher seed (0.89 t/ha) and straw (2.91 t/ha) yield was recorded in weed free plot over all the treatments, which was followed by imazethapyr + imazamox (pre-mix) at 0.05 kg/ha as (0.84and 2.89t/ha) and pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha (0.80 and 2.82 t/ha) treatments. In *Kharif* blackgram, two hand weedings done 20 and 40 DAS provided as high grain yield as the weed free treatment (Chand *et al.* 2004). The weed free treatment reduced the crop weeds competition by providing no weed situation in blackgram field. Thus, the crop plants being vigorous by efficiently utilization of nutrients, moisture, sunlight with space and gave better yield. The weedy check plot gave significantly minimum yield due to heavy competition for nutrient, moisture and light between the crop and weeds. Similar grain yield losses due to weeds were reported by Chand *et al*. (2003) in *Kharif* blackgram. On the basis of visual observation on 0-10 point scale, none of the treatments was found phytotoxic on the crop in terms of different phytotoxic effect during the experimentation. The seedlings and plants did not show any abnormality during the crop growth period.

Effect on economics

The maximum net return of ` 17,135/ha and benefit:cost ratio (2.35) were found with imazethapyr + imazamox (pre-mix) at 0.05 kg/ha as which was followed by pendimethalin + imazethapyr (pre-mix) 1.0 kg/ha (` 16,410 and 2.30) treatment, while minimum with weedy check (-180 and 0.98). On the basis of two years experimentation, it was concluded that weed free (two hand weedings at 20 and 40 DAS) treatment recorded maximum seed yield followed by pre-mix herbicides *i.e.* imazethapyr + imazamox (pre-mix) at 0.05 kg/ha and pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha application. The net return and benefit: cost ratio were highest in imazethapyr + imazamox (pre-mix) at 0.05 kg/ha followed by pendimethalin + imazethapyr (pre-mix) at 1.0 kg/ha.

On the basis of two years experimentation, it can be concluded that highest net return (` 17135) and benefit: cost ratio (2.35) were obtained with the pre-mix imazethapyr + imazamox at 0.05 kg/ha as PoE followed by pre-mix pendimethalin + imazethapyr at 1.0 kg/ha as PoE. However, yield was found superior in weed free treatment which was closely followed by pre-mix imazethapyr + imazamox 0.05 kg/ha and pre-mix pendimethalin + imazethapyr 1.0 kg/ha.

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Weed and fertility management effects on grain yield and economics of finger millet following groundnut

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ABSTRACT

The field experiment was conducted during *Kharif* 2010 with finger millet Hebbal, Bengaluru. The finger millet crop was grown followed by groundnut during summer and continued up to 2014. The pooled data of five years of finger millet crop from 2010 to 2014 during *Kharif* indicated that application of butachlor at 0.75 kg/ha more or less gave similar grain yield (3.12 t/ha) to hand weeding twice (3.52 t/ha) due to good control of weeds. Continuous application of alachlor 1.0 kg /ha in groundnut and 2,4-D sodium salt 0.75 kg/ha in finger millet paved way for dominance of grasses particularly *Digitaria marginata*, *Dactyloctenium aegyptium* and *Echinochloa colona*, whereas pendimethalin treated plots showed higher emergence of *Commelina benghalensis*. A saving in weeding cost to an extent of ` 6,810 to ` 6,980/ha in finger millet was realized by using herbicides as compared to hand weeding. None of the herbicides affected the establishment, growth and yield of succeeding crops over the past five years, in spite of herbicides being applied continuously on the same piece of land.

Key words: Finger Millet, Groundnut, Long term herbicide usage, Weed shift

Finger millet (*Eleusine coracana* (L.)) ranks third in importance among millets in the country in both area (1.27 million ha) and production (1.91 million tonnes) after sorghum and pearl millet. It is commonly being called as *ragi* in Karnataka and it is one of the major staple foods of farming communities of Southern Karnataka. Apart from human consumption, straw is also used as fodder for the live stocks and green straw is suitable for making silage. Higher food production could be achieved by increasing the productivity of different cropping systems using improved technologies and increased cropping intensity both in rainfed and irrigated farming. Weeds are one of the major constraints in the production of finger millet. Even though, weed management strategies have been developed for finger millet and groundnut crops, the weed management strategies for finger millet-groundnut cropping system are limited. The earlier studies indicated that change in cropping system like transplanted finger millet followed by pulses have reduced the menace of *Cyperus rotundus* with concomitant increase in the density of *Portulaca oleracea* and *Digitaria marginata* (Anonymous 1998). By following transplanted finger millet - groundnut system, the density of *C. rotundus* was lowered in finger millet crop after the harvest of groundnut as a result of digging of plants at the time of harvest (Anonymous 1998, Kumara 2004). The usage of recommended herbicide(s) for the first crop in a sequence should not cause any residual effect on the succeeding crop or vice-versa. There is a need to document the shift in weed flora in a cropping system involving cereals, pulse/oilseed crops. In addition, integration of FYM along with recommended fertilizer application appeared to sustain the productivity of crops. Therefore, the effect of weed management practices along with fertility levels in cropping system of groundnut-finger millet on shifting of weed flora, yield and economics was studied.

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MATERIALS AND METHODS

The field experiment was initiated during *Kharif*, 2010 with finger millet as first crop followed by groundnut during summer as the second crop at the Main Research Station, Hebbal, Bengaluru under the jurisdiction of the University of Agricultural Sciences, Bengaluru. The soil type of the experimental site was red sandy loam with average fertility level. The finger millet - groundnut cropping system was followed from 2010 to 2014 on the same piece of land. In finger millet three weed management practices were tried, *viz*.W1- Butachlor 0.75 kg/ha (pre- emergence, within 3 days after planting, DAP), W2 - 2, 4-D NA salt 0.75 kg/ha (post-emergence, 15 DAP), *viz*. butachlor 0.75 kg/ha, 2,4-D sodium and hand weeding twice (20 and 40 DAP) which were compared with two sources of fertility levels, *viz*.

75% NPK through fertilizer + 25% N supplied through FYM, and 100% NPK supplied through fertilizers only. The gross and net plot sizes were 9.0 x 4.5 m and 8.4 x 3.9 m, respectively. Finger millet cv. *'GPU-28'* was grown as *Kharif* crop from 2010 to 2014 with a recommended fertilizer dose of 100 kg N, 50 kg P_2O_5 and 50 kg K_2O per hectare at a common spacing of 22.5 x 15 cm. As per treatment, species-wise weed density was counted at 30, 60 and at 90 DAP in 50 x 50 cm quadrant randomly at two spots per treatment, apart from taking dry weight of weeds (category-wise; sedge, grasses and broad leaf weeds). The overall grain and straw yield of finger millet obtained during 2010 to 2014 with pooled analysis of these five years have been presented in the Table 4. The weed density and dry weight of weeds - sedge, grass and broad-leaf weeds at 30, 60 and at 90 DAP were analyzed using transformation of square root of ($\sqrt{x+1}$) and log ($\sqrt{x+2}$), depending on the variability and presented in Table 1-3. The weed shift and the economics of weed management were also worked out.

RESULTS AND DISCUSSION

Weed flora

The major weed species found in the finger millet experimental plots were *C. rotundus,* (sedge), *Cynadon dactylon, Digitaria marginata, Dactyloctenium aegyptium, Echinochloa colona* (grasses); *Commelina benghalensis, Lagascea mollis, Ageratum conyzoides, Spilanthus acmella, Amaranthus viridis* and *Euphorbia hirta* (broad-leaf weeds). Among different categories, grasses were recorded in higher number followed by broad-leaf weeds and sedges during 30 and 60 days after planting and at harvest in finger millet crop. Similar findings have been reported by Kumar (2004).

Weed density and weed dry weight

The data pertaining to weed density and dry weight recorded at 30, 60 and at 90 DAP as influenced by weed management practices and sources of nutrients in transplanted finger millet is presented in Table 1, 2 and 3. Weed management practices significantly influenced the weed density and dry weight at all stages of finger millet crop. Butachlor 0.75 kg/ha as pre-emergence had significantly reduced the density of grasses followed by sedges and broad-leaf weeds, whereas 2,4-D sodium salt 0.75 kg/h as post- emergence application significantly controlled sedges and broad leaf weeds followed by grasses at 30 and 60 days after planting. Hand weeding at 20 and 40 DAP resulted in significantly lower weed density and dry weight as compared to the application of herbicides. Among herbicides, application of butachlor as pre-emergence herbicide at 1.0 kg/ha resulted in lower grass density whereas post-emergence application of 2,4-D sodium salt at 0.75 kg/ha resulted in lower sedge and broad-

Table 1. Effect of weed management practices on weed density at 30 and 60 DAP in finger millet in finger millet-groundnut cropping system

Treatment	At 30 DAS				At 60 DAS			
	Sedges	Grass	Broad-leaf	Total	Sedges	Grass	Broad-leaf	Total
Weed management								
Butachlor 0.75 kg/ha + with OM	(20.3)2.21	(11.5)3.08	(29)4.24	(60.8)1.74	(26.3)2.78	(19.7)1.80	(42.20)4.43	(88.8)1.90
2,4-D Sodium salt 0.75 kg/ha + with OM	(17.1)2.42	(34)5.62	(16.1)3.09	(67.2)1.79	(15.3)2.23	(49.0)2.40	(17.81)2.64	(82.1)1.83
Hand weeding + with OM	(6.70)1.51	(7.40)2.52	(13.1)2.80	(27.1)1.31	(12.3)2.12	(12.0)1.36	(18.03)2.69	(43.0)1.52
Butachlor 0.75 kg/ha - without OM	(19.9)2.38	(10.1)3.11	(27.9)4.25	(58)1.75	(25.7)2.78	(19.5)1.70	(40.75)4.27	(86.4)1.87
2,4-D sodium salt 0.75 kg/ha - without OM	(18)2.57	(34.2)5.95	(18.8)3.27	(71)1.83	(17.1)2.42	(44.5)2.49	(20.90)2.74	(83.2)1.85
Hand weeding - without OM	(7.45)1.56	(8.30)2.50	(13.3)2.81	(29.0)1.34	(11.4)2.12	(13.5)1.35	(20.22)2.73	(45.2)1.53
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fertility level								
75% NPK+25% N through FYM	(14.7)2.05	(17.6)3.74	(19.3)3.38	(51.7)1.61	(18)2.38	(27.8)1.85	(26.01)3.25	(71.1)1.75
100% NPK	(15.1)2.17	(17.5)3.85	(20)3.44	(52.6)1.64	(18.1)2.44	(26.5)1.85	(27.29)3.25	(71.5)1.75
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Weed management								
Butachlor	(20.1)2.30	(10.8)3.09	(28.4)4.24	(59.4)1.75	(26.1)2.78	(19.8)1.75	(41.48)4.35	(87.3)1.88
2,4-D sodium salt	(17.5)2.50	(34.1)5.78	(17.4)3.18	(69.1)1.81	(16.2)2.33	(46.9)2.44	(19.35)2.69	(82.5)1.84
Hand weeding- 20 and 40 DAP	(7.08)1.54	(7.85)2.51	(13.1)2.81	(28.1)1.33	(11.9)2.12	(13.1)1.36	(19.12)2.71	(44.2)1.52
LSD (P=0.05)	0.20	0.30	0.51	0.07	0.26	0.20	0.33	0.05

OM: Organic matter; Figures in the parentheses are the original values.

Table 2. Effect of weed management practices on weed density and weed dry weight at 90 DAP in finger millet in finger millet groundnut cropping system

Treatment	Weeds' density (no./m^2) at 90DAS				Weeds' dry weight(g/m^2) at 90DAS			
	Sedge	Grass	Broad-leaf	Total	Sedge	Grass	Broad-leaf	Total
Weed management								
Butachlor 0.75 kg/ha + with OM	(27.3)2.56	(34.6)3.14	(44.7)3.32	(106.6)2.01	(17.1)4.12	(26.6)2.45	(39.7)3.15	(83.6)1.88
2,4-D Sodium salt 0.75 kg/ha + with OM	(18.6)1.91	(59.6)3.96	(30.8)2.93	(109.1)2.02	(10.5)3.16	(52.9)3.37	(21.4)2.38	(84.9)1.88
Hand weeding + with OM	(19.7)2.14	(27.2)2.89	(36.6)2.99	(83.5)1.90	(10.2)3.17	(17.5)2.30	(26.8)2.61	(54.6)1.70
Butachlor 0.75 kg/ha - without OM	(24.6)2.43	(39.6)3.16	(39.6)3.20	(103.9)2.00	(14.5)3.76	(31.2)2.51	(34)3.03	(79.8)1.87
2,4-D sodium salt 0.75 kg/ha - without OM	(22.8)2.22	(62.3)4.05	(31.2)2.83	(116.4)2.05	(12.9)3.54	(56.2)3.47	(21.7)2.29	(90.9)1.92
Hand weeding - without OM	(18.3)2.07	(23.3)2.54	(34.8)2.92	(76.4)1.87	(9.4)3.08	(14.4)1.98	(24.7)2.53	(48.6)1.66
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fertility level								
75% NPK+25% N through FYM	(21.9)2.20	(40.5)3.33	(37.3)3.08	(99.7)1.98	(12.6)3.48	(32.3)2.71	(29.3)2.72	(74.3)1.82
100% NPK	(21.9)2.24	(41.7)3.25	(35.2)2.98	(98.9)1.97	(12.3)3.46	(34.0)2.65	(26.8)2.61	(73.1)1.82
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Weed management								
Butachlor 0.75 kg/ha	(25.9)2.49	(37.1)3.15	(42.1)3.26	(105.2)2.00	(15.8)3.94	(28.9)2.48	(36.8)3.09	(81.7)1.88
2,4-D sodium salt	(20.7)2.07	(61.0)4.01	(31.0)2.88	(112.7)2.04	(11.7)3.35	(54.6)3.42	(21.5)2.33	(87.9)1.90
Hand weeding- 20 and 40 DAP	(19.0)2.11	(25.2)2.71	(35.7)2.96	(79.9)1.88	(9.8)3.12	(15.9)2.14	(25.8)2.57	(51.6)1.68
LSD (P=0.05)	0.34	0.30	0.28	0.06	NS	0.21	NS	NS

OM: Organic matter; Figures in the parentheses are the original values.

Table 3. Effect of weed management practices on weed dry weight at 30 and 60 DAP in finger millet in finger millet-groundnut cropping system

Treatment	Weeds dry matter (g/m^2) at 30 DAS				Weeds dry weight (g/m^2) at 60 DAS			
	Sedge	Grass	Broad-leaf	Total	Sedge	Grass	Broad-leaf	Total
Weed management								
Butachlor 0.75 kg/ha + with OM	(5.39)2.13	(3.13)1.58	(12.59)3.30	(21.11)4.11	(12.68)3.55	(7.76)2.57	(23.19)4.29	(43.63)2.99
2,4-D Sodium salt 0.75 kg/ha + with OM	(4.04)1.92	(12.59)3.09	(2.29)1.65	(18.91)3.79	(5.29)2.40	(28.61)4.73	(4.43)1.96	(38.33)2.70
Hand weeding + with OM	(0.57)1.13	(0.91)1.22	(1.16)1.41	(3.24)1.65	(2.44)1.84	(3.62)1.78	(4.79)1.97	(10.8)1.56
Butachlor 0.75 kg/ha - without OM	(5.29)2.17	(2.46)1.58	(12.66)3.44	(20.41)4.24	(11.7)3.49	(7.53)2.44	(22.4)4.12	(41.7)2.92
2,4-D sodium salt 0.75 kg/ha - without OM	(4.16)1.97	(12.14)3.21	(2.81)1.72	(19.1)3.94	(5.95)2.52	(26.65)4.71	(5.70)2.12	(38.3)2.75
Hand weeding - without OM	(0.70)1.13	(1.12)1.21	(1.79)1.42	(3.60)1.66	(2.18)1.77	(3.69)1.84	(5.18)1.94	(11.1)1.53
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Fertility level								
75% NPK+25% N through FYM	(3.33)1.73	(5.54)1.96	(5.54)2.12	(14.2)3.18	(6.80)2.60	(13.33)3.03	(10.0)2.74	(30.94)2.42
100% NPK	(3.38)1.76	(5.24)2.00	(5.75)2.19	(14.7)3.28	(6.64)2.59	(12.62)3.00	(11.0)2.73	(30.37)2.40
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Weed management								
Butachlor 0.75 kg/ha	(5.34)2.15	(2.79)1.58	(12.62)3.37	(20.7)4.18	(12.2)3.52	(7.65)2.51	(22.81)4.21	(42.7)2.96
2,4-D sodium salt	(4.10)1.95	(12.6)3.15	(2.55)1.68	(19.1)3.86	(5.62)2.46	(27.6)4.72	(5.07)2.04	(38.3)2.73
Hand weeding- 20 and 40 DAP	(0.63)1.13	(1.10)1.21	(1.77)1.41	(3.42)1.66	(2.31)1.80	(3.65)1.81	(4.99)1.95	(10.9)1.55
LSD (P=0.05)	0.13	0.14	0.25	0.28	0.32	0.21	0.21	0.14

leaf density but higher grass density which compete with finger millet during the early stages of crop growth. Sources of fertility and their interaction with weed management practices did not differ significantly.

Change in weed flora due to long term use of herbicides

During *Kharif*, 1999, population of grasses, sedge and broad leaf weeds were almost similar in all the three weed management practices. After sixteen

Table 4. Effect of weed management practices on pod and straw yield in finger millet in finger millet-groundnut cropping system

Treatment	Pooled data of 5 years	
	Pod yield (t/ha)	Straw yield (t/ha)
Weed Management		
Butachlor 0.75 kg/ha + with OM	3.11	4.84
2,4-D Sodium salt 0.75 kg/ha + with OM	2.64	4.14
Hand weeding + with OM	3.45	5.18
Butachlor 0.75 kg/ha - without OM	3.13	4.89
2,4-D Sodium salt 0.75 kg/ha - without OM	2.63	4.07
Hand weeding - without OM	3.58	5.52
LSD (P = 0.05)	NS	NS
Fertility level		
75% NPK fertilizer + 25% FYM (0.25%)	3.07	4.72
100% NPK fertilizer only	3.12	4.83
LSD (P = 0.05)	NS	NS
Weed Management		
Butachlor 0.75 kg/ha	3.12	4.86
2,4-D sodium salt	2.63	4.12
Hand Weeding- 20 & 40 DAP	3.52	5.35
LSD (P=0.05)	0.21	0.22

years of detailed study, it is evident that continuous application butachlor has brought down the grass density substantially from 74.4/m^2 in 1999 to 13.3/m^2 in 2014 (Table 7). Similarly, application of 2, 4-D sodium salt has reduced the broad leaf weed density from 36.4/m^2 in 1999 to 2.8/m^2 in 2014. Continuous removal of weeds by manual weeding had reduced the weed density of all the three categories very effectively from a total weed count of 130.4/m^2 in 1999 to 14.1/m^2 in 2014. The results are in conformity with the results obtained by Channa *et al.* (2000).

Grain yield

Over five years (2010 to 2014), the grain yield of finger millet applied with fertilizer gave only yield (3.12 t/ha) which was on par with the finger millet receiving both fertilizer and FYM (3.07 t/ha). Among weed control treatments, grain yield obtained in plot treated with butachlor (3.12 t/ha) was similar to hand weeding twice (3.52 t/ha) and these were significantly superior to 2, 4-D Sodium salt (2.63 t/ha) owing to good control of grasses, as the latter treatment was effective on broad leaf weeds (Table 4). The interaction effect was non-significant.

Table 5. Long term effect of herbicides on soil physico-chemical properties in finger millet production in finger millet-groundnut cropping system

Treatment	pH	EC Ds/M	BD g/cc	OC %	P_2O_5 (kg/ha)	K_2O (kg/ha)
2,4-D sodium salt 0.75 kg/ha + FYM	6.64	0.07	1.36	0.61	88.0	172.4
2,4-D sodium salt 0.75 kg/ha without FYM	6.32	0.09	1.40	0.51	92.7	169.1
Butachlor 0.75 kg/ha + FYM	6.31	0.08	1.38	0.54	86.6	160.8
Butachlor 0.75 kg/ha + without FYM	6.41	0.07	1.33	0.50	95.0	178.0
Hand weeding + FYM	6.30	0.06	1.39	0.60	91.2	178.3
Hand weeding without FYM	6.31	0.08	1.41	0.62	87.9	162.3
Initial soil value (1999)	6.10	0.03	1.25	0.60	56.0	136.0

Initial soil value refers to the soil data at the time of start of the experiment *i.e., Kharif,* 1999.

Table 6. Economics of weed management practices in finger millet production in finger millet-groundnut cropping system

Treatment	Finger millet (*Kharif*, 2014)	
	Cost of weed management (x10^3 `/ha)	Savings over hand weeding (x10^3 `/ha)
Butachlor 0.75 kg/ha	1.05	6.15
2,4-D sodium salt 80 WP 0.75 kg/ha	0.96	6.24
Hand weeding (and 45 DAP)	7.20	--

Cost of herbicides: Butachlor 50 EC Rs. 225/- litre, 2,4-D sodium salt 80 WP - ` 360/- per kilogram, application cost – ` 600/- per ha, cost of labour – ` 200/- per day(for men), ` 150/- (for women) per dayof eight hours work.

Butachlor and hand weeding treatments gave higher grain yield at both sources of fertility than 2,4-D Sodium salt treatment. Similar indications of weed control by using herbicides have been observed by Kumara (2004).

Economics of weed management

In finger millet, use of butachlor 0.75 kg/ha - 3 DAP (` 1,050/ha) and 2,4-D sodium salt 0.75 kg/ha - 15 DAP (` 960/ha) was cheaper than two hand weeding, amounting to ` 7,200/ha. Thus, a saving in weeding cost to an extent of ` 6,150 to ` 6,240/ha was observed though it gave comparable yield to butachlor (Table 6). This suggested that herbicides are economical and cost effective in managing weeds right from the initial stages as compared to hand

Table 7. Change in the weed flora due to weed management practices in finger millet during *Kharif*, 1999 to 2014 in finger millet–groundnut system

Treatment	Density of major category of weeds/m²							
	Initial year – 1999 (30 DAP - First crop)				Final year - 2014 (30 DAP – sixteenth crop sequence) (thirty first crop in the system)			
	Sedge	Grass	Broad-leaf	Total	Sedge	Grass	Broad-leaf	Total
Weed management								
Butachlor 0.75 kg/ha + with OM	30.8	79.2	41.2	151.2	13.0	14.5	29.0	56.5
2,4-D Sodium salt 0.75 kg/ha + with OM	27.2	80.4	35.6	143.2	5.3	30.0	3.0	38.3
Hand weeding + with OM	23.2	68.4	34.0	125.6	3.3	5.0	6.0	14.3
Butachlor 0.75 kg/ha - without OM	34.0	70.0	54.8	158.8	11.7	12.0	23.5	47.2
2,4-D sodium salt 0.75 kg/ha - without OM	29.2	64.4	37.2	130.4	5.0	34.0	2.5	41.5
Hand weeding - without OM	30.4	59.6	44.8	134.8	4.3	4.5	5.0	13.8
Fertility level								
75% NPK + 25% N through FYM	27.2	76.0	36.8	140.0	7.2	16.5	12.7	36.4
100% NPK	31.2	64.8	45.6	141.6	7.0	16.8	10.3	34.2
Weed management								
Butachlor 0.75 kg/ha	32.4	74.4	48.0	154.8	12.4	13.3	26.3	51.9
2,4-D sodium salt 0.75 kg/ha	28.4	72.8	36.4	137.6	5.2	32.0	2.8	39.9
Hand weeding- 20 and 40 DAP	26.8	64.0	39.6	130.4	3.8	4.8	5.5	14.1

W1 : Butachlor 0.75 kg (pre-em.), W2 : 2,4-D sodium salt 80 WP 0.75 kg/ha (post-em.), W3 : Hand weeding (20 and 45 DAP); F1 :75% NPK through fertilizer + 25 % N through FYM, F2 : 100% NPK through fertilizers only; OM = Organic matter,100% NPK = 25 kg N,75 kg P_2O_5,38 kg K_2O per ha

weeding. Gnanamurthy and Balasubramaniyan (1998) and Kumars (2004) also obtained similar benefits in their studies.

Long term effect of herbicides on soil physico-chemical properties

The change in the physico-chemical properties of the soil due to long term application of herbicides was also studied after the harvest of crop finger millet during *Kharif* 2014 (Table 5). Continuous use of 2,4-D sodium salt or butachlor in finger millet did not affect the soil physico-chemical properties, *viz*. pH, EC, bulk density, organic carbon, contents of P_2O_5 and K_2O when compared to initial values over a period of sixteen years from 1999 to 2014. Compared to initial values, the values of these properties were slightly higher in the treatments indicating no adverse effect of herbicides applied continuously. Further, application of FYM slightly increased the organic carbon over fertilizer application alone. The continuous application of fertilizers increased the P_2O_5 and K_2O contents in the soil as compared to initial values. Phosphorus build up was slightly more in fertilizer applied plots than FYM applied plots. Similar findings were reported by Ramamoorthy *et al.* (2009).

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Nutrient uptake by weeds and pea as influenced by phosphorus and weed management

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ABSTRACT

Three P_2O_5 levels, *viz.* 0, 30 and 60 kg/ha were evaluated under six weed management practices, *viz.* weedy check, pendimethalin followed by (*fb*) hand weeding (HW), stale seedbed (SSB), SSB + pendimethalin *fb* HW, raised stale seedbed (RSSB) and RSSB + pendimethalin *fb* HW in pea during *Rabi* 2006-07 and 2007-08 on a silty clay loam soil at Palampur. *Phalaris minor*, *Vicia* sp. and *Polygonum alatum* were the major weeds found growing in association with peas. Stale seedbed and raised stale seedbed were significantly superior to weedy check in reducing total weed dry weight, weed growth rate, NPK depletion by weeds and increasing crop dry matter, crop growth rate (CGR), relative growth rate (RGR), NPK uptake by crop and subsequent radish yield. Superimposition of pendimethalin + hand weeding further improved the effectiveness of stale seedbed and raised stale seedbed in reducing total growth rate of weeds and NPK depletion by weeds and increasing crop dry matter, CGR, RGR, NPK uptake by crop and subsequent radish yield. Weeds in weedy check removed 39.3 and 53.6 kg N/ha, 16.5 and 16.6 kg P/ha and 24.1 and 27.4 kg K/ha during the first and second year, respectively. All weed control methods being at par resulted in significantly higher available P content after pea harvest. Weed dry weight and growth rate of weeds, NPK uptake by green pods and straw of pea, nodules/plant, available soil N and P after harvest of pea and subsequent radish yield increased with increase in the rate of P. NPK depletion by weeds, crop dry weight, CGR and RGR increased upto 30 kg P_2O_5/ha.

Key words: Hand weeding, Nutrient uptake, Pendimethalin, Peas, Phosphorus, Stale seedbed

Pea is one crop, which builds up the soil fertility by atmospheric nitrogen fixation through the root nodules. Besides residual effect on soil fertility, pea has great potential as an exceptionally nutritive and very rich protein food. However, it has higher requirement of phosphorus for symbiotic nitrogen fixation. However, weeds are the major threat in harnessing the full potential of applied and native plant nutrients. They remove considerable amount of nutrients and adversely affect the yield of the crops (Kumar *et al*. 2005). Rana *et al*. (2013) reported 56.8 - 60.1% reduction in peas green pod yield due to full season weed competition. In order to achieve enhanced crop production and higher benefits from applied inputs, there must be a strong weed management strategy. Thus, the judicious management of weeds through integrated weed management practices is imperative to enhance the nutrient use efficiency. Stale seedbed is useful in depleting the weed seed pool (Rasmussen 2004). Raised stale seedbed has an added advantage of easy planting because the soil on a raised bed warms up and dries out faster, better drainage eliminating the problems of water stagnation too close to the plant roots, fewer diseases and easy irrigation by simply running water between the beds and allowing water to seep into the root zone and ultimately enhancing the nutrient use efficiency. The subsequent flushes of weeds after sowing of the crop may be controlled with herbicidal weed management (Rana *et al*. 2004, 2007). Therefore, present study was conducted to work out nutrient removal by weeds and crops as influenced by P levels in relation to weed management methods.

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MATERIALS AND METHODS

The field experiment was conducted during *Rabi* 2006-07 and 2007-08 at Bhadiarkhar farm (Palampur). The soil of the experimental field was silty clay loam in texture, acidic in reaction (pH 5.2) and medium is available N (313.6 kg/ha) and K (202.1 kg/ha) and high in P (25.7 kg/ha). The experiment was conducted in split plot design with four replications. Six weed control treatments, *viz.* weedy check, pendimethalin *fb* hand weeding (HW), stale seedbed (SSB), SSB + pendimethalin *fb* HW, raised stale seedbed (RSSB), and RSSB + pendimethalin *fb* HW were accommodated in main plots while three P_2O_5 levels, *viz.* 0. 30 and 60 kg/ha in the sub-plots (Table 1). Sowing of pea variety '*Palampriya*' was done during the second fortnight of November using 75 kg/ha seed rate in a row to row spacing of 30 cm. Application of herbicides was made with power sprayer using 700 L water per hectare. Except weed control treatments and phosphorus, the crop was raised in accordance with the recommended package of practices. In addition to P_2O_5 as per the treatment, the crop was fertilized with 20 kg N, and 40 kg K_2O/ha as basal dose. Required amount of N, P and K was supplied through urea, single super phosphate and muriate of potash, respectively. Weed dry weight was recorded at 60, 90, 120 DAS and at harvest from two randomly selected spots (0.25 m^2) in each plot and expressed as g m^{-2}. The data on dry weight of weeds were subjected to square root transformation ($\sqrt{x+0.5}$). Yields were harvested from net plot (4.0 x 2.3 m). Oven dried samples of weeds, green pods and straw were analyzed for N, P (Jackson 1967) and K (Black 1965) content as per standard procedures. Uptake of N, P and K by weeds, pods and straw was obtained by multiplying their nutrient content with corresponding dry matter. Total uptake by crop was obtained by adding the uptake by pods and straw. Radish variety '*Pusa Chetki*' was also grown after the harvest of peas in the residual fertility using manual weed control.

RESULTS AND DISCUSSION

Phalaris minor (60.9 and 64.4% of the total weed flora during 2006-7 and 2007-8, respectively), *Vicia* sp. (20.4 and 19.8%) and *Polygonum alatum* (15.2 and 13.6%) were the major weeds found growing in association with pea crop. The other weeds (*Lathyrus aphaca*, *Spergula arvensis* and *Avena ludoviciana*) as a whole constituted 3.5 and 2.2% of the total weed flora during the first and second year, respectively.

Weed control methods

Weed control treatments brought about significant variation in total weed dry weight (120 DAS) during both the year (Table 1). Stale seedbed and raised stale seedbed where one flush of the weeds was destroyed before sowing of pea, were significantly superior to weedy check in reducing total weed dry weight upto 120 DAS during both the year. Depleting the weed seed pool in the top few centimeters of soil by such practices as stale seedbed has been reported quite effective in different crops by a number of workers (Kumar *et al.* 2003, Kumar *et al*. 2005). However, these had higher weed dry weight as compared to pendimethalin + hand weeding. Superimposition of pendimethalin + hand weeding further improved the effectiveness of stale seedbed and raised stale seedbed in reducing total weed dry weight during both the year. Superiority of pendimethalin 1.0 kg/ha in controlling weeds in pea + maize intercropping system on raised seedbed has been reported (Singh *et al*. 2012). The trend in weed growth rate between 60-90 DAS was similar as it was for weed dry weight during both the year. Weed control treatments significantly affected RGR of weeds during 2006-07. Stale or raised stale seedbed alone could not bring down the weed RGR between 60-90 DAS over weedy check. However, pendimethalin + hand weeding alone and along with stale/raised seedbed resulted in significant reduction in the RGR of weeds over the weedy check as well as stale or raised stale seedbed. Superiority of pendimethalin + hand weeding against weeds has been documented (Vaishya *et al.* 1999).

Nutrient uptake is a function of dry weight and nutrient content is expected to follow the trend of dry weight influenced by the content. Like weed dry

Table 1. Effect of weed control methods and P levels on weed dry weight (g/m^2), weed growth rate (g/m^2/day) and weeds RGR (g/g/day) in peas

Treatment	Weed dry weight (120 DAS)		Weed growth rate (60-90 DAS)		Weed RGR (60-90 DAS)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Weed control method						
Weedy	301.9	340.2	8.5	9.7	0.09	0.08
Pendimethalin + HW	135.8	133.6	3.7	2.5	0.08	0.04
Stale seedbed (SSB)	237.0	256.2	6.8	5.9	0.09	0.07
SSB + pendimethalin + HW	74.0	50.0	1.8	1.8	0.07	0.06
Raised stale seedbed (RSSB)	233.7	233.0	6.7	5.8	0.09	0.07
RSSB + pendimethalin + HW	65.3	50.8	1.6	1.4	0.07	0.05
LSD (P=0.05)	51.8	56.3	1.5	1.8	0.01	NS
P_2O_5 (kg/ha)						
0	130.9	150.2	3.5	3.5	0.08	0.06
30	178.6	185.2	5.0	4.6	0.08	0.06
60	214.4	196.5	6.0	5.5	0.08	0.07
LSD (P=0.05)	25.8	31.2	0.7	0.8	NS	NS

weight, weed control treatments brought about significantly variation in N, P and K uptake by weeds during both the years (Table 2). Weeds in weedy check removed 39.3 and 53.6 kg N/ha during the first and second year, respectively. All weed control treatments were significantly superior to weedy check in reducing N depletion by weeds. Pendimethalin *fb* hand weeding alone and along with stale/raised seedbed resulted in significant reduction in N depletion by weeds over the weedy check as well as stale or raised stale seedbed. Weeds in weedy check took 16.5 and 16.6 kg P/ha from soil during the first and second year, respectively. Except stale/raised stale seedbed all other weed control treatments had significantly brought down P depletion by weeds over weedy check. Integration of pendimethalin + hand weeding with the stale/raised stale seedbed was significantly better than pendimethalin + hand weeding alone in reducing P depletion by weeds. Uninterrupted growth of weeds in the weedy check removed 24.1 and 27.4 kg K/ha during the first and second year, respectively. Stale/raised stale seed bed was significantly superior to weedy check in reducing K depletion by weeds. Pendimethalin *fb* hand weeding was superior to both of these. In integration with stale/raised stale seedbed, pendimethalin *fb* hand weeding further significantly reduced K depletion by weeds over its application alone.

Controlling one flush of weeds before sowing peas under the stale or the raised stale seedbeds resulted in significantly higher crop dry matter accumulation, crop growth rate (CGR) and relative growth rate (RGR) over the weedy check (Table 3). The subsequent suppression of other flushes with pendimethalin fb hand weeding gave further boost in crop dry matter accumulation, crop growth rate and relative growth rate. The superiority of pendimethalin in peas has been reported (Rana *et al*. 2004, 2007). The nodule count, however, was not significantly influenced under different weed management treatments (Table 5).

Table 2. Effect of weed control methods and P levels on NPK uptake (kg/ha) by weeds

Treatment	N		P		K	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Weed control method						
Weedy	39.3	53.6	16.5	16.6	24.1	27.4
Pendimethalin + HW	15.3	18.1	10.2	8.2	9.7	9.7
Stale seedbed (SSB)	34.3	45.8	20.6	19.3	16.6	17.8
SSB + pendimethalin + HW	12.2	9.9	4.7	2.9	5.3	3.5
Raised stale seedbed (RSSB)	30.0	36.0	17.0	15.1	15.8	15.9
RSSB + pendimethalin + HW	10.1	9.7	4.9	3.2	4.7	3.6
LSD (P=0.05)	6.2	7.6	5.0	4.2	2.2	3.0
P_2O_5 (kg/ha)						
0	19.3	26.6	9.3	9.5	9.3	10.4
30	24.4	30.4	13.2	11.9	13.6	14.3
60	26.9	29.5	14.5	11.2	15.2	14.3
LSD (P=0.05)	4.3	NS	4.1	NS	2.4	3.3

Table 3. Effect of weed control methods and P levels on growth of crop

Treatment	Crop dry weight		CGR (30–60 DAS) (g/m^2/day)		RGR (30–60 DAS) (g/g/day)	
	2006-07	2007-08	2006-07	2007-08	2006-07	2007-08
Weed control method						
Weedy	126.4	117.4	0.67	0.81	0.01	0.02
Pendimethalin + HW	200.0	179.6	1.32	1.08	0.01	0.01
Stale seedbed (SSB)	182.7	183.3	1.86	2.13	0.01	0.02
SSB + pendimethalin + HW	261.5	246.1	2.67	2.15	0.02	0.02
Raised stale seedbed (RSSB)	185.4	177.1	1.87	1.70	0.01	0.02
RSSB + pendimethalin + HW	267.6	251.2	3.74	3.61	0.02	0.03
LSD (P=0.05)	32.1	33.2	1.2	1.1	0.005	0.001
P_2O_5 (kg/ha)						
0	183.7	169.7	1.40	1.42	0.01	0.02
30	206.1	204.6	2.57	2.31	0.02	0.02
60	222.0	203.0	2.10	2.01	0.02	0.02
LSD (P=0.05)	19.0	11.5	0.5	0.4	0.002	0.002

The crop having higher growth rate is expected to have higher nutrients assimilation by it. Stale or the raised stale seedbeds because of having higher dry matter accumulation resulted in significantly higher N, P and K uptake by pea crop over the weedy check (Table 4) during the first year. However, in the second year, raised stale seed could not significantly increase NPK uptake by crop over the weedy check. Because of higher dry matter accumulation, stale/raised stale seedbeds in integration with pendimethalin + hand weeding were further superior to other treatments in general.

The available N after the first year was not significantly affected under the weed control treatments. The initial available N content before sowing peas was 313.6 kg/ha. The available soil N content ranged from 328.0 to 334.5 kg/ha under the treatments. The gain in N content ranges from 14.4-20.9 kg/ha which may be referred to as the part of atmospheric nitrogen fixation under the prevailing circumstances. The minimum of 14.4 kg/ha was under the weedy check and maximum 20.9 kg/ha under pendimethalin alone and along with stale/raised stale seedbeds. Weed control methods brought about significant variation in the soil available P status after the harvest of peas. All weed control methods being at par resulted in significantly higher available P content after pea harvest. Residual effects of P were also significant on the yield of radish cultivated (clean cultivation-weed free) after the harvest of peas. All weed control methods resulted in significantly higher radish yield over weedy check. Stale/raised stale seed bed had significantly higher yield over weedy check. Pendimethalin + hand weeding alone and its imposition in stale/raised stale seedbed had further higher yield over stale/raised stale seedbed. This clearly indicated that weeds not only have direct effect on the growth, development and yield of the present crop but had subsequent after effects.

Phosphorus

The data on weed dry weight, weed growth rate and weed RGR as affected by phosphorus levels have been given in Table 1. Phosphorus application could bring about significant variation in the dry weight and growth rate of weeds. Both weight and growth rate of weeds were significantly higher under P application over no application of P. Weed weight during the first year and growth rate during both the years increased with increase in the application rate of

Table 4. Effect of weed control methods and P levels on NPK uptake by crop

Treatment	N (kg/ha)			P (kg/ha)			K (kg/ha)		
	Pod	Haulm	Total	Pod	Haulm	Total	Pod	Haulm	Total
					2006-07				
Weed control method									
Weedy	15.5	1.4	16.9	5.8	0.6	6.4	10.4	1.3	11.6
Pendimethalin + HW	33.6	3.5	37.1	12.3	1.3	13.7	21.7	2.9	24.5
Stale seedbed (SSB)	37.9	4.2	42.2	13.6	1.6	15.2	19.9	3.3	23.5
SSB + pendimethalin + HW	41.4	4.7	46.1	15.4	1.9	17.3	23.3	3.8	27.0
Raised stale seedbed (RSSB)	28.5	3.6	32.1	11.0	1.4	12.4	15.2	2.7	17.9
RSSB + pendimethalin + HW	46.3	4.8	51.1	17.0	1.8	18.8	27.5	4.2	30.8
LSD (P=0.05)	9.9	1.0	10.7	3.3	0.4	3.6	5.6	1.0	5.5
P_2O_5 (kg/ha)									
0	25.8	2.6	28.4	9.9	1.1	11.0	16.9	2.5	19.3
30	36.3	4.0	40.3	13.2	1.5	14.6	20.0	3.1	22.9
60	39.6	4.5	44.1	14.5	1.7	16.2	22.0	3.5	25.5
LSD (P=0.05)	3.4	0.6	3.8	0.9	0.1	1.1	2.2	0.4	2.1
					2007-08				
Weed control method									
Weedy	6.0	1.5	7.6	1.8	0.5	2.3	4.3	1.5	5.8
Pendimethalin + HW	15.5	4.9	20.4	4.3	1.5	5.8	9.7	4.0	13.8
Stale seedbed (SSB)	19.5	6.5	26.0	5.7	2.0	7.7	10.5	5.2	18.7
SSB + pendimethalin + HW	17.2	6.3	23.5	5.2	2.1	7.3	10.2	4.8	16.5
Raised stale seedbed (RSSB)	7.4	2.7	10.1	2.2	0.8	3.1	4.2	2.2	6.4
RSSB + pendimethalin + HW	21.5	6.6	28.1	6.5	2.1	8.6	13.3	5.9	20.6
LSD (P=0.05)	4.1	2.1	5.9	1.3	0.8	2.1	2.8	2.1	4.1
P_2O_5 (kg/ha)									
0	10.2	3.2	13.4	3.3	1.1	4.4	6.9	3.1	10.8
30	15.4	4.9	20.3	4.4	1.5	5.8	8.8	3.9	13.4
60	17.9	6.3	24.2	5.3	2.0	7.2	10.3	4.9	16.6
LSD (P=0.05)	2.2	1.0	3.0	0.6	0.3	0.8	1.3	0.7	2.3

Table 5. Effect of weed control methods and P levels on available nutrients after harvest

Treatment	Nodule count (no/plant)	N (kg/ha) 2006-07	P (kg/ha) 2006-07	Radish yield (t/ha)
Weed control method				
Weedy	21.2	328.0	26.3	1.9
Pendimethalin + HW	19.6	334.5	31.1	5.9
Stale seedbed (SSB)	21.8	331.1	30.5	4.4
SSB + pendimethalin + HW	21.6	334.5	31.6	6.2
Raised stale seedbed (RSSB)	21.5	330.6	30.4	3.3
RSSB + pendimethalin + HW	21.1	334.5	31.5	6.7
LSD (P=0.05)	NS	NS	2.2	1.3
P_2O_5 (kg/ha)				
0	18.0	322.3	28.0	4.3
30	20.8	332.5	30.6	4.8
60	24.7	341.7	32.0	5.1
LSD (P=0.05)	0.7	7.6	0.7	0.4

Table 6. Integrated effect of weed control methods and phosphorus levels on weed dry weight (120 DAS, transformed) and green pod yield

Treatment	2006-07			2007-08			Mean		
	P_0	P_{30}	P_{60}	P_0	P_{30}	P_{60}	P_0	P_{30}	P_{60}
Weed dry weight (g/m^2)									
Weedy	15.3 (234.0)	17.3 (298.5)	19.3 (373.2)	16.8 (283.2)	18.3 (341.3)	19.8 (396.1)	16.0 (258.6)	17.8 (319.9)	19.6 (384.7)
Pendimethalin + HW	10.0 (104.0)	10.6 (114.8)	13.2 (188.5)	10.3 (109.4)	11.6 (140.9)	11.9 (150.5)	10.2 (106.7)	11.1 (127.8)	12.6 (169.5)
Stale seedbed (SSB)	13.8 (192.6)	15.3 (235.5)	16.6 (283.0)	17.1 (292.6)	15.6 (242.1)	15.2 (234.1)	15.6 (242.6)	15.4 (238.8)	15.9 (258.6)
SSB + pendimethalin + HW	8.9 (80.1)	8.1 (65.5)	8.7 (76.6)	6.6 (46.0)	7.1 (51.2)	7.2 (52.9)	7.9 (63.0)	7.6 (58.3)	8.0 (64.7)
Raised stale seedbed (RSSB)	10.9 (118.5)	16.7 (280.5)	17.4 (302.1)	11.5 (135.8)	16.4 (272.6)	17.0 (290.7)	11.2 (127.1)	16.6 (276.6)	17.2 (296.4)
RSS + pendimethalin + HW	7.5 (56.5)	8.7 (76.5)	7.9 (63.0)	5.9 (34.2)	7.9 (63.1)	7.3 (55.0)	6.8 (45.3)	8.3 (69.8)	7.7 (59.0)
LSD (P=0.05) (1)	2.0			2.5			2.0		
(2)	2.3			2.6			2.3		
Green pod yield (t/ha)									
Weedy	1.48	1.78	1.55	1.55	1.84	1.97	1.52	1.81	1.76
Pendimethalin + HW	2.76	3.62	3.63	2.52	3.51	3.46	2.64	3.57	3.54
Stale seedbed (SSB)	3.08	3.69	3.73	3.22	4.70	4.46	3.15	4.19	4.10
SSB + pendimethalin + HW	3.80	4.07	4.22	3.41	4.90	5.41	3.60	4.48	4.82
Raised stale seedbed (RSSB)	2.05	2.72	3.66	2.26	2.61	3.30	2.15	2.67	3.48
RSSB + pendimethalin + HW	4.16	4.54	5.35	4.14	4.78	4.84	4.15	4.66	5.09
LSD (P=0.05) (1)	0.60			0.63			0.47		
(2)	1.08			0.74			0.50		

Data given in parentheses are the means of original values subjected to square root transformation $\sqrt{x+0.5}$; LSD - (1), P level at the same weed control method; LSD - (2), Weed control method at the same or different P level.

P. Owing to higher dry weight due to P application, N and P depletion during the first year and K depletion by weeds during both years were increased with increase in the rate of P upto 30 kg/ha (Table 2).

Phosphorus is an indispensable nutrient in legumes because of its key role in nitrogen fixation. Therefore, increasing crop dry weight, CGR and RGR due to P application was quite obvious over its no application (Table 3). However, 30 and 60 kg P_2O_5/ha levels were statistically at par with each other in influencing crop dry weight, CGR and RGR of pea crop. The increase in growth and yield attributes of pea owing to phosphorus application over no phosphorus application has been amply documented (Dass *et al*. 2005). The accumulated amount of growth due to phosphorus was the result of higher assimilation of applied and native plant nutrients. N, P and K uptake by the economic and byproducts of peas and of total thereof was in general increased with increase in the dose of P (Table 4). The role of phosphorus in fixing atmospheric nitrogen is clearly visible through data on nodule count presented in Table 5, which revealed that they have increased with increase in the level of P_2O_5. Improved growth/yield due to P was also observed by several workers (Aga *et al*. 2004, Dass *et al*. 2005). Available soil N and P status after the harvest of peas crop increased with increase in the dose of phosphorus. Similarly, residual effects of P were significant on radish yield which showed increase in its yield with increase in the level of P.

Interaction

Weed control methods interacted significantly with phosphorus levels for weed dry weight accumulation at 120 DAS (Table 6). Under weedy check, pendimethalin + hand weeding, stale seedbed and raised stale seedbed, phosphorus application resulted in higher weed dry weight over no phosphorus application. The weed dry weight in general increased with increase in the level of phosphorus. But under stale seedbed *fb* pendimethalin + hand weeding or raised stale seedbed *fb* pendimethalin fb hand weeding, weed dry weight was more or less similar under phosphorus application and no phosphorus application. In each phosphorus level, all weed control treatments were significantly superior to weedy check. However, weed dry weight under the stale/raised stale seedbed with P application was statistically at par to that under weedy check without phosphorus application.

Weed control and phosphorus levels also interacted significantly for green pod yield (Table 6). It was clearly evident that under the weedy check phosphorus application favoured weed growth at the cost of green pod yield as P application here could not significantly increase yield over no P application. However, under other treatments where weed competition was lower at the critical period of competition, phosphorus application gave significantly higher yield over no phosphorus application.

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Integrated weed management in summer sesame

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ABSTRACT

A field experiment was conducted during 2010 to 2012 at Junagadh (Gujarat) to study the integrated weed management in sesame. Pendimethalin as pre-emergence, while imazethapyr and quizalofop-ethyl as post-emergence were tested alone and in integration with hand weeding and interculturing. The quizalofop-ethyl 40 g/ha as post-emergence (20-25 DAS) + HW and IC (45 DAS) and pendimethalin 450 g/ha as pre-emergence + HW and IC (30 DAS) were found equally effective to the weed free check in controlling weeds and improving growth and yield attributes and ultimately seed yield (1.21 and 1.16 t/ha) and stalk yield (2.01 and 1.85 t/ha) of sesame. These treatments also recorded higher net returns (` 44,066 and 42,242/ha) and B:C ratio (3.58 and 3.54), therefore, these integrated weed management practices could become effective and economical under south Saurashtra agro-climatic conditions of Gujarat.

Key words: Hand weeding, Imazethapyr, Intercultivation, Pendimethalin, Quizalofop, Weed flora

Sesame (*Sesamum indicum* L.), commonly known as '*til'*, is one of the important edible oilseeds cultivated in India. India is the major producer of this crop in the world and occupies well over 36% of the total acreage and contributes about 25% of the total output. In Gujarat, sesame is cultivated in about 2.89 lakh hectares area with an annual production of about 1.27 lakh tonnes of seeds and productivity of 438 kg/ha (DOA 2011). Sesame is grown in almost all the districts as a *Kharif* and semi-*Rabi* crop. Now sesame cultivation has also gained popularity as a summer irrigated crop in the state due to less infestation of pests and diseases as well as higher yield and monetary returns. Initial slow growth of sesame seedlings makes itself poor competitor with more vigorous weeds. Scanty scientific information is available regarding weed management in summer sesame especially for south Saurashtra region of Gujarat, hence, present experiment was undertaken to find out appropriate weed management practices for summer sesame.

MATERIALS AND METHODS

A field experiment was conducted at Weed Control Research Scheme, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) during summer seasons of 2010 to 2012. The soil of the experimental plot was clayey in texture and slightly alkaline in reaction (pH 7.8 and EC 0.34 dS/m) as well as low in available nitrogen (239 kg/ha), available phosphorus (24.4 kg/ha) and medium in available potash (236 kg/ha). The experiment comprising of 12 treatments, *viz*. pendimethalin 450 g/ha as pre-emergence, pendimethalin 450 g/ha pre-emergence + HW and IC (30 DAS), imazethapyr 75 g/ha as post-emergence (20-25 DAS), imazethapyr 37.5 g/ha as post-emergence (20-25 DAS) + HW and IC (45 DAS), imazethapyr 75 g/ha as post-emergence (20-25 DAS) + HW and IC (45 DAS), quizalofop-ethyl 40 g/ha as post-emergence (20-25 DAS), quizalofop-ethyl 20 g/ha as post-emergence (20-25 DAS) + HW and IC (45 DAS), quizalofop-ethyl 40 g/ha as post-emergence (20-25 DAS) + HW and IC (45 DAS), HW and IC (20 DAS), HW and IC twice (20 and 40 DAS), weed-free check, and weedy check was laid out in randomized block design with three replications.

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The sesame variety *'Gujarat Til 2'* was sown at 45 cm row spacing. The crop was fertilized with 50-11-0 kg NPK/ha as basal. The pre-emergence herbicides were applied to soil on next day of sowing, while post-emergence spray was done at 20-25 DAS according to soil moisture condition. The spray volume for pre- and post-emergent herbicide application was 500 L/ha. Inter-culturing (IC) was carried out in inter-row space through bullock drawn implement simultaneously with hand weeding (HW). The crop was raised as per the recommended package of practices.

RESULTS AND DISCUSSION

The weed flora of experimental field mainly comprised of *Cyperus rotundus*, *Echinocloa colona*, *Cynodon dactylon*, *Digitaria sanguinalis*, *Digera arvensis*, *Trianthema portulacastrum* and *Physalis minima*.

Effect on crop

Various weed management practices significantly influenced growth and yield attributes of sesame (Table 1). Significantly the highest plant height, number of branches per plant, number of capsules per plant and test weight were recorded under the weed-free check, however it remained at par with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha as pre-emergence + HW and IC, HW and IC twice, quizalofop-ethyl 20 g/ha as post-emergence + HW and IC and imazethapyr 75 g/ha as post-emergence + HW and IC in respect of plant height, with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC and pendimethalin 450 g/ha as pre-emergence + HW and IC in respect of number of branches per plant and test weight and with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha as pre-emergence + HW and IC, HW and IC twice, and imazethapyr 75 g/ha as post-emergence + HW and IC in respect of number of capsules per plant. Whereas, significantly the lowest values of these growth and yield attributes were registered under the weedy check. Periodical removal of weeds by hand weeding and inter-culturing or herbicide application supplemented with weeding and inter-culturing suppressed weeds, which in turn provided better weed free environment to the crop during critical period for growth and development. Baskaran and Solaimalai (2002) also reported similar results.

Different weed management treatments significantly influenced the seed yield of sesame during individual years and in pooled results. The weed-free check yielded by producing significantly the highest seed yield of 1.36, 1.44, 1.33 and 1.38 t/ha during 2010, 2011, 2012 and in pooled results, respectively. The next best treatments in this regard were quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha as pre-emergence + HW and IC and HW and IC twice. Significantly the lowest seed yield (0.39, 0.30, 0.27 and 0.32 t/ha) was observed under the unweeded control during all the three years and in pooled results. The yield increased with weed-free, quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha as pre-emergence + HW and IC and HW and IC twice over the unweeded control was to the tune of 329, 278, 264 and 243%, respectively.

The highest stalk yield of 2.03, 2.18, 2.21 and 2.14 t/ha was recorded under the weed-free check in 2010, 2011, 2012 and in pooled results, respectively, however it remained at par with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha as pre-emergence + HW and IC and HW and IC twice in 2010, with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC and pendimethalin 450 g/ha as pre-emergence + HW and IC in 2011 and with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC in 2012 and pooled results. Efficient control of weeds and improved growth and yield attributes under these treatments might have reflected in increased seed and stalk yields. Whereas, significantly the lowest stalk yield of 0.64, 0.89, 0.52 and 0.68 t/ha was registered under the weedy check in individual years and pooled results, respectively. These results were in conformity with findings of Punia *et al.* (2001) and Gnanavel and Anbhazhagan (2006).

Effect on weeds

The data (Table 2) indicated that different weed management treatments exerted significant effect on dry weight of weeds during 2010, 2011, 2012 and in pooled results. All the weed management treatments including weed-free treatment significantly reduced dry weight of weeds over the unweeded control. During all the individual years and in pooled results, the weed-free recorded significantly the lowest weed dry weight (0.17, 0.03, 0.02 and 0.07 t/ha), which was statistically at par with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha

Table 1. Effect of integrated weed management on growth, yield attributes and yield of sesame

Treatment	Dose (g/ha)	Plant height (cm)	Branc-hes per plant	100-seed weight (g)	Seed yield (t/ha)				Stalk yield (t/ha)			
					2010	2011	2012	Pooled	2010	2011	2012	Pooled
Pendimethalin	450	50.6	2.20	4.93	0.68	0.72	0.54	0.64	1.05	1.17	0.89	1.04
Pendimethalin + HW and IC	450	62.5	2.87	5.70	1.14	1.21	1.16	1.17	1.77	1.90	1.88	1.85
Imazethapyr	75	53.4	2.40	4.84	0.70	0.78	0.65	0.71	1.12	1.28	1.07	1.16
Imazethapyr + HW and IC	37.5	46.0	1.93	4.40	0.44	0.51	0.40	0.45	0.71	0.90	0.70	0.76
Imazethapyr + HW and IC	75	58.1	2.73	5.31	0.89	0.95	0.86	0.90	1.49	1.55	1.39	1.48
Quizalofop	40	56.7	2.47	5.05	0.72	0.82	0.66	0.74	1.25	1.43	1.17	1.28
Quizalofop + HW and IC	20	58.3	2.60	5.16	0.76	0.84	0.71	0.77	1.39	1.47	1.24	1.37
Quizalofop + HW and IC	40	62.7	3.13	5.75	1.18	1.22	1.24	1.21	1.95	2.04	2.05	2.01
HW and IC		47.3	2.20	4.63	0.47	0.57	0.51	0.52	0.73	1.15	1.00	0.96
HW and IC twice		62.5	2.80	5.31	1.05	1.16	1.09	1.10	1.72	1.86	1.76	1.78
Weed-free		63.9	3.27	5.92	1.36	1.44	1.33	1.38	2.03	2.18	2.21	2.14
Weedy		45.8	1.87	4.15	0.39	0.30	0.27	0.32	0.64	0.89	0.52	0.68
LSD (P=0.05)		5.9	0.35	0.53	0.17	0.20	0.17	0.10	0.31	0.27	0.27	0.16

Table 2. Effect of integrated weed management on weed parameters and economics

Treatment	Dose (g/ha)	Weed dry weight (t/ha)				Weed density (no./m^2)*	WCE (%)	WI (%)	Net returns ($x10^3$ `/ha)	B:C
		2010	2011	2012	Pooled					
Pendimethalin	450	1.72	2.03	1.96	1.91	9.27 (86)	77	54	16.98	2.10
Pendimethalin + HW and IC	450	0.41	0.26	0.33	0.33	6.84 (47)	159	15	42.24	3.54
Imazethapyr	75	1.60	1.84	1.65	1.70	8.55 (73)	88	49	19.58	2.21
Imazethapyr + HW and IC	37.5	2.39	2.64	2.70	2.58	10.8 (117)	41	68	6.02	1.36
Imazethapyr + HW and IC	75	1.08	1.08	1.19	1.12	7.41 (55)	118	35	28.00	2.61
Quizalofop	40	1.37	1.12	1.03	1.17	7.76 (61)	115	47	21.22	2.34
Quizalofop + HW and IC	20	1.21	1.66	1.68	1.52	8.29 (69)	97	45	22.41	2.35
Quizalofop + HW and IC	40	0.28	0.29	0.25	0.27	6.11 (37)	162	12	44.07	3.58
HW and IC	-	2.01	2.41	2.63	2.35	9.85 (97)	53	63	10.20	1.64
HW and IC twice	-	0.47	0.50	0.52	0.50	7.22 (53)	151	20	38.40	3.25
Weed-free	-	0.17	0.03	0.02	0.07	3.50 (12)	173	0	49.93	3.56
Weedy	-	3.08	3.42	3.60	3.37	12.7 (163)	0	78	1.61	1.11
LSD (P=0.05)		0.39	0.41	0.43	0.23	1.68	-	-	-	-

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

as pre-emergence + HW and IC and HW and IC twice in 2010, with quizalofop-ethyl 40 g/ha as post-emergence+ HW and IC and pendimethalin 450 g/ha as pre-emergence + HW and IC in 2011 and 2012, and with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC in pooled results. Whereas, the unweeded control recorded the highest dry weight of weeds.

Pooled over three years, significantly the lowest weed density (12 per m^2) was observed under the weed-free check, followed by quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha as pre-emergence + HW and IC and HW and IC twice, which have weed density of 37, 47 and 53 per/m^2, respectively. On the other hand, significantly the highest weed density (163 per m^2) was recorded under the weedy check. Mean data of weed control efficiency (WCE) and weed index (WI) given in Table-2 showed that the weed-free check recorded the highest WCE of 173%, followed by treatments, *viz*. quizalofop-ethyl at 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha as pre-emergence + HW and IC and HW and IC twice by recording WCE of 162, 159 and 151%, respectively. Similarly, treatments *viz*., quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, pendimethalin 450 g/ha as pre-emergence + HW and IC and HW and IC twice recorded lower WI of 12, 15 and 20%, respectively. The results corroborate the findings of Sukhadia *et al*. (2004) and Gnanavel and Anbhazhagan (2006).

Economics

The weed-free check recorded maximum net returns of ` 49,927/ha, followed by quizalofop-ethyl 40 g/ha as post-emergence + HW and IC and pendimethalin 450 g/ha as pre-emergence + HW and IC, which gave net returns of ` 44,066 and 42,242/ha, respectiviely.

The maximum B:C ratio of 3.58 was accrued with quizalofop-ethyl 40 g/ha as post-emergence + HW and IC, closely followed by the weed free check and pendimethalin 450 g/ha as pre-emergence + HW and IC by recording B:C ratio of 3.56 and 3.54, respectively. Parasuraman and Rajagopal (1998) also reported analogous results.

It was concluded that effective control of weeds in summer sesame along with higher yield could be achieved by hand weeding and inter-culturing as and when required or application of quizalofop-ethyl 40 g/ha as post-emergence at 20-25 DAS + HW and IC at 45 DAS or pendimethalin 450 g/ha as pre-emergence + HW and IC at 30 DAS under south Saurashtra agro-climatic conditions of Gujarat.

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Post-emergence herbicides on weeds and productivity of garden pea under mid-hill conditions of Himalaya

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ABSTRACT

To standardize dose and time of application of post-emergence herbicides in garden pea (*Pisum sativum* var. *hortense*) under mid-hills of Himalaya, eleven treatments, *viz.* imazethapyr 100 and 150 g/ha at 20 and 40 DAS, quizalofop 25 and 37.5 g/ha at 20 DAS, isoproturon 1.0 and 1.25 kg/ha at 40 DAS, pendimethalin 1.5 kg/ha (pre-emergence), hand weeding twice (30 and 60 DAS) and unweeded check were tested during the winter (*Rabi*) season of 2005-06 and 2006-07 at Palampur. The major weed flora was constituted of *Phalaris minor, Avena fatua* and *Vicia sativa* in both the year. Post-emergence application of all the herbicides except quizalofop 25 g/ha at 20 DAS and hand weeding twice resulted in significantly lower dry weight of weeds over pre-emergence pendimethalin 1.5 kg/ha. Higher doses of all the post-emergent herbicides were superior to their lower doses. Significantly lower dry matter accumulation of all the weed species and highest weed control efficiency was obtained with imazethapyr 150 g/ha (40 DAS). Imazethapyr 150 g/ha at 40 DAS resulted in maximum plant height, dry matter accumulation, crop growth rate, relative growth rate nodule count and weight and green pod and haulm yields. Weeds in untreated check reduced pea pod yield by 56.8% over the best post-emergent herbicidal treatment (imazethapyr 150 g/ha at 40 DAS) in 2005-06 and 60.1% in 2006-07.

Key words: Dose, Garden pea, Imazethapyr, Mid-hill Himalaya Quizalofop, Time of application, Yield

Garden pea (*Pisum sativum* var. *hortense*) is one of the most important cool season crops of Himachal Pradesh. Pea crop has a great potential both for seeds as pulse (field pea) and pods as vegetable (garden pea). Weeds have been reported to cause 81% loss in its yield (Singh *et al.* 1996). The critical period for crop-weed competition in pea varied from 40-60 days after sowing (Bhyan *et al.* 2004). Manual weeding is effective but it is cumbersome, time consuming and uneconomical, while mechanical means generally lead to root injury (Casarini *et al.* 1996). In this context, the use of herbicides is the better alternative. Various pre-plant and pre-emergence herbicides have been tested under different agro-climatic conditions of Himachal Pradesh and recommended for control of weeds in pea (Singh *et al.* 1996). However, the information on post-emergence herbicides to control weeds is very scanty. Many times, the extension workers and farmers of the state demand information on post-emergence herbicides especially when due to one or the other reason they fail to apply pre-emergence herbicides.

Recently, new post-emergence herbicides, *viz.* imazethapyr and quizalofop have been introduced. However, their doses and time of application are to be standardized for effective control of weeds in pea crop under varied agro-ecological situations. To find out the effective dose and time of application of post-emergence herbicides for weed control in pea, the present investigation was carried out.

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MATERIALS AND METHODS

Field investigation was carried out during winter (*Rabi*) 2005-06 and 2006-07 at Palampur (1290.8 m altitude, $32^0 06`05``$ N and $76^0 34`10``$ E). Eleven treatments, *viz.* imazethapyr 100 and 150 g/ha (20 and 40 DAS), quizalofop 25 and 37.5 g/ha (20 DAS), isoproturon 1.0 and 1.25 kg/ha (40 DAS), pendimethalin 1.5 kg/ha (pre-emergence), hand weeding twice (30 and 60 DAS) and unweeded check were tested in randomized complete block design with three replications. Application of herbicides as per the treatment was made with knapsack sprayer using water 800 L/ha. Garden pea '*Palam Priya*' was treated with bavistin at 2.5 g/kg seed and sown on November 19, 2005 and November 20, 2006 on lines 40 cm apart using 80 kg seed/ha. The crop was harvested on April 4, during the first year and April 7 during the second year. The crop in its life cycle experienced 206.5 mm rainfall in the first year and 577.2 mm in the second year. The soil was silty clay loam in texture, acidic in reaction and medium in available N (290.6 kg/ha), P (16.8 kg/ha) and K (224.4 kg/ha). N, P_2O_5 and K_2O (50, 60 and 30 kg/ha, respectively) were applied as basal through urea and complex fertilizer of 12-32-16 grade. The crop was given 4 irrgations in the first year including the presowing irrigation in the first year and two in the second year. The observations on weeds (dry weight, and weed control efficiency), crop (phytotoxicity, growth, development, yield) and chemical studies (total soluble solids, ascorbic acid and protein content in seed) were recorded. Weed count and dry weight was recorded at 90 DAS, 120 DAS and at final picking. Yields were harvested from net plot in four pickings. The harvesting was done by end of March each year.

The economic threshold (economic injury levels), the weed density at which the cost of treatment equals the economic benefit obtained from that treatment, was calculated after Stone and Pedigo (1972) as below:

Economic threshold = Gain threshold/ Regression coefficient

Where, gain threshold = Cost of weed control/ Price of produce, and regression coefficient (b) is the outcome of simple linear relationship between yield (Y) and weed density/biomass (x), Y = a + bx.

The different impact indices were worked out after Walia (2003).

RESULTS AND DISCUSSION

Weeds

At 90 days after sowing (DAS), the major weed flora constituted of *Phalaris minor, Vicia sativa*, and *Avena fatua* in both the year of experimentation. Among other weeds *Lolium temulentum, Stellaria media* and *Coronopus didymus* showed their infestation. All weed control treatments were significantly superior to weedy check in reducing the dry weight of *P. minor* (Table 1). In general, *P. minor* control efficiency, increased with increase in dose. Imazethapyr at 150 g/ha (40 DAS) and quizalofop at 37.5 g/ha being at with imazethapyr at 100 g/ha (40 DAS), significantly reduced the dry weight of *P. minor* over other treatments. *P. minor* control efficiency under imazethapyr at 150 g/ha (40 DAS) and quizalofop at 37.5 g/ha was 77.1 and 76.9% during 2005-06 and 82.1 and 79.9% during 2006-07, respectively. In both the year of experimentation, imazethapyr at 150 g/ha (40 DAS) and quizalofop 37.5 g/ha (20 DAS) resulted in significantly lower dry weight of *A. fatua*. Imazethapyr 150 g/ha (40 DAS) and quizalofop 37.5 g/ha were closely followed by imazethapyr at 100 g/ ha at 40 DAS, hand weeding twice in increasing the *Avena fatua* control efficiency. Amongst all weed control treatments, pendimethalin gave least *A. fatua* control efficiency both during 2005-06 and 2006-07. Haar *et al.* (2001) also reported poor control of *A. fatua* with the application of pendimethalin. Imazethapyr at 150 g/ha (40 DAS) had highest *V. sativa* control efficiency. Being at par with imazethapyr at 100 g/ha (40 DAS) and hand weeding twice, imazethapyr at 150 g/ha (40 DAS) had significantly reduced dry weight of *V. sativa* as compared to rest of the treatments. Quizalofop at 25 and 37.5 g/ha (20 DAS) gave least *V. sativa* control efficiency. At lower rate, quizalofop did not differ significantly from weedy check in curtailing its dry weight. In both the years of experimentation, application of imazethapyr 100 and 150 g/ha (40 DAS) and hand weeding twice was most effective in reducing dry weight of other weeds. All these had hundred per cent other weeds' control efficiency. Doberzanski *et al.* (1991) observed highly effective weed control in garden pea with imazethapyr. Singh and Nepalia (1994) reported that hand weeding was quite effective in controlling weeds in pea crop. Pendimethalin at 1.5 kg/ha (pre-emergence) was next better treatment. Isoproturon at 1.0 and 1.25 kg/ha (40 DAS) and imazethapyr at 100 and 150 g/ha (20 DAS) were statistically at par with each other. Quizalofop at 25 g/ha (20 DAS) was least effective against other weeds. Significantly, lowest total weed dry weight was obtained with imazethapyr at 150 g/ ha (40 DAS). This was followed by imazethapyr at 100 g/ha (40 DAS) and hand weeding twice. Vaishya *et al.* (1999) also reported that pendimethalin 1.0 kg/ ha was inferior to hand weeding (20 and 40 DAS) in reducing dry weight.

Crop

Imazethapyr 150 g/ha (40 DAS) being statistically at par with its lower dose at 100 g/ha (40 DAS), hand weeding twice, quizalofop at 25 and 37.5 g/ha (20 DAS) and pendimethalin 1.5 kg/ha (pre-emergence) resulted in significantly taller plants over rest of the treatments (Table 2). This may be ascribed to least competition from weeds due to their effective suppression. Imazethapyr 150 g/ha (40 DAS) and hand weeding twice remaining statistically at par with imazethapyr at 100 g/ha (40 DAS), imazethapyr at 150 g/ha (20 DAS) and quizalofop at 37.5 g/ha (20 DAS) resulted in significantly higher plant dry matter accumulation as compared to other treatments. Isoproturon (40 DAS) and imazethapyr (20 DAS) at

Table 1. Effect of treatments on dry matter accumulation (g/m^2) of weeds and control efficiency at 120 DAS

Treatment	Dose (g/ha)	Time (DAS)	Dry weight (g/m^2)					Control efficiency (%)				
			P. minor	*A. fatua*	*V. sativa*	Others	Total	*P. minor*	*A. fatua*	*V. sativa*	Others	Total
Imazethapyr	100	20	17.1	15.7	15.9	4.2 (16.9)	65.5	65.0	56.3	40.9	45.2	54.0
Imazethapyr	150	20	14.7	15.0	15.2	4.2 (16.7)	61.5	69.9	58.2	43.3	45.9	56.8
Imazethapyr	100	40	12.6	13.8	6.9	1.0 (0.0)	33.3	74.3	61.5	74.5	100.0	76.6
Imazethapyr	150	40	10.0	10.8	4.9	1.0 (0.0)	25.7	79.6	69.8	81.8	100.0	82.0
Quizalofop	25	20	21.2	15.4	24.4	4.7 (20.9)	81.9	56.6	57.0	9.0	32.3	42.4
Quizalofop	37.5	20	10.6	11.1	22.2	3.5 (11.5)	55.4	78.3	69.0	17.4	62.7	61.1
Isoproturon	1000	40	15.5	15.4	16.4	4.3 (17.2)	64.4	68.4	57.1	38.8	44.2	54.7
Isoproturon	1250	40	14.8	15.1	16.1	4.2 (17.0)	63.1	69.7	57.8	40.0	44.8	55.7
Pendimethalin	1500	1	19.5	31.6	8.8	3.1 (8.7)	68.7	60.0	11.7	67.2	71.7	51.7
Hand weeding	-	30 & 60	15.9	15.3	6.8	1.0 (0.0)	37.9	67.5	57.4	74.6	100.0	73.4
Weedy check	-	-	48.8	35.8	26.8	5.6 (30.9)	142.3	0.0	0.0	0.0	0.0	0.0
LSD (P=0.05)			3.4	3.2	3.1	0.3	7.4					

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

Table 2. Effect of treatments on plant height, dry matter accumulation, CGR, NAR and nodules count (no./plant) and weight (mg/plant) of pea

Treatment	Dose (g/ha)	Time (DAS)	Plant height (cm)	Plant Dry matter (g/m^2)	CGR (g/m^2/ day)	RGR (g/g/day)	Nodule count pre or post flowering		Nodule weight pre or post flowering	
							Pre-	Post-	Pre-	Post-
Imazethapyr	100	20	59.9	349.8	5.1	0.0190	42.5	25.2	44.7	25.5
Imazethapyr	150	20	61.6	368.9	5.5	0.0189	44.5	30.4	45.4	30.9
Imazethapyr	100	40	63.9	403.2	7.0	0.0234	47.9	32.9	49.2	33.4
Imazethapyr	150	40	65.4	418.2	7.4	0.0236	49.0	34.0	50.3	34.5
Quizalofop	25	20	62.0	204.1	2.4	0.0129	42.4	29.0	42.9	29.5
Quizalofop	37.5	20	62.2	403.4	7.0	0.0234	47.1	32.5	48.0	33.3
Isoproturon	1000	40	61.7	337.1	4.7	0.0180	39.3	24.1	40.1	24.3
Isoproturon	1250	40	62.2	349.9	5.1	0.0194	39.0	24.0	39.4	24.1
Pendimethalin	1500	1	62.6	340.4	4.7	0.0172	41.9	28.5	42.8	29.0
Hand weeding	-	30 & 60	64.5	407.1	7.0	0.0231	46.3	33.2	47.7	33.4
Weedy check	-	-	57.6	178.9	2.2	0.0170	33.3	22.3	33.7	22.7
LSD (P=0.05)			3.2	58.4	1.7	0.0051	1.8	1.0	2.3	1.2

CGR = Crop growth rate; RGR = Relative growth rate; NAR = Net assimilation rate

both rates were comparable to pendimethalin 1.5 kg/ ha (pre-emergence). However, quizalofop 25 g/ha (20 DAS) did not significantly increase plant dry matter accumulation over the weedy check. The enhanced growth of weeds caused intense competition with the crop for growth factors and resulted in significant decrease in plant height and dry matter production due to unchecked weed growth in peas.

Crop growth rate (CGR) and relative crop growth rate (RGR) worked out from 120 DAS to harvest were significantly highest in the treatment imazethapyr 150 g/ha (40 DAS) in both the years. The higher weed control efficiency under imazethapyr 150 g/ha (40 DAS) reduced crop weed competition and helped in significant increase in the rate of growth of the crop. However, this was statistically at par with the crop growth rate obtained under imazethapyr 100 g/ha (40 DAS), quizalofop 37 g/ha (20 DAS) and hand weeding twice treatments. Reduced crop weed competition due to effective control of weeds by various treatments resulted in better utilization of growth factors by the crop and this resulted in its better growth and development. This can be ascribed to fact that the effective control of weeds led to the favorable environment for growth and photosynthetic activity of the crop. Skrzypczak *et al.* (1994) also reported almost similar results with imazethapyr at 150 g/ha (40 DAS). Application of isoproturon at 1.25 kg/ha exhibited slight phytotoxicity in both the years, however, plants recovered by 120 DAS.

The data on nodules number at pre-flowering (90 DAS) and post-flowering (120 DAS) stage have been given in Table 2. Imazethapyr 100 and 150 g/ha (40 DAS) and quizalofop 37.5 g/ha (20 DAS) being statistically at par with hand weeding twice resulted in significantly higher number of nodules over rest of the treatments at pre-flowering stage during 2005-06.

However, in 2006-07 significantly highest number of nodules was obtained with imazethapyr 150 g/ha (40 DAS). Imazethapyr at 150 g/ha (40 DAS) remaining at par with hand weeding twice gave significantly higher number of nodules over rest of the treatments at post-flowering stage during 2005-06. In 2006-07 significantly highest number of nodules was obtained with imazethapyr 150 g/ha (40 DAS). Quizalofop at 25 g/ha both at pre- and post-flowering stage were as good as the herbicidal check pendimethalin 1.5 kg/ha. Isoproturon at both rates was least effective at both stages in both the years. Imazethapyr 150 g/ha (40 DAS) resulted in significantly higher nodules dry weight at pre-flowering stage in both the year. However, it was statistically at par with its lower dose at 100 g/ha (40 DAS), quizalofop 37.5 g/ha and hand weeding twice during 2005-06 and imazethapyr 100 g/ha (40 DAS) in 2006-07.

At post-flowering stage in both the years, imazethapyr 100 and 150 g/ha (40 DAS) resulted in significantly higher dry weight of nodules. Quizalofop at 25 g/ha (20 DAS) both at pre and post-flowering stages was as effective as pendimethalin in both the year. However, isoproturon at both the rates was least effective amongst all treatments at both the stages of observation. The higher number and dry weight of root nodules can be ascribed to the effective control of weeds which led to the favorable environment for growth and development. However, data on number of days taken for attainment of various development stages, *viz.* 75 per cent flowering and first and last picking was not significant in both the years of experimentation (data not shown).

Weed control treatments brought about significant variation in green pod yield (Table 3). All weed control treatments were significantly superior to weedy check in influencing green pod yield. Each of the herbicide at higher rate was superior to its lower rate in influencing green pod yield. Significantly highest green pod yield was obtained with imazethapyr at 150 g/ha (40 DAS) in both the years. Hand weeding twice and imazethapyr at 100 g/ha (40 DAS) being statistically similar with each other were the other superior treatments in influencing green pod yield. All the post-emergent herbicidal treatments except quizalofop at 25 g/ha were superior to standard pre-emergent herbicidal check (pendimethalin 1.5 kg/ha) in influencing green pod yield. Weeds in untreated check reduced pea pod yield by 56.8% over the best post-emergent herbicidal treatment in 2005-06 and 60.1% in 2006-07.

The grain yield was negatively associated with total weed count (r= -0.957**, significant at 1% level of significance) and total weed biomass (r= -0.953**). The linear relationship between weed count/weed dry weight (x) and grain yield (Y) of pea is given hereas under,

Weed count

$Y= 7718 – 17.8\ x$ (R^2= 0.917).......(i)

Weed weight

$Y= 8609 – 41\ x$ (R^2= 0.908).......(ii)

The equation (i) explains that 91.7% variation in yield due to weed count could be explained by the regression equation. The further analysis indicated that decrease in yield per unit increase in weed count (1 weed/m^2) is estimated to be 17.8 kg/ha. Similarly from the equation (ii) it may be inferred that 90.8% of variation in yield of pea due to weed dry weight could be explained by the regression equation. With every 1 g/m^2 increase in weed dry weight, the pod yield of pea was expected to fall by 41 kg/ha.

Table 3. Effect of treatments on green pod and haulm yield of pea

Treatment	Dose (g/ha)	Time of application (DAS)	Green pod yield (t/ha)	Haulms yield (t/ha)	CWC	Gt	Et		CRI	WMI	AMI	EI	WI
							Wc	Wdm					
Imazethapyr	100	20	3.70	3.95	1250	66	3.7	1.6	3.62	3.51	2.51	1.94	18.7
Imazethapyr	150	20	3.96	4.26	1809	95	5.3	2.3	4.14	3.56	2.56	2.36	13.1
Imazethapyr	100	40	4.39	4.72	1241	65	3.7	1.6	8.49	3.00	2.00	5.57	1.0
Imazethapyr	150	40	4.60	4.95	1858	98	5.5	2.4	11.51	2.94	1.94	7.81	3.7
Quizalofop	25	20	3.03	3.02	948	50	2.8	1.2	2.29	3.27	2.27	0.67	40.3
Quizalofop	37.5	20	4.21	4.54	1231	65	3.6	1.6	4.90	3.61	2.61	3.09	5.2
Isoproturon	1000	40	3.72	4.05	597	31	1.8	0.8	3.74	3.53	2.53	2.06	16.9
Isoproturon	1250	40	3.85	4.05	685	36	2.0	0.9	3.88	3.53	2.53	2.18	15.4
Pendimethalin	1500	1	3.34	3.66	2238	118	6.6	2.9	3.15	3.27	2.27	1.43	27.3
Hand weeding	-	30 & 60	4.38	4.81	4334	228	12.8	5.6	7.51	3.17	2.17	4.97	0.0
Weedy check	-	-	2.32	2.28	-	-	-	-	-	-	-	-	57.0
LSD (P=0.05)			0.16	0.25									

CWC, cost of weed control (`/ha); Gt, gain threshold; Et, Economic threshold; Wc, weed count; Wdm (weed dry weight); CRI, crop resistance index; WMI, weed management index; AMI, agronomic management index; EI, efficiency index; WI, weed index.

The economic threshold levels of weeds at the current prices of treatment application and the crop production on the basis of weed infestation (population) in wheat are given in Table 3. The economic threshold levels (number of weeds/unit area) with the weed management practices studied varies between 1.8-12.8/m^2. In terms of weed biomass the economic threshold varies from 0.9 under isoproturon 1000 g/ha to 5.6 g/m^2 under hand weeding twice. There was clear indication that any increase in the cost of treatment would lead to higher values of economic threshold, whereas an increase in price of crop produce would result in lowering the economic threshold.

Imazethapyr 150 g/ha (40 DAS) resulted in highest crop resistance index (CRI) and efficiency index (EI). This was followed by imazethapyr 100 g/ha (40 DAS), hand weeding twice and quazalofop 32.5 g/ha (20 DAS). Agronomic management index (AMI) and weed management index (WMI) were lowest under imazethapyr 150 g/ha (40 DAS) followed by imazethapyr 100 g/ha (40 DAS), hand weeding twice and pendimethalin 1500 g/ha/ quazalofop 25 25 g/ha (20 DAS). Weed index which indicates fall in yield over a weed free practice presently hand weeding twice, was minimum under imazethapyr 150 g/ha (40 DAS) followed by imazethapyr 100 g/ha (40 DAS) and quazalofop 37.5 g/ha. The effect of treatments on ascorbic acid, total soluble solids and protein content was not significant during both the years (Data not shown).

From the present investigation it may be inferred that imazethapyr at 150 g/ha (40 DAS) was the most effective herbicide for controlling of weeds. Application of imazethapyr at 150 g/ha was found more remunerative in terms of green pod and haulms yield of garden pea.

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Bio-efficacy on tank-mixed propaquizafop and imazethapyr against weeds in soybean

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ABSTRACT

Intensive use of agro-chemicals coupled with congenial edaphic and weather conditions during *Kharif* season aggravate the weed menace, resulting into low yields of soybean. The experiment was conducted on the agricultural farm at Jawaharlal Nehru Krishi Vishwa Vidyalaya at Jabalpur in 2011-12. The rampant weed species identified in the experimental field was monocot weeds *Cyperus rotundus* (25.8 and 23.6%) followed by *Echinochloa colona* (23.1 and 23.3%) and *Commelina benghalensis* (15.6 and 17.8%). Beside these dicot weeds *Eclipta alba* (19.1 and 20.3%), and *Alternanthera philoxeroides* (16.4 and 14.9%) were also found in soybean ecosystem at 45 DAS and harvest stage, respectively. The weed menace was minimum under weed free treatment. Among the propaquizafop treatments, activity of propaquizafop at lowest dose 62.5 g/ha and highest dose 75 g/ha as post emergence was not well marked against most of weeds (broad-leaved) but imazethapyr applied at 50, 75, 100 g/ha controlled broad-leaved and grassy leaved weeds. Among herbicidal treatments, combined application of propaquizafop + imazethapyr as post-emergence 75 + 100 g/ha was most effective to reduced most of weed flora.

Key words: Bioefficacy, Chemical control, Propaquizafop, Soybean, Tank-mix, Weeds

Soybean is a crop of multiple qualities, as it is both a pulse and oilseed crop. It provides 40% protein and 20% edible oil, besides minerals and vitamins. In India, it is cultivated in 9.73 million hectares area with annual production of 9.96 million tonnes. In Madhya Pradesh, it is grown over an area of 5.35 million hectares with a production of 6.41 million tonnes. (Annonymous 2010). Although the ecological conditions of the state are congenial for soybean production, but the yield is substantially low (1007 kg/ha), despite of the best management practices. Being a rainy season crop, the environment is more conducive for excessive weed infestation in soybean. Severe weed competition is one of the major constraints for low productivity of soybean. Weeds in general, cause competition stress on soybean growth, especially during the first 40 days after sowing. Weeds alone are responsible for reduction in seed yield of soybean to the range of 25 to 70% depending upon the weed flora and intensity. Therefore, it is important to keep the soybean crop weed free as far as possible, so as to get higher seed yield (Kewat *et al*. 2000). Now a days pre-emergence herbicides are not very popular among the farmers due to short time span for sowing during *Kharif* season. Therefore, farmers are using post-emergence herbicides for control of weeds in soybean. Hand weeding is the most efficient mean to control weeds in soybean, but it is time consuming and difficult due to unavailability of laborers during peak period of demand. Hence, the use of suitable herbicide appears to be an alternative option to minimize the weed problem. But, each herbicide has its own spectrum of weed control. Secondly, the timing of herbicides application also has much concern on weed control efficiency. Therefore, in this study possibility of pre-emergent or post-emergent herbicides for effective weed control in soybean was explored.

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MATERIALS AND METHODS

A field experiment was conducted at Breeder Seed Production Unit, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Adhartal Jabalpur (M.P.). The rainfall received during the crop season was 1281.7 mm. Minimum and maximum mean temperature ranged from 20.7 ^{0}C to 31.1 ^{0}C, respectively. The soil was neutral in reaction (pH7.2), medium in organic carbon (0.60%), available N (372 kg/ha), available P (16.40 kg P_2O_5/ha) and high in available K (293 kg K_2O/ha). The field experiment was laid out in randomized block design with three replications. The experiment consisted of ten treatments. The herbicide spray solution was prepared by mixing the required quantity of both herbicide propaquizafop and imazethapyr or alone herbicide in water at 500 L/ha for each plot. The sowing of seed was done manually on 22 July, 2012 at seed rate of 80 kg/ha. The sowing of seeds in each plots was done in rows 45 cm apart at the depth of 3-4 cm. Full dose of major plant nutrients (20 kg N + 60 kg P_2O_5 + 20 kg K_2O/ha) was applied as basal application through urea, single super phosphate and muriate of potash. Before sowing, the seeds were treated with carbendazim at 2.0 g/kg of seed followed by inoculation with *Rhizobium japonicum* culture at 5 g/kg of seed. The observations on weed density and dry weight were recorded at 45 DAS and harvest using quadrate of 0.25 square meter (0.5 m x 0.5 m) was randomly placed at four places in each plot. The data on weed count and weed biomass were subjected to square root transformation *i.e.*($\sqrt{x+0.5}$), before carrying out analysis of variance and comparisons were made on transformed values.

RESULTS AND DISCUSSION

Among the monocot, *Cyperus rotundus (*25.8 and 23.6%) was the most dominant weed followed by *Echinocloa colona* (23.1 and 23.3%) and *Commelina benghalensis* (15.6 and 17.8%) at 45 DAS and harvest, respectively, whereas dicot weeds like *Eclipta alba* (19.1 and 20.3%), and *Alternanthera philoxeroides* (16.4 and 15.0%) were present in lesser number in soybean ecosystem at 45 DAS and harvest, respectively. The highest weed infestation were recorded in weedy check plot. Application of propaquizafop as post-emergence at highest dose 75 g/ha caused significantly reduction in weed density and dry weight of monocot weeds over weedy check, followed by propaquizafop 62.5 g/ha. Imazethapyr as at lowest dose (50 g/ha) caused significant reduction in the density of this weed over weedy check plots. However, the efficacy of imazethapyr was further improved with the corresponding increase in rates of application being the higher when it was applied between 75 and 100 g/ha. The effectiveness of propaquizafop was enhanced further when it was applied in combination with imazethapyr at highest doses (75 + 100 g/ha), followed by combined application of both the herbicide (propaquizafop + imazethapyr 62.5 + 75.0 and 50.0 + 50.0 g/ha). However, none of the herbicidal treatment surpassed hand weeding in reducing the dry weight at 45 DAS and harvest stage.

Among weed control treatments, higher weed control efficiency was noted in plots receiving combined application of propaquizafop + imazethapyr 75 + 100 g/ha at harvest, as compared to combined application of propaquizafop + imazethapyr at 62.5 + 75 g/ha followed by imazethapyr applied as post-emergence at 100 g/ha, propaquizafop at 75 g/ha and combined application of propaquizafop + imazethapyr

Table 1. Effect of different treatments on weed density at 45 DAS and harvest in soybean

Treatment	Density/m²									
	C. rotundus		*E. colona*		*C. benghalensis*		*Eclipta alba*		*A. philoxeroides*	
	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest
Propaquizafop 62.5 g/ha	4.34 (18.3)	4.22 (17.3)	2.57 (6.08)	1.77 (2.63)	3.41 (11.1)	3.16 (9.50)	4.44 (19.2)	4.33 (18.2)	3.21 (9.83)	3.15 (9.43)
Propaquizafop 75 g/ha	4.33 (18.3)	4.06 (15.9)	2.36 (5.08)	1.74 (2.53)	3.24 (10.0)	3.00 (8.50)	4.41 (18.9)	4.32 (18.1)	3.15 (9.40)	3.08 (9.00)
Imazethapyr 50 g/ha	2.83 (7.5)	1.75 (2.57)	2.27 (4.65)	1.66 (2.25)	2.42 (5.37)	1.49 (1.72)	2.75 (7.04)	1.81 (2.77)	1.89 (3.06)	1.66 (2.27)
Imazethapyr 75 g/ha	2.79 (7.26)	1.73 (2.48)	2.22 (4.45)	1.60 (2.07)	2.23 (4.47)	1.46 (1.62)	2.63 (6.42)	1.68 (2.33)	1.80 (2.75)	1.55 (1.90)
Imazethapyr 100 g/ha	2.43 (5.40)	1.53 (1.83)	1.99 (3.47)	1.37 (1.37)	2.20 (4.34)	1.37 (1.38)	2.50 (5.73)	1.51 (1.77)	1.67 (2.30)	1.34 (1.30)
Propaquizafop + imazethapyr 50 + 50 g/ha	2.61 (6.30)	1.55 (1.90)	2.18 (4.24)	1.50 (1.75)	2.22 (4.44)	1.45 (1.60)	2.54 (5.93)	1.58 (2.00)	1.73 (2.50)	1.45 (1.61)
Propaquizafop + imazethapyr 62.5+75 g/ha	2.36 (5.06)	1.50 (1.76)	1.92 (3.17)	1.30 (1.20)	2.21 (4.40)	1.39 (1.42)	2.39 (5.19)	1.46 (1.63)	1.61 (2.09)	1.42 (1.53)
Propaquizafop + imazethapyr 75 + 100 g/ha	2.25 (4.57)	1.42 (1.53)	1.86 (2.95)	1.27 (1.12)	2.10 (3.93)	1.37 (1.37)	2.21 (4.40)	1.42 (1.53)	1.54 (1.87)	1.36 (1.35)
Hand weeding (20 and 40 DAS)	0.71 (0.00)	1.23 (1.02)	0.71 (0.00)	1.23 (1.01)	0.71 (0.00)	1.26 (1.09)	0.71 (0.00)	1.23 (91.0)	0.71 (0.00)	1.24 (1.05)
Weedy check (control)	6.07 (36.3)	6.32 (39.4)	5.74 (32.5)	6.27 (38.8)	4.73 (21.9)	5.46 (29.3)	5.23 (26.8)	5.87 (33.9)	4.85 (23.1)	5.05 (25.0)
LSD (P=0.05)	0.096	0.079	0.107	0.125	0.107	0.196	0.143	0.120	0.072	0.129

*Figure in parentheses are original values

50+ 50 g/ha. However, the highest WCE was noted under weed free treatment (100 and 98.6%), which was proved superior over all the herbicidal treatments at harvest.

Crop biomass and leaf area index

Crop biomass was differed significantly under different weed control treatments (Table 3) biomass increased with application of propaquizafop (62.5 and 75 g/ha) and further increased with application of imazethapyr between 50.0 to 100.0 g/ha being higher when propaquizafop applied in combination with imazethapyr as post-emergence (62.5 + 75 and 75 + 100 g/ha). But combined application of propaquizafop + imazethapyr (50 + 50 g/ha) was less as compared to application of imazethapyr 100 g/ha while crop biomass was minimum under weedy check. However, the highest crop biomass was recorded under hand weeding treatments. Application of propaquizafop as post-emergence at 62.5 and 75 g/ha slightly increased the LAI. The LAI of imazethapyr at dose 100 g/ha was better than combined application of propaquizafop + imazethapyr at dose (50 + 50 g/ha) being the higher when applied propaquizafop + imazethapyr at doses (75 + 100 and 62.5 + 75 g/ha) and proved equally good to that of hand weeding twice at 60 DAS.

Yield attributes and yield

Yield attributes, *viz.* pods per plant, number of seeds per pod, seed yield and stover yield (Table 3) were recorded significantly higher under two hand weeding at 20 and 40 DAS followed by combined application of propaquizafop + imazethapyr at (75 + 100 g/ha and 62.5+75 g/ha) over weedy check plots. Excellent growth and development of soybean plants under weed free environment during critical period of crop growth might have resulted in superior yield attributes under hand weeding treatment. Almost similar results were obtained by Raghuwanshi *et al.* (2005) and Shete *et al*. (2008). Application of imazethpyr at 75 and 100.0 g/ha as post-emergence produced better yield attributing characters (pods per plant and seeds per pod) but combined application with both herbicides (75.0 + 100 g/ha) was superior as compared to other herbicidal treatments. However, seeds per pod were superior but numerical higher over weedy check plots. Among treatments, the minimum seed index (6.92) was recorded in weedy check plot which was significantly increased when weed control measures were adopted. The application of imazethapyr at dos 100 g/ha produced higher seed index as compared to combined application of propaquizafop + imazethapyr at dose

Table 2. Effect of different treatments on weed dry weight (g/m^2) at 45 DAS and harvest in soybean

Treatment	*C. rotundus*		*E. colona*		*C. benghalensis*		*E. alba*		*A. philoxeroides*	
	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest
Propaquizafop 62.5 g/ha	2.96 (8.25)	2.85 (7.61)	2.54 (5.93)	1.58 (1.99)	3.30 (10.4)	2.98 (8.38)	2.99 (8.47)	2.64 (6.47)	2.96 (8.27)	2.71 (6.87)
Propaquizafop 75.0 g/ha	2.94 (8.14)	2.79 (7.29)	2.39 (5.19)	1.57 (1.95)	3.15 (9.41)	2.81 (7.38)	2.74 (7.03)	2.35 (5.03)	2.95 (8.18)	2.71 (6.83)
Imazethapyr 50.0 g/ha	1.99 (3.47)	1.61 (2.09)	2.30 (4.77)	1.52 (1.81)	2.73 (6.97)	1.24 (1.05)	2.17 (4.22)	1.50 (1.76)	2.35 (5.04)	1.29 (1.16)
Imazethapyr 75.0 g/ha	1.99 (3.46)	1.60 (2.06)	2.28 (4.71)	1.51 (1.77)	2.71 (6.85)	1.23 (1.02)	2.14 (4.07)	1.47 (1.66)	2.34 (4.98)	1.28 (1.13)
Imazethapyr 100.0 g/ha	1.95 (3.32)	1.57 (1.97)	2.14 (4.06)	1.36 (1.35)	2.67 (6.62)	1.19 (0.92)	2.08 (3.83)	1.37 (1.38)	2.17 (4.20)	1.24 (1.05)
Propaquizafop + imazethapyr 50.0 + 50.0 g/ha	1.98 (3.44)	1.59 (2.02)	2.20 (4.36)	1.43 (1.55)	2.68 (6.70)	1.14 (0.79)	2.11 (3.95)	1.40 (1.47)	2.21 (4.37)	1.26 (1.10)
Propaquizafop + imazethapyr 62.5 + 75.0 g/ha	1.95 (3.29)	1.49 (1.73)	1.94 (3.27)	1.31 (1.22)	2.42 (5.34)	1.08 (0.66)	2.01 (3.56)	1.34 (1.29)	2.11 (3.94)	1.20 (0.95)
Propaquizafop + imazethapyr 75.0 + 100 g/ha	1.91 (3.14)	1.45 (1.60)	1.91 (3.16)	1.16 (0.84)	2.37 (5.12)	1.03 (0.57)	1.89 (3.06)	1.26 (1.09)	2.08 (3.84)	1.20 (0.93)
Hand Weeding (20 and 40 DAS)	0.71 (0.00)	0.89 (0.290	0.71 (0.00)	1.00 (0.500	0.71 (0.00)	0.87 (0.25)	0.71 (0.00)	0.98 (0.46)	0.71 (0.00)	1.02 (0.54)
Weedy Check (control)	5.56 (30.4)	5.66 (31.5)	4.55 (20.2)	5.79 (33.0)	4.22 (17.3)	5.49 (29.6)	4.46 (19.4)	5.37 (28.3)	4.66 (21.2)	5.01 (24.63)
LSD(P=0.05)	0.095	0.112	0.113	0.141	0.089	0.244	0.141	0.230	0.087	0.131

*Figure in parentheses are original values.

50 + 50 g/ha. Among the combined application of herbicidal treatments propaquizafop + imazethapyr at doses 75 + 100 (7.72) produced higher seed index as compared to other herbicidal treatments. However, super value (7.74) was recorded in plots receiving hand weeding twice (20 and 40 DAS).

The seed yield was lowest in the plots under weedy check due to severe competition stress right from crop establishment up to the end of critical period of crop growth, leading to poor growth parameters and yield attributing traits and finally the seed yield. All the treated plots receiving either manual weeding or herbicidal treatments produced higher yield over weedy check plots. Weed free treatment produced the maximum seed yield and proved its superiority over all the treatments. Sharma and Shrivastava (2002), Vyas and Jain (2003) and Halvankar *et al.* (2005) also reported that, hand weeding as an effective method of weed control for achieving the maximum yield of soybean. Among the herbicidal treatments, application of propaquizafop at 62.5 g/ha gave lower seed yields but increase correspondingly with the increase in application rate and imazethpyr at 50 g/ha gave lower seed yield but increased correspondingly with the increase in application rate being higher when imazethpyr was applied 75, 100 g/ha. However, seed yield was further increase in plot receiving combined application of propaquizafop + imazethapyr at (75 + 100 g/ha) being at par to hand weeding twice. Excellent weed free conditions, provided congenial environment for better growth and development of growth parameters, yield attributes and in turn the seed yield. The data revealed that maximum reduction in yield (41.83%) occurred in weedy check plots where weeds were not controlled throughout the crop season. Application of propaquizafop, imazethapyr alone and combined application of propaquizafop + imazethapyr as post-emergence at highest doses 75, 100 and 75 + 100 g/ ha, respectively curbed the weed menace to 20.1, 17.4 and 12.0%, respectively. Among weed control treatments, the minimum harvest index was recorded in weedy check plots (30.6) which was increased when the application of propaquizafop (62.5, 75 g/ha) and imazethapyr (50, 75, 100 g/ha) being highest (34.8) under combined application of propaquizafop + imazethapyr at 75 + 100 g/ha and hand weeded plots (35.8) and proved superior over rest of the treatments.

Economics

Among the herbicidal treatments, combined application of propaquizafop + imazethapyr (75 + 100 g/ha) fetched the highest GMR and NMR. The GMR was followed by imazethapyr at 100 g/ha but NMR closely followed by imazethapyr at (62.5 + 75 g/ha)

Table 3. Effect of different weed control treatments on yield, WCE and economics of soybean

Treatment	Pods/ plant	Seeds /pod	LAI (at 60 DAS)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index	Weed index	Weed control efficiency (%)	Net monetary returns (x10^3 `/ha)	B:C Ratio
Propaquizafop 62.5 g/ha	49.0	2.07	6.34	2.06	4.35	32.2	27.9	78.7	25.4	2.04
Propaquizafop 75 g/ha	51.8	2.10	6.56	2.29	4.62	33.1	20.1	80.6	30.6	2.25
Imazethapyr 50 g/ha	58.6	2.12	6.88	2.32	4.65	33.3	19.1	94.6	31.3	2.28
Imazethapyr 75 g/ha	58.8	2.14	7.19	2.35	4.66	33.5	18.1	94.8	31.8	2.30
Imazethapyr 100 g/ha	63.1	2.18	7.84	2.37	4.67	33.6	17.4	95.5	32.3	2.31
Propaquizafop + imazethapyr 50 + 50 g/ha	62.9	2.15	7.67	2.35	4.66	33.6	17.8	95.2	31.7	2.27
Propaquizafop + imazethapyr 62.5 +75 g/ha	66.1	2.20	8.22	2.42	4.70	33.9	15.6	96.0	33.1	2.33
Propaquizafop + imazethapyr 75 + 100 g/ha	66.2	2.23	8.83	2.52	4.75	34.8	12.1	96.5	35.3	2.41
Hand weeding (20 and 40 DAS)	67.3	2.27	9.11	2.67	4.78	35.8	0.00	98.6	30.2	1.91
Weedy check (control)	45.6	1.98	5.66	1.67	3.77	30.6	41.83	0.00	16.4	1.68
LSD (P=0.05)	0.74	NS	0.09	0.34	0.14	-	-	-		

and imazethapyr at highest dose 100 g/ha as post-emergence. The B-C ratio was maximum under propaquizafop + imazethapyr (75. +100 g/ha) (2.41) followed by propaquizafop + imazethapyr (62.5+75.0 g/ha) (2.33), imazethapyr 100 g/ha (2.31), imazethapyr 75 g/ha (2.30), imazethapyr 50 g/ha (2.28), propaquizafop + imazethapyr (50 +50 g/ha) (2.27), propaquizafop 75 g/ha (2.25), propaquizafop 62.5 g/ha (2.04), hand weeding 20 and 40 DAS (1.91) and minimum in weedy check (1.68).

Major dominant weeds infesting the soybean crop were *Cyperus rotundus, Echinochloa colona, Commelina benghalensis, Eclipta alba,* and *Alternanthera philoxeroides.* Combined application of propaquizafop + imazethapyr herbicides as post-emergence was more effective at (75 + 100 g/ha) against mixed weed flora in soybean. Growth parameters, yield attributes and seeds yield were superior under combined application of propaquizafop + imazethapyr at (75 + 100 g/ha) as post-emergence without any phytoxicity on soybean plants. Application of propaquizafop + imazethapyr at (75 + 100 g/ha) as post-emergence was found more remunerative in terms of NMR (` 35,298).

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Weed management in soybean with pre- and post-emergence herbicides

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ABSTRACT

A field experiment was conducted to study the efficacy of different pre- and post-emergence herbicides and their combinations to control the weeds in soybean during *Kharif* season of the year- 2012. Application of imazethapyr 0.100 kg/ha + quizalofop-ethyl 0.075 kg/ha as post-emergence was found to be more efficient to control monocot and dicot weeds in soybean which recorded lowest weed density, dry matter and weed index. It also found superior in respect of various growth and yield attributes. Highest seed yield (2.45 t/ha) and straw yield of soybean and maximum gross return (` 81,500/-) and net return (` 56,269/-) were also recorded in imazethapyr 0.100 kg/ha + quizalofop-ethyl 0.075 kg/ha as post-emergencewith highest B:C ratio of 3.23. It was also found responsible for highest uptake of N, P and K by soybean crop and lowest uptake of these plant nutrients by weed plants.

Key words: Growth, Imazamox, Imazethapyr, Pendimethalin, Quizalofop-ethyl, Soybean, Weed control

Losses due to weeds have been one of the major limiting factors in soybean production. Weeds compete with crop for light, moisture and nutrients, with early-season competition being the most critical. The grain yield reduction due to the weed infestation in soybean may be up to 31- 84% (Kachroo *et al*. 2003). Most of the yield reduction due to weed competition occurs during the first six weeks after planting; therefore, major emphasis on control should be given during this period. Good soybean weed control involves utilizing all methods available and combining them in an integrated weed management system, but considering the present day labour scarcity and their higher wages for cultural and mechanical weed control, the economics and feasibility of soybean cultivation is quiet disturbed. Hence the emphasis should be given to adapt the chemical methods of weed control to solve the problem of minimum available labour and their high cost. In this view, the present investigation was conducted to find out the best suitable combination of different herbicides to control weeds in soybean with lower cost and higher grain yield.

MATERIALS AND METHODS

An agronomic investigation was conducted at Agronomy Farm of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola in *Kharif* 2012 in randomized block design with eight treatments replicated thrice. The experimental site was located at 77^0 02' E longitudes and $20^0$42' N latitude with average annual rainfall of 950 mm. The soil of experimental field was clayey and slightly alkaline in reaction with pH 7.8 with low available N (221.47 kg/ha), medium P (16.86 kg/ha) and high in K (387.25 kg/ha).The gross and net plot sizes were 4.5 x 4.0 m and 3.6 x 2.8 m, respectively. The soybean variety *'JS 335'* was sown at 45 x 5 cm spacing on 2^{nd} July of year 2012. Treatment consist of recommended practice of weed control (1 hand + 1 hoeing) and pre-emergence application of pendimethalin 1.0 kg/ha and post-emergence (PoE) application of quizalofop-ethyl 0.075 kg/ha, imazethapyr 0.100 kg/ha and its combination with 0.070 and 0.080 kg/ha of imazamox. Imazethapyr is also combined with quizalofop-ethyl as post-emergence application. Hand weeding and hoeing were given at 20 and 40 DAS, respectively. Herbicides were applied with knapsack sprayer through 500 liter of water per hectare. Pendimethalin was applied as pre-emergence at 2 DAS, while quizalofop-ethyl, imazethapyr and imazamox were applied as post-emergence at 20 DAS as per the treatment details (Table 1). The fertilizer dose of 30 kg N and 75 kg P per hectare was applied to crop through urea and single super phosphate as half of N and whole P at the time of sowing and remaining half of N was applied at 30 days after sowing. Protective irrigations were given to crop whenever dry spells appeared during the crop growth. Other plant protection practices for disease and pest control were also applied in similar manner for all the treatments. Regular biometric observations in respect of different weed parameters and growth attributes of crop were recorded at regular interval during the crop growth, however the observation data at peak growth stage *i.e.* 80 DAS, is discussed in results and discussion.

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The weed control efficiency was calculated by using the following formula:

$$WCE\ (\%) = \frac{DWC - DWT}{DWC} \times 100$$

(Where, WCE = Weed control efficiency in percent, DWC = Dry matter weight of weed in control plot and DWT = Dry matter weight of weed in treated plot).

Weed index was computed by the formula given below-

$$\text{Weed Index (WI) } \% = \frac{X - Y}{X} \times 100$$

(Where, X = weight of seed yield (t/ha) in treatment which has highest yield and Y = weight of seed yield (t/ha) in treatment for which weed index is to be calculated).

RESULTS AND DISCUSSION

Effect on weed parameters

Different dicot weed species observed in experimental field were *Lagasia mollis, Euphorbia hirta, Digera arvensis, Tridex procumbense, Parthenium hysterophorus, Celosia argentea, Euphorbia geniculata, Alysicarpus rugosus, Alternanathera triandra, etc*. Different monocot weed species observed were *Commelina benghalensis, Dinebra arabica, Poa annua, Echinochloa crusgalli, Eragrostis major, Cynodon dactylon, Cyperus rotundus, etc*. Treatment application of imazethapyr 0.100 kg/ha + quizalofop-ethyl 0.075 kg/ha as PoE was found to be superior for controlling monocot and dicot weeds in soybean which recorded lowest weed count of these weeds, however it was found to be on par with 1 hand weeding + 1 Hoeing, pendimethalin1.0 kg/ha as PE, premix imazethapyr + imazamox 0.070 kg/ha as PoE and premix imazethapyr + imazamox 0.080 kg/ha as PoE in respect of monocot weeds and quizalofop-ethyl 0.075 kg/ha as PoE, imazethapyr 0.100 kg/ha as PoE, premix imazethapyr + imazamox 0.070 kg/ha as PoE and premix imazethapyr + imazamox 0.080 kg/ ha as PoE in respect of dicot weeds. This might be due to the action of different pre and post emergence herbicides used in soybean. The primary mode of action of pendimethalin is to inhibit microtubule formation in cells of susceptible monocot and dicot weeds which are an important part of the cell division process. As a result of restricted cell division, growth of the emerging weed seedling is prevented, eventuating in death due to lack of food reserves. Similar results of application of pendimethalin in soybean were also reported by Malik *et al.* (2006). Post emergence application of imazethapyr is responsible for inhibition of acetolactate synthase (ALS) or acetohydroxyacid synthase (AHAS) in broad leaf weeds which caused destruction of these weeds at 3-4 leaf stage (Chandel and Saxena 2001). Quizalofop-ethyl inhibit the activity of the acetyl-CoA carboxylase enzyme, which is necessary for fatty acid synthesis in grassy weeds. These effects of quizalofop for controlling weeds in soybean were in confirmation with the earlier results reported by Pandey *et al.* (2007). Lowest weed dry matter, weed index and highest weed control efficiency was found in imazethapyr 0.100 kg/ha + quizalofop ethyl 0.075 kg/ha as PoE (Table 1).

Effect on growth and yield attributing characters, yield and economics

Different weed control treatments were found to be significantly affecting to various growth and yield attributing characters in soybean over control treatment. Taller plants and highest plant dry matter were observed in application of imazethapyr 0.100 kg/ha + quizalofop-ethyl 0.075 kg/ha as PoE over all the other treatments. This might be due to providing favorable environment for crop with controlling

Table 1. Effect of different weed control treatments on weed parameters in soybean at 80 DAS

Treatment	Weed density (no./m^2)		Weed dry matter (g)	Weed control efficiency (%)	Weed index (%)
	Monocot	Dicot			
T_1- Weedy check	37.3	36.6	25.4	-	60.1
T_2- One hand weeding + 1 hoeing	25.0	25.6	18.2	56.7	10.5
T_3- Pendimethalin as 1.0 kg/ha PE	24.6	25.6	14.2	51.4	6.99
T_4- Quizalofop ethyl 0.075 kg/ha PoE	27.6	24.0	14.4	48.4	18.1
T_5- Imazethapyr 0.100 kg/ha PoE	28.3	25.0	14.6	49.3	11.1
T_6- Imazethapyr 0.100 kg/ha + quizalofop-ethyl 0.075 kg/ha PoE	23.3	21.6	13.9	64.9	-
T_7- Premix imazethapyr + imazamox 0.070 kg/ha PoE	25.0	23.0	15.8	56.5	13.1
T_8- Premix imazethapyr + imazamox 0.080 kg/ha PoE	23.6	22.6	15.0	51.1	9.52
LSD (P = 0.05)	2.99	3.95	4.82	-	-

PE = pre-emergence, PoE= post-emergence

Table 2. Effect of different weed control treatments on various growth and yield attributing characters, yield and economics of soybean

Treatment	Plant height at 80 DAS (cm)	Plant dry matter at 80 DAS (g)	Number of pods per plant	100 seed weight (g)	Seed yield (t/ha)	Straw yield (t/ha)	Cost of cultivation ($x10^3$ `/ha)	Net return ($x10^3$ `/ha)	B:C ratio
T_1	52.1	12.3	26.0	10.4	0.98	1.27	22.5	9.99	1.44
T_2	63.3	16.6	38.3	11.4	2.19	2.91	25.9	47.0	2.81
T_3	63.5	12.3	40.6	11.6	2.27	3.15	24.1	51.8	3.16
T_4	60.9	13.1	33.0	11.2	2.00	2.70	23.6	43.1	2.82
T_5	59.2	15.3	35.3	11.9	2.17	3.07	24.1	48.5	3.01
T_6	64.1	18.7	45.3	12.0	2.45	3.23	25.2	56.2	3.23
T_7	63.2	17.5	36.3	11.3	2.13	2.96	22.7	48.3	3.13
T_8	61.3	16.4	34.0	10.9	2.1	3.08	22.7	51.2	3.03
LSD (P=0.05)	6.01	3.94	3.56	0.56	0.27	0.62	-	10.1	-

weeds, which reduces the competition of crop with weeds for space, air, sunlight, moisture and nutrients. Significantly higher number of pods and seed weight per plant were found in imazethapyr 0.100 kg/ha + quizalofop- ethyl 0.075 kg/ha as PoE over all the other treatments. Similar results were earlier reported by Kalhapure *et al.* (2011). Imazethapyr 0.100 kg/ha + quizalofop-ethyl 0.075 kg/ha as PoE was recorded highest 100 seed weight, seed yield and straw yield per hectare, gross return, net return and B:C ratio as compared to all the other treatments (Table 2). The improvement in yield and economical parameters which resulted from better weed control with different weed management practices in soybean was also earlier reported by Sharma (2000) and Raskar and Bhoi (2002).

Nutrient uptake by crop and weed

Highest uptake of N, P and K per hectare by soybean crop was observed in application of imazethapyr 0.100 kg/ha + quizalofop ethyl 0.075 kg/ ha as PoE, however it was on par with 1 hand weeding + 1 hoeing, pendimethalin as PE 1.0 kg/ha as PE and premix imazethapyr + imazamox 0.080 kg/ ha as PoE in the case of N and with pendimethalin as PE1.0 kg/ha as PE and premix imazethapyr + imazamox 0.080 kg/ha as PoE for P and with imazethapyr 0.100 kg/ha as PoE in respect of K. The uptake of N, P and K by weeds was also found significantly lower in imazethapyr 0.100 kg/ha + quizalofop-ethyl 0.075 kg/ha as PoE over all the other treatments (Table 3).

Table 3. Effect of different weed management treatments on nutrient uptake by soybean crop and weed plants

Treatment	Nutrient uptake by crop (kg/ha)			Nutrient uptake by weeds (kg/ha)		
	N	P	K	N	P	K
T_1	60.2	8.74	18.3	12.0	5.47	7.71
T_2	137.1	22.1	53.5	7.40	1.97	3.23
T_3	143.1	24.1	58.4	5.30	0.51	0.43
T_4	124.3	19.5	47.6	6.15	0.71	0.93
T_5	136.7	22.4	54.5	6.50	0.81	1.24
T_6	155.4	25.7	66.4	4.80	0.29	0.39
T_7	132.7	21.5	52.6	7.20	1.21	1.77
T_8	139.1	23.2	56.4	6.85	0.97	1.51
LSD(P = 0.05)	18.5	2.90	7.64	1.62	0.07	0.03

It can be concluded that, application of imazethapyr 0.100 kg/ha + quizalofop-ethyl 0.075 kg/ ha as post emergence is the best weed management practice in soybean to obtain greater yield and economic return with more efficient weed control.

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Residues of imazethapyr in field soil and plant samples following an application to soybean

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ABSTRACT

Imazethapyr is widely used in pulses and leguminous crops including soybean for control of a broad spectrum of weed species. This has often resulted in carryover effects on several sensitive rotational crops. Therefore field studies were conducted for two consecutive years to evaluate residues of imazethapyr in the soil and the soybean crop produce. Imazethapyr was applied at 100 and 200 g/ha as post-emergence herbicide in soybean field. Residues of imazethapyr were found in the range of 0.011 to 0.063 µg/g in the straw following an application in soybean field at 100 to 200 g/ha in both the years. However in the soil and soybean oil, residues were found below 0.01 µg/g in both the years at two levels of application of imazethapyr. The overall residues were less in the soil as compared to the plant samples. Terminal residues of imazethapyr in soybean plant and soil were found below maximum residue level (MRL) limits. This study demonstrated enrichment of imazethapyr residues in soybean plants after repeated application. Based on this study a pre-harvest interval of 80-90 days for soybean crop after imazethapyr application is suggested.

Key words: Imazethapyr, HPLC-PDA, Oil, Terminal Residues, Soil, Soybean plant

Soybean (*Glycene max*) is one of the most important crops in the world. Weeds impact soybean yields by competing for limited resources, primarily light, water, and nutrients. The yield of soybean crop in Asia is much lower than the potential yield. One of the major reasons for low yield is the severe crop – weed competition during critical crop growth period (Barnes and Lavy 1991) which necessitate the use of herbicides. As a consequence of herbicide use, the presence of residues in field crop may cause numerous environmental problems. Herbicides residues also remain on the soil surface due to the adsorption process which may potentially affect quality and yield of the next crop cultivated on the same field. Stable herbicides may be taken up by plants, which results in unwanted terminal residues (Barnes and Lavy 1991, Battaglin *et al.* 2000). Imazethapyr is used as a selective herbicide for the control of a broad spectrum of weed species (Sikkema *et al.* 2005, Sondhia 2013). Good crop tolerance and weed control in pulses and other leguminous crops have contributed to an increase in the popularity of this herbicide (Loux *et al.* 1989, Sondhia 2013).

Imazethapyr inhibits acetohydroxy acid synthase (AHAS), an enzyme common to the biosynthetic pathway for these amino acids. This inhibition causes a disruption in protein synthesis, which in turn, leads to interference in DNA synthesis and cell growth. Imazethapyr dissipates in soil by microbial degradation and photolysis under field conditions (Stougaard 1990, Sondhia 2013). Imidazolinone herbicides are generally weakly adsorbed to the soil (Gan *et al.* 1994). Organic matter and pH significantly affect imazethapyr behavior in the soil (Mangles 1991). Some authors reported leaching of imazethapyr below 25 cm in four months in acidic and sandy loam soils under laboratory and field studies (Battaglin *et al.* 2000, Sondhia 2013). Residues of imazethapyr were reported in stream and river water in Midwestern US at concentrations above the maximum residue limits in 71% of samples (Basham *et al.* 1987).

Knowledge herbicide to persist in soil and plant and injure rotational crops is important in weed management strategies. Soybean is commonly rotated with wheat in the tropical region. Residue of ALS inhibitors or their metabolites can persist into the following growing seasons and can potentially injure sensitive crops grown in rotation such as canola and lentils, mustard, or sugar beet (Moyer and Hamman 2001, Schoenau *et al.* 2005, Poienaru and Sarpe 2006). Since herbicides are necessary to manage prominent weeds, the presence of this residues in crop produce at harvest is of great concern. Therefore a two years field study was conducted to determine the terminal residues of imazethapyr in soil, soybean grain, oil, oilcake and straw.

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MATERIALS AND METHODS

Field experiments were conducted for two consecutive years during 2006-07 in a randomized block design with three replications. Soybean variety '*JS 335*' was sown and imazethapyr (10% SL) was sprayed as post-emergence *i.e.* 20 days (after sowing of soybean seeds) at rates of 100 (recommended dose) and 200 g/ha (double the recommended dose). Physico-chemical properties of imazethapyr are given in Table 1. A further three triplicate plots were sprayed with water without any herbicide and maintained as control. The crop was grown under irrigated conditions with recommended package of practices. During 2006 and 2007, the soybean field received approximately 890 and 995 mm rainfall, respectively (Fig. 1).

Soil samples were collected at harvest (110 days), which is equivalent to 90 days after spraying of the herbicide in soybean crop in both the years. Five-soil cores of each approximately 3 kg soil were randomly taken from untreated and treated plots avoiding outer 20 cm fringes of the plots by using a soil auger up to a depth of 20 cm from the surface. Pebbles and other unwanted materials were removed manually. The soil samples were air dried, under shade, powdered and passed through a 3 mm sieve to achieve uniform mixing. The soil was clay loam in texture (clay 35.47%, silt 12.45%, and sand 52.09%), having nitrogen 300 kg/ha, phosphorus 40 kg/ha, and potassium 300 kg/ha, organic carbon 0.82 %, EC 0.35 mmhos/cm and pH 7.2.

At harvest, approximately 500 g of representative soybean grains and straw samples were collected from each imazethapyr treated and control plots. The straw samples were cut in small pieces and air-dried under shade. Soybean grains and straw samples were then ground in mechanical grinder. The imazethapyr reference analytical standard was obtained from AccuStandard, USA. All other chemicals and solvents used in the study were of analytical grade obtained from Merck, Germany. Imazethapyr residues in soil, and plant samples (oil cake, straw and pod) were determined as described by Sondhia (2013) using a Shimadzu HPLC coupled to diode array detector (DAD). Phenomenex C-18 (ODS) column (250 x 4.6 mm) and methanol: water (70:30 v/v) as mobile phase at a flow rate of 0.8 mL/min was used to separate imazethapyr residues. The LOD and the LOQ were found to be 0.001 and 0.01 µg/mL, respectively.

RESULTS AND DISCUSSION

In soil, and soybean oil, residues were found below 0.01 µg/mL in both the applied doses of imazethapyr *viz.* 100 and 200 g/ha, respectively in both the years. In contrast to the soil, residual concentration of 0.022 µg/g and 0.069 µg/g residues were detected in mature soybean pods where imazethapyr was applied at 100 and 200 g/ha doses in 2006. However, in 2007, 0.042 µg/g and 0.081 µg/g residues of imazethapyr were detected in the mature pod of soybean, following an application of imazethapyr at 100 and 200 g/ha, respectively (Table 2). This showed an enrichment of imazethapyr residues in soybean plant parts in second year of application. Residual concentration of 0.011 µg/g were detected in oil cake in 2007 under the lower dose however, 0.026 µg/g to 0.056 µg/g residues were detected in 2006 and 2007 at higher dose.

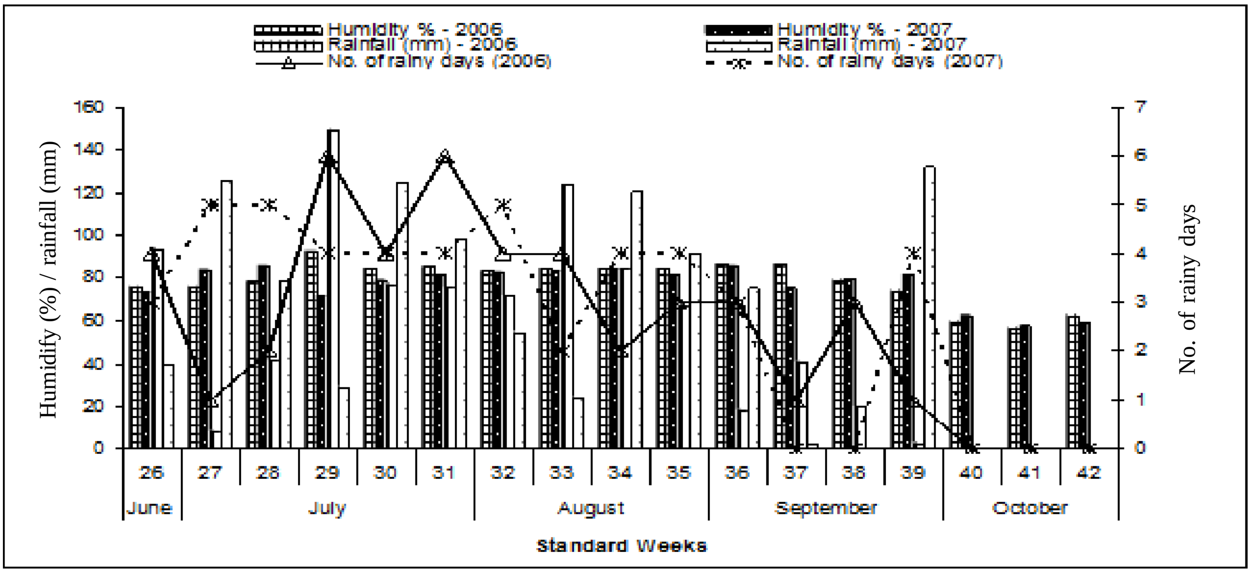


Fig. 1. Variation in humidify, rainfall and number of rainy days during 2006-07

Table 1. Some important physico-chemical properties of imazethapyr

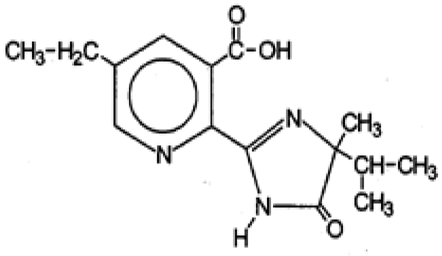
Chemical structure	IUPAC name	
	Molecular formula	$C_{15}H_{19}N_3O_3$
	Molecular weight	289.3
	Formulation	SL 10%
	Solubility in water	1400 mg/L
	Vapor pressure	$<1x10^{-7}$ mmHg at 60 ^{0}C
	Henry's constant	1.30 X 10^{-02} Pa m^3/mol at 25^{o}C
	Partition coefficient Log P_{ow}	1.49

Table 2. Imazethapyr residues in soybean oil, oilcake, grains, straw and soil at harvest

Substrate	Imazethapyr residues (µg/g)*			
	100 g/ha		200 g/ha	
	2006	2007	2006	2007
Soybean straw	0.011 (±0.001)	0.049 (±0.004)	0.013 (±0.002)	0.063(±0.003)
Soil	<0.01	<0.01	<0.01	<0.01
Oil	<0.01	<0.01	<0.01	<0.01
Oil cake	<0.01	0.011	0.026 (±0.001)	0.056 (±0.009)
Mature pod	0.022 (±0.004)	0.042(±0.007)	0.069 (± 0.008)	0.081(±0.006)

*mean of four replications

Sorption studies conducted in four soil types showed that imazethapyr had low Koc values (19.8-83.9), which suggested that little adsorption would be expected for any of soils and indicated that imazethapyr has high mobility and consequently a high potential to leach (Sondhia 2003). The amount of rainfall during the crop growing season when imazethapyr was applied might also have affected the persistence of the herbicide. During 2006 and 2007 the soybean field received approximately 890 and 995 mm rainfall, respectively. Due to higher solubility of imazethapyr in water (1.4-3.7 g/L), higher rainfall may have enhanced the leaching potential in soil in 2007 after the application of imazethapyr, this may have resulted in a reduced availability of imazethapyr in soil and hence less or no residues were found in soil and soybean plant produce at harvest (Barnes and Lavy 1991, Poienaru *et al.* 2006). However, reduced rainfall in 2006 means that there is increased herbicide adsorption making imazethapyr less available for plant uptake (Cantwell *et al.* 1989, Goetz *et al.* 1990) and less residues in soybean plants. This showed the fast degradation of imazethapyr residues in the soil and plants under reported agroclimatic conditions, although imazethapyr has a soil photolysis half-life of 33 months, and, in some field dissipation studies, the consistently persistence of imazethapyr was reported regardless of the soil type, agriculture practice and climatic effects (Imazethapyr 2015).

Marsh and Lloyd (1996) reported that imazethapyr persisted for longer period in Romanian soil and showed residual effect on succeeding barley and winter wheat even after 2-3 years. Cabbage was reported as the most sensitive to imazethapyr soil residues. Cabbage yields were reduced in 2 of 3 years while cabbage, tomato and cucumber showed visual injury symptoms after imazethapyr application in 2 of 3 years following post-emergence imazethapyr and imazamox application (Sullivan *et al.* 1998). Arora and Sondhia (2013) reported 0.082 and 0.023 µg/g residues in soybean grain and straw as a result of 200 g/ha application of imazethapyr in soybean crop. Low detections of residues was also indicative of low uptake, low translocation, or rapid degradation within the plant (Sidhu and Feng 1993).

Soil type, soil pH and Koc play an important role in the degradation and bioavailability of herbicides (Sullivan *et al.* 1988, Poienaru and Sarpe 2006, Sondhia 2013). Dissipation of imazethapyr is faster in soils with high pH and low adsorption since the amount available in the soil solution for microbial transformation is greater. The soil of experimental field in this study was almost neutral (pH 7.2) so that due to the small adsorption imazethapyr residues were not available in surface soil (0-20 cm) and were consequently not detected at harvest in soil. Sullian *et al.* (1998) reported imazethapyr residues mainly in the top 0-10 cm soil fraction but some imazethapyr was found in 10-20 cm and 20-40 cm depths. Besides the organic matter, the clay content can also play an important role in degradation of pesticides but Hollaway *et al.* (2006) reported persistence of imazethapyr residues for 24 and 5 months after treatment in clay soil and sandy soil respectively.

Some researchers recommend re-cropping periods of up to 6-34 months for imazethapyr due to leaching and persistence that may damage subsequent rotation crops and reported that imazethapyr has a rapid initial phase of degradation, followed by a slower second phase leading to long term persistence especially in clay soil (Bresnahan *et al.* 2000). Combination of chemical, biological, physical and environmental factors may operate at different level in influencing the degradation of herbicides (Sondhia 2013, 2013). Less persistence of imazethapyr was found in silty clay soil and high organic matter containing soils. Low concentration of the imazethapyr in soil is compensated by high microbial activity, which increased the rate of degradation (Sidhu and Feng 1993, Sondhia 2013).

In the soil almost neutral pH, high organic matter, soil clay content and sufficient rains might be the reason for less terminal residues of imazethapyr. The terminal residues of imazethapyr in plant parts were found higher in 2007 in comparison to 2006, however residues were below the maximum residue limits in soybean plants (0.1 mg/kg) set by some European countries (Canada Gazette 2006). This study demonstrated enrichment of imazethapyr residues in soybean plants after repeated application. Based on this study a pre-harvest interval of 80-90 days for soybean crop after the herbicide application is suggested.

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Control of broomrape in Indian mustard

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ABSTRACT

To study the efficacy of pendimethalin alone or in combination with neem cake and castor cake, seed treatment with various herbicides and post-emergence application of glyphosate at very low concentrations, field experiments were conducted during *Rabi* season of 2008-09 and 2009-10, at village Obera, Distt. Bhiwani and Dry land Research Area of CCS HAU Hisar (Haryana). Feasibility of adoption of results of study was tested by multi location field trials conducted through farmers' participatory approach in different parts of state during 2010-2013. Pre-emergence, pre-plant incorporation or herbigation of pendimethalin along with hoeing as well as use of organic manures, *viz.* castor cake and neem cake proved ineffective in minimizing density of this weed. Seed coating of mustard seeds with 1.0 ppm of chlorsulfuron or triasulfuron gave 70-98% control of *Orobanche aegyptiaca* but efficacy of seed treatment with sulfosulfuron was poor. Post emergence application of glyphosate at 25 and 50 g/ha with 1% solution of $(NH_4)_2SO_4$ at 25 and 55 DAS showed promise with 63-100% control of this weed not only in experimental fields but in large scale farmers' fields. Glyphosate dose range is very limited. Over dosing of glyphosate, resulted in 15-35% toxicity to mustard in terms of marginal leaf chlorosis, slow leaf growth and bending of apical stems and stunting with yield penalty. Bleaching of few leaves of mustard occurred with 50 g/ha dose at 55 DAS, which also recovered within 20 days resulting with no loss in yield.

Key words: Castor cake, Chlorsulfuron, Glyphosate, Indian mustard, Neem cake, *Orobanche*, Sulfosulfuron, Triasulfuron

Orobanche or Broomrape (*Orobanche* spp.), locally known as Margoja, Rukhri, Khumbhi or Gulli, is a phanerogamic, obligate, troublesome holo root parasite that lack chlorophyll (Saghir *et al.* 1973) and obtain carbon, nutrients, and water through haustoria which connect the parasite with the host vascular system. (Press *et al.* 1986). The attached parasite functions as a strong metabolic sink, often named "super- sink", strongly competing with the host plant for water, minerals and assimilates. The diversion of these substances to the parasitic weed causes moisture and assimilate starvation, host plant stress and growth inhibition leading to extensive reduction in crop yield and quality in infested fields. Depending upon the extent of infestation, environmental factors, soil fertility, and the crops' response, damage from *Orobanche* can range from zero to complete crop failure (Dhanapal *et al.* 1996). This parasitic weed has the tendency to proliferate well in coarse textured soils with high pH, low nitrogen status and poor water holding capacity. In Haryana state, infestation of obnoxious weed *Orobanche aegyptiaca* has been observed in mustard fields in 0.25 m ha area in South-Western part of the state. Pre-emergence, Pre- plant incorporation or herbigation of trifluralin along with hoeing proved ineffective in minimizing the density of this weed. Post emergence application of glyphosate at normal doses, kerosene oil and paraquat caused toxicity to mustard crop. Change in the genotype or sources of nutrient supply did not prove effective in minimizing density of this weed. Keeping it in view, present experiment was planned to study the effectiveness of neem and castor cakes, seed treatment with herbicides and post-emergence application of glyphosate at low doses against *Orobanche* in mustard crop.

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MATERIALS AND METHODS

The experiment was conducted at the farm of farmer of village Obera of Distt. Bhiwani situated at latitude of N 28 ° 41' 07.1" and E 075 ° 45' 18.9". During *Rabi* 2008-09. Variety '*RH-30*' was planted on 18.10.2008 in randomized block design in plot size of 25 x 5 m^2 with three replications and 15 treatments. During 2009-10, same experiment with some modifications like addition of castor cake and seed treatment with chlosulfuron and neem cake in combination with glyphosate was conducted at Dry land Research area of CCS HAU Hisar in randomized plot design with three replications in a plot size of 6 x 6 m^2. In the same year, another study to evaluate the effect of neem and castor cakes alone and with post-emergence treatment of glyphosate at 50 g/ha was also conducted in Village Obera (Bhiwani) on 24 october 2009 in a plot size of 16 x 6 m^2. During all the years of study, fields selected were heavily infested with *Orobanche aegyptiaca* during previous years. Various treatments were imposed as per schedule as given in tables 1-3. Data on per cent visual control of the weed was recorded at 80 and 120 days of sowing. Results obtained from these trials were further validated in large scale multi-location trials conducted at different locations in Haryana through farmers' participatory approach during the *Rabi* seasons of 2010-11 to 2013-14. A total of 157 demonstrations were conducted in mustard growing areas of Haryana state covering 253 ha area.

RESULTS AND DISCUSSION

During both the years, pendimethalin alone or in combination with neem cake did not prove useful in minimizing population of *Orobanche aegyptiaca* at village Obera (Bhiwani) as well as at Hisar. Neem and castor cakes either alone or in combination with pendimethalin, did not prove effective in minimizing *Orobanche* population as shown by significantly higher population and poor control of this weed in these treatments as compared to glyphosate at various dose (Table 1 and 2). Even application of neem cake twice (in furrow as well as before first irrigation) at 400 kg/ha did not prove effective against *Orobanche* (15-22% control only) but when neem and castor cakes were supplemented with glyphosate at 50 g/ha at 55 DAS, it proved highly effective with 90-92% control of *Orobanche* with 5% crop suppression but with out any yield penalty (Table 3). Seed coating of mustard seeds with 1.0 ppm solution of chlorsulfuron or triasulfuron gave 70-98% control of *O. aegyptiaca.* Efficacy of seed treatment with sulfosulfuron at 1.0 ppm was less (55-65%) but its use with post-emergence glyphosate application at 25 g/ha at 55 DAS provided good (81-87%) control of *Orobanche* up to 120 days after sowing (Table 1 and 2). The crop showed growth suppression from the very initial stage, resulting in poor yield. All glyphosate treatments proved very effective and provided 86-100% control of *O. aegyptiaca*. Although application of glyphosate 50 g/ha at 25 DAS with 1% solution of $(NH_4)_2SO_4$ gave 98% control of this weed with 35% suppression in crop growth in terms of marginal leaf chlorosis, slow leaf growth, bending of apical stems and even stunting. The crop recovered with irrigation after 3-4 days of herbcide application but with less yield even to untreated check during 2008-09. During 2009-10, although application of glyphosate 50 g/ha at 30 DAS and 25 g/ha at 55 DAS along with $(NH_4)_2SO_4$ gave 100% control of the weed, about 15% suppression in crop growth was observed at Hisar. Three hand hoeings employed at 30, 60 and 90 DAS did not prove effective against this weed.

Table 1. Effect of weed control measures on *Orobanche* population and seed yield of mustard (2008-09)

Treatment	*Orobanche* panicles /plot (80 DAS)	*Orobanche* panicles /plot (120 DAS)	% *Orobanche* reduction over WC (120 DAS)	Mustard yield (t/ha)	Remarks
Pendimethalin 1.0 kg/ha *fb* HW at 60 DAS	1.0 (0)	8.4 (70)	26.6	1.52	
Neemcake 200 kg/ha in furrow *fb* HW at 60 DAS	1.4(1)	6.2(38)	59.6	1.56	
Neemcake 200 kg/ha in furrow and pendimethalin 0.5 kg/ha *fb* HW at 60 DAS	2.0(3)	8.4(69.3)	26.6	1.46	
Neemcake 400 kg/ha in furrow *fb* HW at 60 DAS	2.1(4)	9.0(79.7)	14.9	1.38	
Neemcake 400 kg/ha in furrow and pendimethalin 0.5 kg/ha *fb* HW at 60 DAS	1.4(1)	10(100)	+8.8	1.27	
Glyphosate 25 g/ha with 1% $(NH_4)_2SO_4$ at 25 DAS	1.4(1)	4.2(16.7)	83.0	1.78	
Glyphosate 25 g/ha with1% $(NH_4)_2SO_4$ at 55 DAS	1.7(2)	1.7(2)	96.9	1.84	
Glyphosate 25 g/ha with $(NH_4)_2SO_4$ at 25 DAS and 50 g/ha at 55 DAS	1.0(0)	1.6(1.7)	97.8	1.98	
Glyphosate 50 g/ha with 1% $(NH_4)_2SO_4$ at 25 DAS	1.0(0)	1.3(0.7)	98.0	1.25	35% crop suppression
Glyphosate 25 g/ha with 1% $(NH_4)_2SO_4$ at 25 and 55 DAS	1.0(0)	1.4(1)	98.0	1.96	
Seed treatment with triasulfuron 1.0 ppm	1.9(3)	5.4(28)	70.2	1.79	
Seed treatment with sulfosulfuron 1.0 ppm	1.4(1)	5.8(32.3)	65.9	1.65	
Seed treatment with sulfosulfuron 1.0 ppm+ glyphosate 25 g/ha at 55 DAS	1.4(1)	4.4(18.3)	80.8	1.56	Crop suppression
HW at 30, 60 and 90 DAS	1.0(0)	9.7(92.3)	2.12	1.44	
Weedy check	3.1(9)	9.6(91.3)	-	1.40	
LSD(P=0.05)	0.5	0.8	-	0.18	

The data are square root transformed and values in the parentheses are original values.

Table 2. Effect of different weed control measures on *Orobanche* population and seed yield of mustard (Hisar) 2009-10

Treatment	*Orobanche* panicles/plot (80 DAS)	*Orobanche* panicles /plot (120 DAS)	% *Orobanche* reduction over control (120 DAS)	Mustard yield (t/ha)	Remarks
Pendimethalin 1.0 kg/ha *fb* HW at 60 DAS	14.4(212)	18.4(337)	11.0	0.68	
Neem cake 200 kg/ha in furrow *fb* HW at 60 DAS	14.5(245)	19.2(368)	2.6	0.64	
Neem cake 400 kg/ha in furrow *fb* one HW at 60 DAS	3.9(144)	7.6(327)	13.4	0.76	
Neem cake 200 kg/ha in furrow *fb* glyphosate 50 g/ha	1.7(2)	2.8(7)	98.1	0.86	
Castor cake 300 kg in furrow	6.4(41)	8.5(71)	81.2	0.79	
Castor cake 400 kg (broadcasting) *fb* HW	5.8(32)	7.3(52)	86.2	0.88	
Castor cake 500 kg in furrow	6.1(37)	9.0(81)	78.5	0.92	
Castor cake 400 kg/ha in furrow *fb* HW	5.4(28)	6.8(46)	87.8	0.90	
Glyphosate 25 g/ha with 1% $(NH_4)_2SO_4$ at 25 DAS	3.6(12)	7.5(56)	85.1	0.85	
Glyphosate 25 g/ha with 1%$(NH_4)_2SO_4$ at 55 DAS	4.7(20)	7.1(50)	86.7	0.86	
Glyphosate 25 g/ha with1% $(NH_4)_2SO_4$ at 25 DAS and 50 g/ha at 55 DAS	1(0)	3.9(14)	96.2	0.94	5% crop suppression
Glyphosate 50 g/ha with 1%$(NH_4)_2SO_4$ at 55 DAS	1(0)	1.4(1)	99.7	0.86	15% crop suppression
Glyphosate 50 g/ha with 1% $(NH_4)_2SO_4$ at 25 DAS and 25 g/ha at 55 DAS	1(0)	1(0)	100	0.88	15% crop suppression
Seed treatment with chlorsulfuron 1.0 ppm	1(0)	2.8(7)	98.1	0.90	
Seed treatment with triasulfuron 1.0 ppm	1.4(1)	2.7(6)	98.4	0.89	
Seed treatment with sulfosulfuron 1.0 ppm	5.3(25)	13.0(168)	55.5	0.76	
Seed treatment with sulfosulfuron 1.0 ppm+ glyphosate 25 g/ha at 55 DAS	1.5(2)	6.6(43)	88.6	0.88	
HW at 30, 60 and 90 DAS	2.7(8)	4.7(21)	94.4	0.92	
Control	15.7(248)	19.5(378)	0	0.73	
LSD (P=0.05)	1.0	0.4	-	0.62	

The data are square root transformed and values in the parentheses are original values

Table 3. Effect of different weed control measures on *Orobanche* control and seed yield of mustard (Obera, Bhiwani) 2009-10

Treatment	*Orobanche* control (%)	Seed yield (t/ha)	Remarks
Neem cake 400 kg/ha in furrow	24.8(18)	1.69	
Neem cake 400 kg/ha in furrow+ neem cake in furrow before first irrigation	22.5(15)	1.77	
Neem cake 400 kg/ha in furrow *fb* glyphosate 50 g/ha at 60 DAS with 1%$(NH_4)_2SO_4$	73.0(91)	1.90	5% crop suppression
Castor cake 400 kg/ha in furrow	28.2(22)	1.72	
Castor cake 400 kg/ha in furrow+ castor cake in furrow before first irrigation	22.8(15)	1.86	
Castor cake 400 kg/ha in furrow *fb* glyphosate 50 g/ha at 60 DAS with 1% $(NH_4)_2SO_4$	71.9(90)	1.94	5% crop suppression
Farmers practice (one hoeing)	16.6(8)	1.57	
Farmers practice + glyphosate 50 g/ha at 60 DAS with 1% $(NH_4)_2SO_4$	73.4(92)	1.85	5% crop suppression
LSD (P=0.05)	6.0	0.12	

The data are square root transformed and values in the parentheses are original values

Maximum seed yield of mustard (1.98 and 0.94 t/ha) was observed with use of glyphosate 25 g/ha at 25 DAS and 50 g/ha at 55 DAS along with 1% $(NH_4)_2SO_4$ which was at par with glyphosate 25 g/ha at 55 DAS with 1% $(NH_4)_2SO_4$ and glyphosate 25 g/ha at 25 and 55 DAS with 1% $(NH_4)_2SO_4$ during 2008-09 and three hand hoeing, glyphosate 50 g/ha at 25 DAS and 25 g/ha at 55 DAS along with 1% $(NH_4)_2SO_4$. during 2009-10. Competition from *Orobanche* through out crop season caused 29.4 and

Table 4. Comparative performance of glyphosate application *vis-à-vis* farmers' practice for *Orobanche* management and its subsequent effect on seed yield of mustard in large scale multi-locational trials

Year	No. of trials	Area covered (ha)	*Orobanche* control (%)	Seed yield (t/ha)		Percent reduction in yield
				Treated*	Farmer's practice**	
2010-11	12	5	82 (70-95)	1.72 (1.40-2.10)	1.49 (1.20-1.95)	15.5
2011-12	24	20	79 (65-90)	1.59 (1.20-2.20)	1.37 (0.90-1.80)	16.3
2012-13	86	156	72 (55-90)	1.75 (1.25-2.25)	1.54 (1.00-1.95)	13.9
2013-14	35	82	63 (40-90)	1.65 (1.25-2.40)	1.44 (1.10-2.10)	14.6

*25 g/ha at 30 DAS and 50 g/ha at 55-60 DAS-2 sprays; **one hoeing at 25-30 DAS; figures in parenthesis indicate range of the treatment effect on *Orobanche* control and mustard seed yield

22.0% reduction in seed yield of mustard during 2008-09 and 2009-10, respectively. At Obera during 2009-10, maximum seed yield of mustard (1941 kg/ha) was obtained with the use of castor cake 400 kg/ha in furrow *fb* glyphosate 50 g/ha at 55 DAS with 1% $(NH_4)_2SO_4$ which was at par with neem cake 400 kg/ha in furrow *fb* glyphosate 50 g/ha at 55 DAS with 1% $(NH_4)_2SO_4$ and farmer's practice of two hoeing *fb* glyphosate 50 g/ha at 55 DAS. Application of either neem cake or castor cake twice (sowing + first irrigation) although helped to boost crop growth, was not effective in controlling *Orobanche*. This is in conformity of results of Punia *et al.* (2012) and Punia and Singh (2012) who reported 65-85% control of *Orobanche* even up to harvest (without any crop injury) with glyphosate applied twice at 25 g/ha at 25 DAS followed by 50 g/ha at 55 DAS and yield improvement from 12 to 41% over the traditional farmers' practice at farmers fields in different years of the study.

Results of 157 demonstrations conducted on use of glyphosate at low doses in mustard growing areas of Haryana state covering 253 ha area showed that overall 74.4% (range 63-82%) reduction in *Orobanche* weed infestation with 15.0% (range 13.9-16.3%) increase in yield in glyphosate treated plots (25 g/ha at 30 DAS followed by 50 g/ha at 55-60 DAS) when compared with the farmers' practice of one hoeing at 25-30 DAS (Table 4).

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Integrated weed management in groundnut

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ABSTRACT

Field experiment was conducted to study the influence of integrated weed management practices on seed pod yield in groundnut at Agricultural Research station, Vaigaidam during *Rabi* 2011-12. Weed control efficiency was higher with pre-emergence application of oxyfluorfen at 0.25 kg/ha followed by hand weeding on 20 DAS and pendimethalin at 0.75 kg/ha followed by a hand weeding on 20 DAS at different intervals of 10, 25, 40 and 60 DAS. Weed density of sedge was significantly lowered with pre-emergence application of oxyfluorfen at 0.25 kg/ha on 3 DAS. Number of pods per plant and seed pod yield was significantly higher with pre-emergence application of pendimethalin at 0.75 kg/ha, alachlor 1.0 kg/ha) and oxyfluorfen at 0.25 kg/ha followed by hand weeding at 20 DAS. Layby application of pendimethalin at 0.75 kg/ha at 3 and 45 DAS after earthing up was also at par with pre-mergence herbicide followed by hand weeding. Phytotoxicity symptoms has been observed with layby application of oxyflourfen 0.25 kg/ha on 45 DAS after earthing up and this resulted lower yield even if this treatment has recorded lesser weed density.

Key words: Groundnut, Integrated weed management, Lay by application, Seed pod yield, Weed control efficiency

Groundnut is an important oil seed crop of India which is cultivated in nearly 6 million ha area with the production of 7.5 million tones and average productivity of 1.27 t/ha. Though India ranks first in the world under groundnut area and there is need to import 8.03 million tones of edible oil (Kalhapure *et al*. 2013). Weeds are the major cause of minimizing production and yield losses in groundnut (Gosh e*t al.* 2000).

Agricultural Research Station, Vaigaidam is one of the renowned centres for producing breeder seeds in groundnut. Major problem in seed production is labour shortage during the peak period of important operations like sowing, weeding and harvesting. For groundnut, there should be a weed free condition up to 40 DAS otherwise the reduction in growth and yield can't be compensated at later stage due to severe weed infestation. Thus a field experiment was conducted to evaluate suitable integrated weed management practices for increasing weed control efficiency and reducing labour usage in groundnut production.

MATERIALS AND METHODS

Field experiment was conducted on integrated weed management practices on seed pod yield at Agricultural Research station, Vaigaidam during *Rabi'* 2011-12. The soil of the field experimental field was having pH (6.5), available N (242 kg/ha), P_2O_5 (11 kg/ha) and K_2O (335 kg/ha).Treatments consisted of Pre-emergence application of pendimethalin 0.75 kg/ha, alachlor 1.0 kg/ha and oxyfluorfen 1.0 kg/ha followed by hand weeding on 20 DAS. To control late emerging weeds after 45 DAS, layby application of pendimethalin 1.0 kg/ha and oxyfluorfen 0.25 kg/ha was done since hand weeding was impossible due to peg penetration at later stage. The experiment was laid out in randomized block design with three replications. Groundnut variety *'TMV 7'* was sown. Crop was fertilized with 25:50:75 kg NPK ha under surface irrigation. Herbicides were applied using manually operated knapsack sprayer fitted with flat fan nozzle using spray volume of 600 L/ha. Weed density were recorded at 10, 25, 40 and 60 DAS. Economics was worked as per the prevailing market price.

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RESULTS AND DISCUSSION

Effect on weeds

Predominant weeds identified in the experimental were *Chloris barbata, Panicum repens* and *Dactyloctenium ageyptium* among grasses. Among the sedges, *Cyperus rotundus* and *Cyperus esculentus* were predominant. Major broad leaved weeds were *Celosia argentia, Trianthema* *portulacastrum, Tridax procumbens, Euphorbia geniculata,Digera arvensis, Parthenium hysterophorus, Portulaca oleraceae, Phyllanthus niruri* and *Phyllanthus medraspatensis.*

Grass weed density was significantly lowered with pre-emergence application of pendimenthalin 0.75 kg/ha, alachlor 1.0 kg/ha and oxyfluorfen 0.25 kg/ha. Sedge weed density was significantly lowered with pre-emergence application of oxyfluorfen at 0.25 kg/ha on 3 DAS. Remaining all other treatments recorded significantly higher sedge weed population. Pre-emergence application of oxyfluorfen also influenced germination of *C. rotundus.* Broad-leaved weed density was also significantly lowered with pre-emergence application of pendimethalin 0.25 kg/ha, alachlor 1.0 kg/ha and oxyflourfen at 250 g/ha.

Total weed density was significantly lowered with pre-emergence application of oxyfluorfen 0.25 kg/ha than all other treatments. This might be due to reduced sedge weed population and broadleaved weed density comparatively than other test herbicides.

Grass weed density was significantly lowered with pre-emergence application of pendimethalin 0.75 kg/ha and oxyfluorfen 0.25 kg/ha *fb* a hand weeding on 20 DAS and hand weeding twice on 15 and 30 DAS. Post-emergence application of quizalofop-ehyl 0.25 kg/ha was also significantly lowered the grass weed density over all other treatments. Sedges weed was significantly lowered with pre-emergence application of oxyfluorfen 0.25 kg/ha on 3 DAS and hand weeding twice on 15 and 30 DAS. Broad-leaved weed density was also significantly lowered with pre-emergence application of pendimethalin 0.75 kg/ha, and oxyfluorfen 250 g/ha *fb* a hand weeding on 20 DAS and hand weeding twice on 15 and 30 DAS and layby application of oxyfluorfen 0.25 kg/ha on 3 and 45 DAS after earthing up is also on par.

Total weed density was significantly lowered with pre-emergence application of oxyfluorfen at 0.25 kg/ha and hand weeding twice on 15 and 30 DAS than all other treatments. This might be due to the reduction in sedge weed population and as well as broad-leaved weed density comparatively than other test herbicides. Hand weeding has better efficiency in controlling over all weed density.

Except unweeded control, all other treatments have recorded significantly lower grass weed density on 40 DAS and all other test herbicides are on par with each other. Sedge weed density was significantly lowered with pre-emergence application of pendimethalin 0.75 kg/ha and oxyfluorfen 0.25 kg/ha on 3 DAS *fb* hand weeding and as well as their sequential application on 45 DAS after earthing up.

Table 1. Effect of different weed management practices on weed density per m^2 (no/m^2) on 10 and 30 DAS in groundnut during *Rabi* 2011-12

Treatment	10 DAS				30 DAS			
	Grasses	Sedges	Broad-leaved	Total	Grasses	Sedges	Broad-leaved	Total
PE alachlor 1.0 kg/ha (sand application) + HW 20 DAS	1.73 (1.0)	2.77 (5.7)	2.65 (5.0)	3.70 (11.7)	2.24 (3.0)	3.7 (11.7)	2.71 (5.3)	4.32 (20.0)
PE alachlor 1.0 kg /ha + hand weeding in 20 DAS	1.53 (0.3)	2.45 (4.0)	2.08 (2.3)	2.94 (6.7)	2.00 (2.0)	3.27 (8.7)	2.65 (5.0)	3.92 (15.7)
PE pendimethalin 0.75 kg/ha + hand weeding on 20 DAS	1.53 (0.3)	2.65 (5.0)	1.63 (0.7)	2.83 (6.0)	1.41 (0.0)	3.32 (9.0)	2.16 (2.7)	3.61 (11.7)
Lay by pendimethalin 0.75 kg/ha + 0.75 kg/ha after earthing up on 45 DAS	1.53 (0.3)	2.58 (4.7)	1.63 (0.7)	2.77 (5.7)	1.73 (1.0)	2.7 (5.3)	2.16 (2.7)	2.77 (9.0)
PE oxyfluorfen 0.25 kg/ha + HW on 20 DAS	1.53 (0.3)	1.83 (1.3)	1.41 (0.0)	1.91 (1.7)	1.83 (1.3)	2.08 (2.3)	1.83 (1.3)	2.58 (5.0)
Layby oxyfluorfen 0.25 kg/ha + 0.25 kg/ha after earthing up on 45 DAS	1.53 (0.3)	2.16 (2.7)	1.91 (1.7)	2.58 (4.7)	1.91 (1.7)	2.71 (5.3)	2.45 (4.0)	2.83 (11.0)
PE pendimethalin 0.75 kg/ha + EPOE quizalofop-ethyl at 0.25 kg/ha on 20 DAS	1.63 (0.7)	2.65 (5.0)	2.16 (2.7)	3.22 (8.4)	1.53 (0.3)	3.11 (7.7)	3.16 (8.0)	4.43 (16.0)
Hand weeding twice (15 and 30 DAS)	2.82 (6.0)	2.77 (5.7)	3.16 (8.0)	4.65 (19.7)	1.83 (1.3)	2.00 (2.0)	2.16 (2.7)	2.82 (6.0)
Un weeded control	3.46 (10.0)	3.46 (10.0)	4.51 (18.3)	6.35 (38.3)	4.16 (15.3)	4.0 (14.0)	5.29 (26.0)	7.98 (55.3)
LSD (P=0.05)	0.4	0.6	0.8	0.7	0.4	0.6	0.8	0.9

Figures in parentheses are mean of original values

Table 2. Effect of different weed management practices on weed density per m^2 (no/m^2) on 40 and 60 DAS in groundnut during *Rabi 2011*- 12

Treatment	40 DAS				60 DAS			
	Grasses	Sedges	Broad-leaved	Total	Grasses	Sedges	Broad-leaved	Total
PE alachlor 1.0 kg/ha (sand application) + HW 20 DAS	1.73 (1.0)	2.24 (3.0)	3.27 (12.7)	3.83 (12.7)	2.16 (2.7)	2.71 (5.3)	3.27 (8.7)	4.32 (16.7)
PE alachlor 1.0 kg/ha + hand weeding 20 DAS	1.41 (0.0)	2.24 (3.0)	2.94 (6.7)	3.42 (9.7)	2.08 (2.3)	2.45 (4.0)	3.00 (7.0)	3.92 (13.3)
PE pendimethalin 0.75 kg/ha + hand weeding on 20 DAS	1.41 (0.0)	2.71 (5.3)	2.52 (4.3)	3.42 (9.7)	1.53 (0.3)	2.58 (4.7)	2.83 (6.0)	3.61 (11.0)
Layby pendimethalin 0.75 kg/ha + 0.75 kg/ha after earthing up on 45 DAS	1.63 (0.7)	2.52 (4.3)	2.38 (3.7)	3.27 (8.7)	1.53 (0.3)	2.08 (2.3)	2.24 (3.0)	2.77 (5.7)
PE oxyfluorfen 0.25 kg/ha + HW on 20 DAS	1.41 (0.0)	1.91 (1.7)	1.91 (1.7)	2.31 (3.3)	1.63 (0.7)	1.91 (1.7)	2.08 (2.3)	2.58 (4.7)
Layby oxyfluorfen 0.25 kg/ha + 0.25 kg/ha after earthing up on 45 DAS	1.41 (0.0)	2.24 (3.0)	2.52 (4.3)	3.06 (7.3)	1.53 (0.3)	2.16 (2.7)	2.24 (3.0)	2.83 (6.0)
PE pendimethalin 0.75 kg/ha + EPOE quizalofop-ethyl 0.25 kg/ha on 20 DAS	1.53 (0.3)	3.00 (7.0)	3.37 (9.3)	4.32 (16.7)	1.91 (1.7)	2.77 (5.7)	3.51 (10.3)	4.43 (17.7)
Hand weeding twice (15 and 30 DAS)	1.41 (0.0)	2.38 (3.7)	3.88 (12.7)	4.28 (16.3)	2.00 (2.0)	2.31 (3.3)	2.83 (6.0)	3.64 (11.3)
Un weeded control	4.04 (14.3)	3.79 (12.3)	5.54 (28.7)	7.57 (55.3)	4.32 (16.7)	2.40 (17.3)	5.45 (27.7)	7.98 (61.7)
LSD (P=0.05)	0.4	0.8	0.7	0.8	0.4	0.5	0.6	0.5

Figures in parentheses are mean of original values

Hand weeding twice has also recorded lesser sedge weed density than all other treatments. Broad-leaved weed density was also significantly lowered with pre-emergence application of pendimethalin 0.75 kg/ha and oxyfluorfen 0.25 kg/ha on 3 DAS and *fb* a hand weeding on 20 DAS and as well as their sequential application on 45 DAS after earthing-up.

Grass weed density was significantly lowered with pre-emergence application of pendimethalin 0.25 kg/ha, alachalor and oxyfluorfen 0.250 kg/ha *fb* a hand weeding on 20 DAS and as well as their layby application on 3 and 45 DAS after earthing up. Post-emergence application of quizalofop-ethyl 250 g/ha also reduced the grass weed density. Sedge weed population was significantly lowered with pre-emergence application of oxyfluorfen 0.25 kg/ha on 3 DAS followed by a hand weeding and as well as is sequential application on 45 DAS (T6) after earthing up. Hand weeding twice on 15 DAS also recorded lesser sedge weed density than all other treatments. Broad-leaved weed density was also significantly lowered with pre-emergence application of oxyfluorfen 0.25 kg/ha on 3 DAS *fb* a hand weeding at 20 DAS and as well as its sequential application at 45 DAS after earthing up overall other treatments. Layby application of pendimethalin 0.75 kg/ha on 3 and DAS after earthing up also reduce the broad-leaved weed density on 60 DAS over all other treatments.

Total weed density was also significantly lowered with pre-emergence application of oxyfluorfen 0.25 kg/ha on 3 DAS *fb* a hand weeding on 20 DAS and as well as its sequential application on 45 DAS after earthing up over all other treatments. Layby application of pendimethalin 0.75 kg/ha on 3 and 45 DAS after earthing up has also reduce the broad-leaved weed density on 60 DAS over all other treatments.

Weed control efficiency was higher with pre-emergence application of oxyfluorfen at 0.25 kg/ha *fb* hand weeding on 20 DAS and pendimethalin 0.75 kg/ha *fb* a hand weeding on 20 DAS at different intervals of 10,25,40 and 60 DAS.

Effect on crop

During *Rabi* 2011-12, number of pods per plant and seed pod yield was significantly higher with pre-emergence application of pendimethalin at 0.75 kg/ha, alachlor 1.0 kg/ha and oxyfluorfen at 0.25 kg/ha *fb* hand weeding on 20 DAS. Layby application of pendimethalin 0.75 kg/ha at 3 and 45 DAS after earthing up was also at par with pre-emergence herbicide followed by hand weeding. This might be due to lesser weed density observed at early crop stage and their consistent control over weeds at later stage. Phytotoxicity symptoms has been observed with layby application of oxyfluorfen at 0.25 kg/ha on 45 DAS after earthing up and crop was completely

Table 5. Effect of different weed management practices on number of pods per plant and seed pod yield (kg/ha) in groundnut during *Rabi* 2011 - 12

Treatment	Number of pods per plant	Seed pod yield (t/ha)	B:C
PE alachlor 1.0 kg/ha (sand application) + HW 20 DAS	22	1.48	2.50
PE alachlor 1.0 kg /ha + hand weeding 20 DAS	38	1.85	3.81
PE pendimethalin 0.75 kg/ha + hand weeding on 20 DAS	37	1.83	3.63
Layby pendimethalin 0.75 kg/ha + 0.75 kg/ha after earthing up on 45 DAS	36	1.83	3.65
PE oxyfluorfen 0.25 kg/ha + HW on 20 DAS	39	1.93	3.85
Layby oxyfluorfen 0.25 kg/ha + 0.25 kg/ha after earthing up on 45 DAS	13	0.97	1.97
PE pendimethalin 0.75 kg/ha + EPOE quizalofop-ethyl 0.25 kg/ha on 20 DAS	22	1.27	2.60
Hand weeding twice 15 and 30 DAS	38	1.84	2.75
Unweeded control	8	0.92	2.08
LSD (P=0.05)	9	0.34	

recovered at 7 Days after herbicide application and this reflected on lower yield even if this treatment has recorded lesser weed density.

Benefit cost ratio was higher with pre-emergence application of oxyfluorfen at 0.25 kg/ha *fb* hand weeding on 20 DAS. Due to reduced yield, layby application of oxyfluorfen at 0.25 kg at 3 DAS and 0.25 kg/ha after earthing up has recorded lower benefit cost ratio.

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Intercropping and weed management effect on soil microbial activities in newly planted mango and citrus orchards

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ABSTRACT

Application of herbicides and other agro-chemicals used in agriculture affects the vital functions and population dynamics of soil microorganisms. Soil microbial population was assessed in 30 days interval up to 90 days in mango and citrus orchards. Among the treatments, intercropping of greengram-pea-greengram recorded higher bacterial population (21.7 x 10^6cfu/g), was followed by intercropping of cowpea-pea-cowpea (19.5x10^6 cfu/g) at 90 days after spraying. It was found that the highest fungi population was recorded in intercropping of greengram-pea-greengram combined with herbicide application treatment (14.4 x 10^3 cfu/g). Similarly, higher actinomycetes population was observed in intercropping of greengram-pea-greengram treatment (8.2 x 10^3cfu/g) followed by intercropping of cowpea-pea-cowpea (7.3 x 10^3cfu/g) in mango orchard. In citrus field, highest bacterial population was observed in intercropping of greengram-pea-greengram treatment (21.3 x 10^6cfu/g).This was followed by intercropping of cowpea-pea-cowpea (18.4 x 10^6 cfu/g). The maximum fungi population (14.8 x 10^3cfu/g) was observed in cowpea-pea-cowpea treatment and maximum actinomycetes (8.4 x 10^3 cfu/g) population was recorded in intercropping of greengram-pea-greengram treatment. Basal respiration was significantly more in treatments of intercropping systems. Among the treatments, intercropping of greengram-pea-greengram treatment (193 mg/kg of CO_2-C) had more basal respiration rate during *Kharif* season in mango orchard. Similar trends were observed in citrus orchard.

Key words: Actinomycetes, Bacteria, Citrus, Fungi, Intercropping, Mango, Soil respiration, Weed management

Intercropping is considered to be one of the most significant cropping techniques in sustainable agriculture. Besides diversifying agricultural output, intercropping also improves nutrient status and the physical properties of the soil. Due to wide spacing and developing root patterns, during initial years (up to 8-10 years) of mango and citrus orchards establishment, large unutilized interspace can be exploited for growing inter and mixed crops successfully and adequate management of the orchard. This enables the farmers to raise extra income during the years when the main crop yields no or low returns. Some fertility restoring crops like legumes and leguminous cover crops should be included into the intercropping patterns. Legume intercropping supporte continuous recycling of plant residues and improved microbiological transformations of nutrients into an available form.

Herbicides form the principal component of weed management in crops and cropping systems. The continuous use of herbicides may lead to many problems like residual toxicity, health hazards and mammalian toxicity. Many herbicides are directly applied to the soil, and if applied by other methods eventually reach the soil either as runoff, drift or washed down through atmospheric precipitation (Cork and Krueger 1991). Herbicides and their degradation products generally get accumulated in the top soil to a depth of approximately 15 cm, the zone of maximum activity of soil flora and fauna, and may upset the equilibrium of soil microflora thereby influencing the future soil fertility and the general growth and development of crop plants (Schuster and Schroder 1990). Hence, a study was carried out to investigate the impact of intercropping and herbicidal applications on soil microflora in mango and citrus orchard.

MATERIALS AND METHODS

The experiments were conducted at DWR, Jabalpur for two consecutive seasons (*Kharif* and *Rabi*) during 2009-10. The treatment consisted of intercropping of cowpea-pea-cowpea; moong-pea-moong; the combination of both the intercropping systems with fluchloralin/ pendimethalin/ fluchloralin in each season; metribuzin 0.5 kg/ha; glyphosate 2.0

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kg/ha; two mechanical weeding in each season and weedy check in randomized block design with three replications.

Enumeration of microorganisms

The soil samples were collected from 0-15cm profile in all the plots at before spraying and at the time of harvest. The soils were soaked into 90 ml deionized water at the amount of 10 g, respectively. This mixed liquor was shaken for 10 min and kept still for 5 min. one ml of the supernatant of the mixed liquor was diluted to proper dilution twice and inoculated in the diluted water at the constant temperature of 30º C. All samples were performed in triplicate, and were used for enumeration microorganisms. The viable microbial counts were analyzed by the standard technique of serial dilution and pour plating. Enumeration of bacteria and fungi were carried out in soil extract agar medium (James 1958) and Rose Bengal Agar medium (Parkinson *et al.* 1971). The Kenknight's Agar medium (Wellingtonn and Toth 1963) is used for enumeration of actinomycetes. After allowing for development of discrete microbial colonies during incubations under suitable conditions, the colonies were counted and the number of viable bacteria, fungi and actinomycetes expressed as colony forming units (cfu) per gram dry weight of soil by taking into account the soil dilutions.

Soil respiration

Soil respiration was determined by incubating moist soil samples (50 g, 60% field capacity) in a air-tight jar with a beaker containing of 10 ml 0.5 M NaOH for 10 days. The evolved CO_2 was measured by titration of excess NaOH with 0.25N HCl after addition of $BaCl_2$ to precipitate CO_3^{-2} ions. The concentration of CO_2-carbon was expressed as mg CO_2-carbon/ kg/10 days (Jenkinson and Ladd 1981).

RESULTS AND DISUSSION

The total bacterial population was significantly more in all the intercropping treatments at 90 days after spraying. With progress of time, population was increased in all the treatments. The maximum bacteria population was found in intercropping of greengram-pea-greengram treatment (21.7 x 10^6 cfu/g) during *Kharif*, this was followed by cowpea-pea-cowpea treatment (19.5 x 10^6 cfu/g) in mango during *Kharif* season (Table 1). Similarly, in citrus field, highest bacterial population was observed in intercropping of greengram-pea-greengram treatment (21.3 x 10^6 cfu/g). This was followed by intercropping of cowpea-pea-cowpea treatment (18.4 x 10^6 cfu/g) during *Kharif* (Table 2). This may be due to the fact that in intercropping conditions, more soil organic matter is available which provides nutrients to microorganisms resulting in their proliferation. Initially, herbicide applied treatments (30 DAS) had significantly less bacterial count than weedy control, which recovered later on (Table 1 and 2). Balasubramanian and Sankaran (2001) also reported initial suppression of soil microflora by the herbicide application in different soils. The toxic effects of herbicides normally appear immediately after the application when their concentration in the soil is highest. Later on, microorganisms take part in degradation process and herbicide concentration and its toxic effect decreases (Radivojevic *et al.* 2004).

In our present study in mango field, fungi population was more in intercropping of greengram-pea-greengram combined with herbicide application treatment (14.4 x 10^3 cfu/g) during *Rabi* followed by intercropping of greengram-pea-greengram (13.5 x 10^3 cfu/g) during *Kharif* season (Table 1). In citrus, results revealed that the highest fungi population were recorded under intercropping of cowpea-pea-cowpea (14.8 x 10^3 cfu/g) during *Rabi* (Table 2). There was not much difference in the fungi population of different treatments. This may be due to fact that the fungi might have become tolerant to herbicide and would have utilized the herbicide as a nutrient source. In mango, higher actinomycetes population was observed in intercropping of greengram-pea-greengram (8.2 x 10^3 cfu/g) followed by intercropping of cowpea-pea-cowpea (7.3x10^3cfu/g) during *Rabi* (Table 1). Similarly, maximum actinomycetes (8.4 x 10^3 cfu/g) population in intercropping of greengram-pea-greengram treatment during *Rabi* (Table 2) in citrus field. The dynamic increase of the microorganisms in the rhizosphere of fruit crops intercropped with legume cultivation can be explained by the favorable quantitative and qualitative composition of organic compounds provided in the form of root exudates and crop residues (Lehmann *et al.* 2000). This fact is confirmed by earlier information from the previous investigators (Al Yahyai 2009, Abouziena 2010). Significantly higher microbial populations in intercropping treatments at all stages of observation might be due to healthy and conducive environment for the microorganisms as compared to the control plots.

Intercropping has significant effects on microbiological and chemical properties in the rhizosphere, which may contribute to the yield enhancement by intercropping. An unintended consequence of application of herbicides is that it

Table 1. Effect of intercropping and herbicidal treatments on soil microbes in mango orchard

Treatment	Soil microbial population (cfu/g soil)								
	Bacteria x10^6			Fungi x10^3			Actinomycetes x10^3		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Kharif									
T_1- Intercropping of cowpea *fb* pea *fb*	7.5	18.2	19.5	4.2	6.3	12.4	4.5	6.8	7.1
cowpea	(0.87)	(1.26)	(1.29)	(0.62)	(0.79)	(1.09)	(0.65)	(0.83)	(0.85)
T_2- Intercropping of moong bean *fb* pea *fb*	8.2	18.4	21.7	6.8	7.3	13.5	3.9	4.8	6.5
moong bean	(0.91)	(1.26)	(1.33)	(0.83)	(0.86)	(1.13)	(0.59)	(0.68)	(0.81)
T_3- T_1 + pendimethalin 1.0 kg/ha/	4.1	12.4	13.9	5.6	6.5	11.8	4.2	5.1	5.5
fluchloralin 1.0 kg/ha in each season	(0.61)	(1.09)	(1.14)	(0.74)	(0.81)	(1.07)	(0.62)	(0.76)	(0.74)
T_4- T_2 + pendimethalin 1.0 kg/ha/	5.3	11.7	14.1	6.2	7.4	13.1	3.7	4.1	4.9
fluchloralin 1.0kg/ha in each season	(0.72)	(1.06)	(1.14)	(0.79)	(0.86)	(1.11)	(0.56)	(0.61)	(0.69)
T_5- Metribuzin 0.5 kg/ha in each season	3.4	6.1	8.3	3.4	5.9	10.5	3.3	3.8	4.5
	(0.53)	(0.78)	(0.91)	(0.53)	(0.77)	(0.02)	(0.51)	(0.57)	(0.65)
T_6- Glyphosate 2.0 kg/ha once in a season	4.0	8.4	11.6	4.1	5.7	9.4	3.8	4.3	4.8
	(0.60)	(0.92)	(1.06)	(0.61)	(0.75)	(0.97)	(0.57)	(0.63)	(0.68)
T_7- Two mechanical weeding per season	6.1	12.3	15.8	5.4	6.2	11.5	4.4	4.9	5.3
	(0.78)	(1.08)	(1.19)	(0.73)	(0.79)	(1.06)	(0.64)	(0.69)	(0.72)
T_8- Weedy check	7.3	9.4	14.5	6.1	7.3	10.8	4.1	4.7	5.1
	(0.86)	(0.97)	(1.16)	(0.78)	(0.86)	(1.03)	(0.61)	(0.67)	(0.70)
LSD (P=0.05)	0.07	0.10	0.10	0.07	0.08	0.09	0.06	0.07	0.07
Rabi									
T_1- Intercropping of cowpea *fb* pea *fb*	8.2	16.4	18.1	4.3	6.8	7.2	4.8	7.3	8.2
cowpea	(0.91)	(1.21)	(1.25)	(0.63)	(0.83)	(0.85)	(0.68)	(0.86)	(0.91)
T_2- Intercropping of moong bean *fb* pea *fb*	9.2	16.8	17.5	6.2	7.3	8.4	3.9	6.2	7.3
moong bean	(1.96)	(1.22)	(1.24)	(0.79)	(0.86)	(0.92)	(0.59)	(0.79)	(0.86)
T_3- T_1 + pendimethalin 1.0 kg/ha/	6.3	12.3	15.8	5.5	9.3	10.3	4.2	5.3	6.9
fluchloralin 1.0 kg/ha in each season	(0.79)	(1.08)	(1.19)	(0.74)	(0.96)	(1.01)	(0.62)	(0.72)	(0.83)
T_4- T_2 + pendimethalin 1.0 kg/ha/	7.5	14.8	16.9	5.9	12.8	14.4	4.3	6.1	7.2
fluchloralin 1.0 kg/ha in each season	(0.89)	(1.17)	(1.22)	(0.77)	(1.10)	(1.15)	(0.63)	(0.78)	(0.85)
T_5- Metribuzin 0.5 kg/ha in each season	5.2	6.8	9.2	6.0	7.4	9.2	3.2	5.3	5.4
	(0.71)	(0.83)	(0.96)	(0.77)	(0.86)	(0.96)	(0.56)	(0.72)	(0.74)
T_6- Glyphosate 2.0 kg/ha once in a season	4.3	8.3	11.3	5.4	6.8	8.4	2.8	4.8	4.9
	(0.63)	(0.91)	(1.03)	(0.73)	(0.83)	(0.92)	(0.44)	(0.68)	(0.69)
T_7- Two mechanical weeding per season	6.2	7.4	14.3	6.2	8.4	8.4	4.2	5.2	5.7
	(0.79)	(0.86)	(1.15)	(0.790	(0.920	(0.92)	(0.62)	(0.71)	(0.75)
T_8- Weedy check	6.9	7.3	12.6	5.7	8.8	9.2	6.2	6.4	6.9
	(0.83)	(0.86)	(1.10)	(0.75)	(0.94)	(0.96)	(0.79)	(0.80)	(0.83)
LSD (P=0.05)	0.08	0.10	0.11	0.07	0.09	0.09	0.06	0.07	0.08

Data in parentheses indicate the log_{10} transformed values, cfu-colony forming units, DAS-Days after spraying

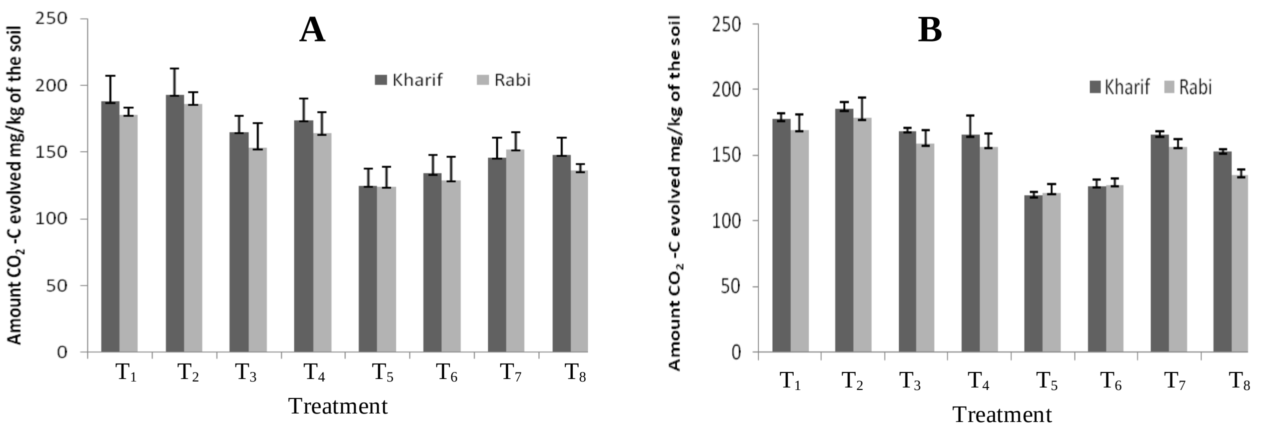
may lead to significant changes in the populations of microorganisms and their activities thereby influencing the microbial ecological balance in the soil (Saeki and Toyota 2004) and affecting the productivity of soils. The behaviour of herbicides in the soil has been studied now for several decades. When herbicides are applied to soil, they may exert certain side effects on non-target organisms.

Basal respiration rate was significantly more in cowpea-pea-cowpea and greengram-pea-greengram as intercropping system combined with and without herbicide treatment. Similar effect was observed by Tu (1991). Among the treatments, intercropping of greengram-pea-greengram showed more respiration rate (193mg/kg of CO_2-C) followed by intercropping of cowpea-pea-cowpea (188 mg/kg of CO_2 -C) during *Kharif* season in mango orchard. Similar trend was observed in citrus orchard (Fig. 1). LiJun *et al.* (2005) reported slight reduction in respiration rate during initial application of herbicides in soil. The potential indirect effect in the rhizospheres of intercropped species is enhanced nutrient mineralization due to change in soil organic matter decomposition rates, resulting from the addition of fresh organic matter. Thus, it can occur in the rhizosphere via root turnover and rhizodeposition. Fontaine *et al.* (2011) suggested that microorganisms use the energy from this fresh material to decompose soil organic matter in order to release organic N when inorganic N is limiting. P limitation has never been proven to provoke a priming effect, but it may be likely in ecosystems that are primarily P limited, such

Table 2. Effect of intercropping and herbicidal treatments on soil microbes in citrus orchard

Treatment	Soil microbial population (cfu/g soil)								
	Bacteria x10^6			Fungi x10^3			Actinomycetes x10^3		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Kharif									
T_1- Intercropping of cowpea *fb* pea *fb*	8.4	14.6	18.4	4.1	5.8	11.9	4.2	6.9	7.3
cowpea	(0.92)	(1.16)	(1.26)	(0.61)	(0.76)	(1.07)	(0.62)	(0.83)	(0.86)
T_2- Intercropping of moong bean *fb* pea *fb*	8.2	13.5	21.3	5.7	7.3	12.3	3.7	4.5	6.9
moong bean	(0.91)	(1.13)	(1.32)	(0.75)	(0.86)	(1.08)	(0.56)	(0.65)	(0.83)
T_3- T_1 + pendimethalin 1.0 kg/ha/	4.3	8.1	12.4	5.1	6.5	10.8	4.1	4.5	6.1
fluchloralin 1.0 kg/ha in each season	(0.63)	(0.90)	(1.09)	(0.70)	(0.81)	(1.03)	(0.61)	(0.65)	(0.78)
T4- T_2 + pendimethalin 1.0 kg/ha/	4.5	8.9	13.4	5.2	7.1	12.9	3.5	5.1	5.9
fluchloralin 1.0 kg/ha in each season	(0.65)	(0.94)	(1.12)	(0.71)	(0.85)	(1.11)	(0.54)	(0.70)	(0.77)
T_5- Metribuzin 0.5 kg/ha in each season	3.2	6.8	11.1	3.1	6.2	11.3	3.2	3.9	4.7
	(0.50)	(0.83)	(1.04)	(0.49)	(0.79)	(1.05)	(0.50)	(0.59)	(0.67)
T_6- Glyphosate 2.0 kg/ha once in a season	3.8	7.4	10.9	4.3	8.7	9.8	3.7	4.2	4.9
	(0.57)	(0.86)	(1.03)	(0.63)	(0.93)	(0.99)	(0.56)	(0.62)	(0.69)
T_7- Two mechanical weeding per season	6.3	11.2	13.8	5.1	6.2	8.9	4.3	4.9	5.6
	(0.79)	(1.04)	(1.13)	(0.70)	(0.79)	(0.94)	(0.63)	(0.69)	(0.74)
T_8- Weedy check	7.3	9.4	14.6	5.4	6.9	10.5	4.2	4.5	5.3
	(0.86)	(0.97)	(1.16)	(0.73)	(0.83)	(1.02)	(0.62)	(0.65)	(0.72)
LSD (P=0.05)	0.07	0.10	0.11	0.06	0.08	0.10	0.06	0.06	0.07
Rabi									
T_1- Intercropping of cowpea *fb* pea *fb*	8.2	16.4	17.3	4.4	6.8	14.8	4.8	6.8	7.5
cowpea	(0.91)	(1.21)	(1.23)	(0.64)	(0.83)	(1.17)	(0.68)	(0.83)	(0.87)
T_2- Intercropping of moong bean *fb* pea *fb*	9.4	17.3	18.2	6.2	7.6	12.3	4.5	7.2	8.4
moong bean	(0.97)	(1.23)	(1.26)	(0.79)	(0.88)	(1.08)	(0.65)	(0.83)	(0.92)
T_3- T_1 + pendimethalin 1.0 kg/ha/	5.2	8.6	9.7	4.0	6.4	8.4	6.2	7.3	8.2
fluchloralin 1.0 kg/ha in each season	(0.71)	(0.94)	(0.98)	(0.60)	(0.80)	(0.92)	(0.79)	(0.86)	(0.91)
T4- T_2 + pendimethalin 1.0 kg/ha/	6.4	7.4	10.1	4.1	6.3	9.2	6.4	7.5	8.3
fluchloralin 1.0 kg/ha in each season	(0.80)	(0.86)	(1.00)	(0.61)	(0.79)	(0.96)	(0.80)	(0.87)	(0.91)
T_5- Metribuzin 0.5 kg/ha in each season	3.2	4.8	6.4	5.2	5.6	6.2	3.8	4.8	6.2
	(0.50)	(0.68)	(0.80)	(0.72)	(0.74)	(0.79)	(0.57)	(0.68)	(0.79)
T_6- Glyphosate 2.0 kg/ha once in a season	2.8	3.4	4.8	5.3	5.7	6.8	3.2	4.9	6.3
	(0.40)	(0.53)	(0.68)	(0.72)	(0.75)	(0.83)	(0.50)	(0.69)	(0.79)
T_7- Two mechanical weeding per season	6.8	7.4	8.4	4.8	6.8	7.8	4.6	5.3	5.9
	(0.83)	(0.86)	(0.92)	(0.68)	(0.83)	(0.89)	(0.69)	90.72)	(0.77)
T_8- Weedy check	7.2	8.3	9.1	4.9	6.4	11.4	4.4	5.1	5.7
	(0.85)	(0.91)	(0.95)	(0.69)	(0.80)	(1.05)	(0.64)	(0.70)	(0.75)
LSD (P=0.05)	0.08	0.08	0.09	0.07	0.08	0.09	0.06	0.07	0.08

Data in parentheses indicate the log_{10} transformed values, cfu-colony forming units, DAS-Days after spraying



(T_1-T_8: Treatments enforced as detailed in table 1)

Fig. 1. Intercropping and herbicidal treatments on soil respiration in A) mango and B) citrus orchard

as in the tropics. A positive priming effect (stimulation of SOM mineralization) should lead to the recycling of organic N and P and may ultimately enhance plant growth.

Based on our results, it is apparent that legume intercropping in mango and citrus orchard supported high microbial activity and further accelerated by organic matter incorporation. Results also indicated that the herbicidal treatments at the level tested were not drastic enough to be considered deleterious to soil microbial and soil respiration which are important to soil fertility. In addition to the more direct short-term supply of nutrients from decomposing leaf litter, nutrients can also be supplied indirectly from the mineralization of soil organic matter formed from the cumulative input of organic residues. Microbes play a key role in the process of organic matter decomposition and release of nutrients. Improvement in soil organic matter and microbial activity due to the addition of organic residues in tree-crop combination can lead to long-term sustainability of the tree-crop agroecosystem.

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Lethal soil temperature under plastic mulch on growth and suppression of nutgrass

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ABSTRACT

Lethal soil temperature impedes tuber formation, enhances respiration and depletes the tuber's reserves and reduced size and viability. Attempts were made to increase soil temperature to lethal level by clear plastic mulch (PM), with hot water irrigation (HW), and its effect was assessed on growth of *C. rotundus*. During June 2010, quantity and frequency of hot water irrigation required to maximize the soil temperature was standardized using rain out shelter, load cell–digital weighing device by gravimetric method (40 liter/m^2 and once in 4 days). During September 2011, effect of randomly stitched varied thickness 50, 75, 125 and 175 micron plastic mulch of size 1.25 x 1.25 m^2 was spread over *C. rotundus* infected micro-plot and HW irrigated on soil temperature was assessed. Increased soil temperature under different thickness PM was at par with 175 micron. Further, the mean soil temperature and day/night fluctuation in plastic mulch with hot water (PM + HW) plot was congenial for *C. rotundus* growth, enhanced spouting and development of new tubers during September. During April 2012, hot water irrigated during 2.00-3.00 PM, soil temperature reached lethal level. Further, woolen blanket cover (WBC) between 4.0 PM to next day 9.0AM, retained warm temperature during night and maintained higher initial soil temperature next day. Thus during April, led soil temperature (58° C) to lethal level during 30 days of integrating PM + HW + WBC and caused drastically reduction of biomass (87%), number of tubers (62%) per 0.025m^2 with loss of tuber viability.

Key words: *Cyperus rotundus*, Hot water, Lethal soil temperature, Nutgrass, Plastic mulch

Solar radiation penetrates transparent plastic mulch; water vapors present lower side reflects the long wave radiation emitted by soil thus soil become warmer and creates green house effect (Shekh and Patel 2006). Plastic mulch over plant canopy between 4.0 PM to next day 10.00AM increased relative humidity (RH), and air temperature above ambient by 10.7% and 1^0C during February 2011 and 2.1% and 2.5° C during May 2010 apart from elevated CO_2 led to enhanced growth of weed and altered herbicide efficacy along (Mahesha 2011). Plastic mulch enclosure increased CO_2 during night, which was utilized during early morning hours (6-10 AM) led to increased photosynthates. Thus assimilated 15, 97 and 84% more carbon at CO_2 700 ppm than ambient CO_2 by exposing to 30/20, 30/25 and $35/25^0$C day/night air temperature in pine apple respectively, (Zhu *et al*. 1999) and in cucumber (Taub *et al*. 2000). Thus growth and development of weed depends on soil temperature, air temperature and CO_2 level.

Soil temperature determines size, shape, quality of root and hastens uptake and translocation of water, nutrient (Dong *et al.* 2001). Lethal soil temperature harmful to root activity, causes lesion of stem, stops tuber formation of potato (above 29° C) and rate of decomposition increased. Lethal air temperature injuries like 1) thermal death point (50° C), 2) reduced uptake and assimilate (Ca uptake at 28° C in maize), 3) nitrate reductase activity decreased, 4) reduce shoot and root growth, 5) pollen abortion and 6) dehydration and scorching of leaves and stem were noticed.

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Water saturated soil helps to conduct heat to deeper layer of soil. Well prepared seed bed (free from sharp debris), irrigated before plastic mulching killed- i) root knot nematodes, ii) noxious weeds seed, ii) root rot pathogens and improves nutrients thus led to healthier plants by solarization. Mean and day/night soil temperature fluctuation optimized the growth. For instances, four degree celsius day/night temperature fluctuation had 96% sprouting of tuber. Higher diurnal fluctuation of 0, 4, 8 and 12^0C with same mean 32° C, *viz*. 32/32, 30/34, 28/36 and 26/38 caused 72, 75, 87 and 97% sprouting of purple nut sedge tubers (Travior *et al*. 2008). Tuber viability had 50% thermal time (TT_{50}) of 71, 23, 1.8 and 0.5 hrs for 45, 50, 55 and 60° C respectively. Thus twenty three hours of exposure at 50^0C had same effect as that of 30 min at 60° C on loss of tubers viability

(Webster 2003). Emerging shoot of purple nut sedge has sharp tip and tear the plastic mulch. Hence attempts were made to maximize soil temperature to lethal level (60° C) by hot water irrigation (HW), below polythene mulch (PM) and by covering, woolen blanket cover (WBC) between 4 AM - 9 AM, during different seasons to assess their efficacy on soil temperature at different depth and suppression of purple net sedge sprouting.

MATERIAL AND METHODS

Assessment of quantity of hot water per pot

During June 2010, pots filled with red loamy soil were maintained at different soil moisture *viz.* 60, 80 and 100 field capacity (FC). These pots were surface irrigated with hot water (HW) after covering with plastic mulch (PM) of 175 micron thickness to quantify hot water required to raise the soil temperature to lethal level. Soil moisture of 60, 80 and100 FC maintained by irrigating Q60, Q80 and Q100 quantity (ml/ pot) using the following equation 1.

Q100 = W100—Wpds —(1)

Where, W100 (g) indicates weight of pot at 100% FC which includes pot wt. + dry wt. of soil + 100% FC soil moisture (12 h after irrigating the pot till the water flow out of drainage), Wpds denotes pot wt with dry soil (g) and Q100 is the quantity of water (g = ml) per pot at 100 FC. Q100 value for each pot was obtained and multiplied with 0.6 or 0.8 to get Q60 and Q80 quantity of hot water required to reach 60 and 80 % FC respectively. Care was taken to keep pots under rain out shelter (ROS), irrigated with varied quantity of water to maintain different FC by using standardized gravimetric method with load cell and digital weighing device as described by Udaya Kumar *et al.* (1998).

Soil temperature was recorded using digital thermometer having -50 to 300° C range after hot water irrigation at different depth 5,10 and 15 cm at 10 min interval for 90 min. Soil moisture reached 60% FC every 4th day for sandy loam type and surface irrigated with HW recorded maximized soil temperature. Fourty L/m^2 of hot water (20 + 20 L/m^2 at 30 min interval) once in four days was required to maximize the soil temperature. Mean soil temperature at different depth with PM, PM + HW, HW and control was computed with deviation for different days of irrigation having varied hot water temperature 65-85° C. Pattern of soil temperature rise in different depth, time taken to reach and duration of maximum soil temperature retained was assessed.

Assessment of different depth soil temperature and its effect on *C. rotundus* under field condition

During May 2011, *C. rotundus* infested field was demarked by 2 x 2 m^2 plots with solar water heater of 200 litres capacity irrigating to center of the demarked plot. Spade width of soil was removed from a depth of 15 cm around the plot's periphery and PM was made air tight by tucking the edges of the mulch with removed soil around the periphery. Below PM was irrigated with hot or normal water (160 L/4 m^2) and soil temperature was recorded at 5, 10 and 15 cm depths. Digital thermometer was placed in different concentric circles having varied distances and soil temperature was recorded after normal/hot water irrigation at 10 min interval for 90 min form three concentric circles in each replication. Replications consistsed of different days of irrigation (as quantity of hot water was 160 lit/4 m^2) which led to variation in hot water temperature (65-85°C). Thus mean soil temperature maximized was altered in PM+HW and HW treatments between replications and in different depths. However, pattern and duration of maximized and retention time showed similar pattern of pot culture hence data was not presented.

During September 2011, different thickness of PM (50, 75, 125 and 175 micron) sheets of size 1.25 x 1.25 m^2 was stitched together by placing randomly and it was spread over weed canopy of 2 x 2 m^2 plot. Four thicknesses of PM in plots with or without hot/ normal water surface irrigation in main plots and control in three replications was laid out in split plot design. The soil temperature was recorded at 30, 60 and 90 min. The data revealed that variation in soil temperature was not significant between thicknesses of PM after hot water irrigation (HW). Therefore, during other seasons, only PM of 175 micron was used. HW was surface irrigated at 10-11 AM during May 2011, September 2011 and March 2012 at 1-2 PM of April 2012. Five replications with four treatments (control, HW, PM + HW, PM + HW + WBC) were maintained during other seasons.

Mean soil temperature was computed over different depths, at three different distance of concentric circles, 4 replicates and different interval after irrigation at varied irrigation days. Biomass (fresh weight g/0.025 m^2) using top loading digital display SAMSUI (2 kg) balance and number of tubers of different sizes (#/0.025 m^2) distributed at various depth from 15 cm was recorded by harvesting the plant material after 30 days of treatments. Viability of tubers was assessed using standard tetrazolium chloride test by slicing the tuber and exposing the cut end to the tetrazolium chloride solution in Petri dish with filter paper. Intensity of pink colour was used to count viable tubers.

RESULTS AND DISCUSSION

Plastic mulch with hot water irrigation (PM + HW) had higher soil temperature than control for all the depths (Fig. 1). Shallow depth at 5 cm reached maximum temperature of 57° C by 20 min after hot water irrigation whereas 10 and 15 cm depth reached maximum temperature of 48 and 43° C by 30 and 40 min, respectively. The highest soil temperature was maintained for 90 min for all depths during June 2010. April month solarization with 50 micron PM raised the soil temperature to 51.3 and 48.4 from control 41.8 and 39.5 for 5 and 10 cm depth (Nanjappa *et al.* 1999). Standard error for each mean soil temperature denotes variation in hot water temperature between days of irrigation. Low temperature of 36.4° C during September 2011 and highest of 54.6 (lethal soil temperature) during April 2012 with PM + HW with woolen blanket cover during night time (WBC) was recorded (Table 1). During May 2011, September 2011, March and April 2012 temperature increase was 10.8, 4.8, 11.4 and 9.1° C in HW plot than control. Whereas, with PM+HW soil temperature was of 5° C higher than HW irrigation at all seasons. Further, with PM + HW + WBC 2° C more lethal soil temperature was reached during April 2012. Thus importance of hot water irrigation to raise the soil temperature to lethal level was emphasized. According to Department of Agrometeorology, Bengaluru has maximum soil and air temperatures during April; Puna and Kolkata during May and New Delhi during June months. Thus, April month for Bengaluru well suited to impose PM or PM + HW treatment to increase soil temperature to lethal level.

Table 1. Effect of plastic mulch, hot water irrigation and their combination on different seasons soil temperature fort Bangalore conditions (Mean of 3 or 4 irrigations and different depths)

Treated plot	May 2011	September 2011	March 2012	April 2012**
Hot water (HW)	39.1[b]	31.7[a]	41.2[b]	48.0[b]
Plastic mulch(PM) + HW	44.1[a]	36.4[a]	46.5[a]	52.9[a]
PM + HW + WBC	NA	NA	NA	54.6[a]
Control	29.9[c]	29.9[b]	29.8[c]	38.9[b]
LSD (P = 0.05)	2.21	2.87	4.12	6.14

** indicates soil temperature measured during 2.00PM during April 2012, rest of soil temperature was measured during 10 AM; plot with PM + HW + WBC treatment was introduced later thus data was not available (NA); WBC denotes woolen blanket cover during night time to retain high soil temperature and initial soil temperature next day.

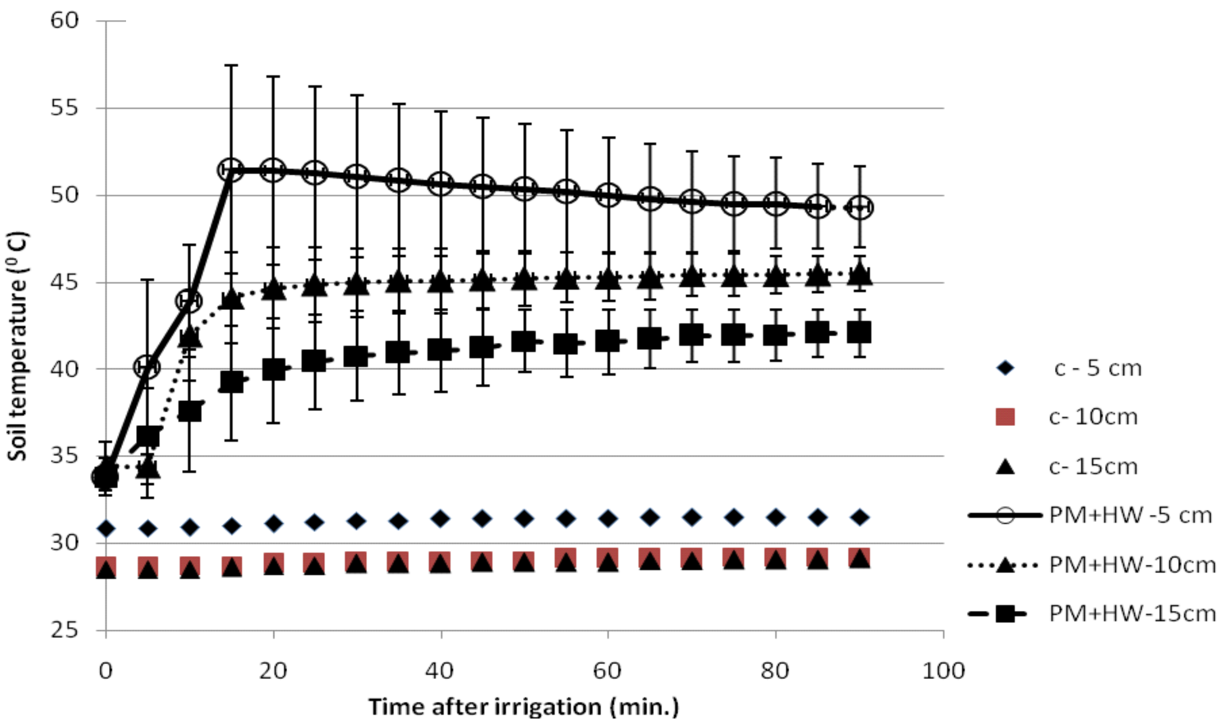

Fig.1. Effect of PM + HW on pattern of soil temperature reaching maximum and retention time of periodic mean and its deviation (due to replications, different irrigation days, different concentric circles) during June 2010 under field condition.

Table 2. Effect of different seasons' soil temperature on biomass (g/ 0.025 m²) and number of tubers/ 0.025 m² of *Cyperus rotundus* after 30 days of plastic mulch

Treatment	No. of tubers/0.025 m²				Biomass (g/0.025 m²)			
	May-11	Sep.-11	March -12	April -12	May-11	Sep.-11	March -12	April -12
Control	144.5ᵃ	31.6 (5.79ᶜ)	69ᵃ	69.5ᵃ	363.1ᵃ	115(10.7ᶜ)	73ᵃ	141ᵃ
HW	81.4ᵇ	57.2(7.69ᵇ)	73ᵃ	41.0ᵇ	196ᵇ	196(14.0ᵇ)	61ᵇ	84.0ᵇ
PM + HW	53.6ᵇ	97.2(9.96ᵃ)	28ᵇ	30.5ᶜ	127ᵇ	331(18.2ᵃ)	25ᶜ	68ᶜ
PM + HW + WBC	NA	NA	NA	26.0ᶜ	NA	NA	NA	18.2ᵈ
LSD (P=0.05)	50.7	(1.57)	15	7.44	94.8	(3.5)	10.1	10.7

Different alphabet denoted and superscripts showed significant from each other # figures parentheses are origin valves and subjected to square root transformation

Further a strong relation between temperature of hot water used for irrigation and maximum soil temperature was noticed. Correlation coefficient values (r= 0.744* and 0.667* for 5 and10 cm depth, respectively) across seasons (Naveen Kumar 2012) and between soil temperature of HW and PM + HW (r= 0.947**, 0.972** and 0.962** at 5, 10 and 15 cm depth, respectively) (Anonymous 2011). Thus prediction of soil temperature for different depth in PM + HW was possible using soil temperature of HW treatment.

Highest biomass (331 g/0.025 m²) was recorded during September 2011 with PM + HW and least biomass (18 g/0.025 m²) during April 2012 with PM + HW + WBC (Table 2). Further, during April 2012 the soil temperature was 9.1°C, 14°C and 15.7°C higher than ambient due to HW, PM + HW and PM + HW + WBC, respectively. This led to decrease in total biomass of 40, 52 and 87 and tubers population by 41, 56 and 62 per cent than control in HW, PM + HW and PM + HW + WBC, respectively. A strong positive relationship between number of tubers and biomass of *C. rotundus* grown at different seasons with varied soil temperature was observed (r = 0.849**). But, soil temperature has showed significant negative relationship with biomass (r = -0.586*) and tuber number (r = -0.583*) suggesting that increase in soil temperature to lethal level reduced biomass and number of tubers. The PM + HW maintained high soil temperature at all depths and consequently showed significantly lower biomass and tuber number than control after 30 days during summer months, but PM + HW during September 2011 had higher sprouting and maximum growth. Minimum, maximum and optimum temperature for *C. rotundus* bud dormancy was 10, 45 and 30-35° C (Holt and Orcutt 1996). During September, the mean soil temperature for PM + HW was raised 32.5 from 24 and 41.5 from 35° C of control for 1st and 2nd irrigation, respectively. Similarly, day/night temperature were 38.6/20, 43/22 for PM + HW than 28/20, 34/22 for control for 1st and 2nd irrigation thus diurnal soil temperature fluctuation (ÄT) was 18.6, 21.3 for PM + HW than 8, 13.4 for control, respectively, thus optimized the (ÄT) soil temperature. Maximum purple nutsedge shoot elongation occurred at 40/30° C for 1/23 h or 30/20° C for 15/9 h it was the bud response to alternating temperature (Sun and Nishimato 1999). Four degree celsius diurnal temperature day/night fluctuation 38/34 had 75% sprouting of tuber. Higher diurnal fluctuation of 12° C with same mean 32° C *viz.* 38/26 caused 97% sprouting of purple nut sedge tubers (Travior *et al.* 2008). GA_1 level was regulated by temperature fluctuation (30 min exposure to 35° C from 20° C) in presence of light which led to bud breaking and shoot elongation in pea (Stavang *et al.* 2007). Thus temperature fluctuation during September with prevailing optimum mean temperature might have helped the sprouting of tuber and elongation of shoot by elevated growth regulator.

The emergence of purple nutsedge occurred from 95% of tubers present in upper 15 cm soil layer. (Travior *et al.* 2008). In PM + HW, tubers experienced lethal soil temperature which led to lower root activity and shoot experienced green house effect, *viz.* high RH, air temperature, elevated CO_2 (Mahesh 2011), ethylene (Naveen Kumar 2012) which led to senescence of shoot. Thus impeded tuber formation and enhanced respiration depleted the tuber's reserves reduced tuber size and viability. Plastic mulch with hot water irrigation effectively reduced tuber population, size and viability of small, medium and large *C. rotundus* till 15 cm depth than control. Development of technology to heat the soil till deeper layer and get other benefits of solarization is the need of the hour.

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Population dynamics and sex ratio of two biocontrol agents of water hyacinth

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ABSTRACT

Population dynamics and sex ratio of two co-existing species of Water hyacinth weevils, *Neochetina bruchi* Hustache, 1826 and *N. eichhorniae* Warner, 1970 (Coleoptera: Curculionidae) were studied. The weevil attack on Water hyacinth was investigated monthly for four years in different water bodies. The weevil's abundance was affected by temperature, humidity and rainfall. The population of the weevils in general was highest (14.97 weevils/plant) in September when the humidity level was very high (88%) with the average of temperature almost 26° C. The lowest abundance (2.49 weevils/plant) was in January when the temperature was the lowest (15.7° C). The abundance of *N. bruchi* was significantly higher than the population of *N. eichhorinae* (1:0.04) in Jabalpur, India. Statistical studies revealed that the sex ratio was in favour of female in both the species (1:0.52 and 1:0.70 for *N. bruchi* and *N. eichhorniae*, respectively).

Key words: *Eichhornia crassipes*, *Neochetina* spp., Population dynamics, Seasonal variation, Sex ratio, Water hyacinth

Water hyacinth, *Eichhornia crassipes* (Mart) Solms. (*Pontederiaceae*), of South American origin is one of the most troublesome aquatic weeds in several tropical and subtropical regions of the world. Its explosive growth rate and ability to infest a wide range of fresh water habitats have created enormous environmental and economic problems. Among the proposed methods, the use of the water hyacinth weevils, *Neochetina bruchi*, Hustache 1826 and *N. eichhorniae*, Warner 1970 (Coleoptera: Curculionidae) as potential biocontrol agent has been widely researched (Firehun *et al.* 2015). For instance, several authors have studied the biology and host range of water hyacinth weevils (Borkakati *et al*. 2007, Hamadina 2015), while several others have focused on the damage potential and impact of the weevils on water hyacinth (Ray *et al*. 2009, Sushilkumar 2011). It was also found that these weevils were very effective in slowing the rate of expansion of water hyacinth mats by reducing new growth along the rapidly growing plant parts while the larval tunneling into the petiole causes severe internal damage causing the leaves to wilt and prone to secondary invasion by other organisms including aphids, mites and pathogens (Wilson *et al*. 2007, Ray and Hill 2012). However, the seasonal variation and population dynamics of these two species of the water hyacinth weevils, occupying same habitat at the same time has not yet been fully explored.

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Hence, population dynamics and sex ratio of two biocontrol agents of water hyacinth narcly *Neochetina bruchi* and *N. eichhorniae* were evaluated.

MATERIALS AND METHODS

Periodical monitoring of various water bodies infested with water hyacinth in Jabalpur (India) was done for 4 years during 2004-2008. Twenty five water hyacinth plants infested with weevils were randomly collected every month from at least 5 different water bodies. The weevils were removed from the plants and identified into species and sexes and averaged. External morphology of the adults was studied in 70% ethanol by a stereomicroscope (Leica WILT-M3Z). The species of water hyacinth weevils were identified as per the description given by Julien *et al.* (1999) *i.e.* on the basis of the elytral marking. The sexes of *N. eichhorniae* and *N. bruchi* were separated by the attachment of antennae to the rostrum (Deloach 1975).

Correlation studies were also undertaken to determine the role of weather variables on population built up of the weevils. The weather data (Table 1) were recorded from meteorological observatory of Jawaharlal Nehru Agricultural University, Jabalpur, India. Water quality parameters (Table 2) were also taken to determine the effect of water quality on population find in both the species (APHA, AWWA and WEF 1998).

The four year data were taken as replication for analysis of variance (ANOVA). Monthly analysis of population density of *Neochetina* spp. was done using one-way ANOVA with means separated using Duncan's multiple range test (DMRT) for multiple comparison of weevil population in various months. The comparison of the month wise mean population, temperature and relative humidity data for 4 years was analysed using multiple correlation analysis, taking population (Y) as the dependent variable while temperature (X_1) and humidity (X_2) as independent variables. The statistical analysis for the population dynamics and sex ratio of the two species was done as per factorial ANOVA with month and sex as two factors, using statistical software package MSTAT-C. The population means for the two species for different months were compared with DMRT also using MSTAT-C.

RESULTS AND DISCUSSION

The water hyacinth weevils occurred throughout the year in all the water hyacinth infested water bodies under observation. Though both the weevil species coexisted successfully in the same habitat throughout the study period, they showed high variation in abundance in various months (F=12.35; df= 11, 36; p<0.01) (Table 1). Weather parameters in correlation with each other also had an impact on the weevil population (Table 1, Fig. 1). Though both temperature and humidity showed effect on population of the weevils, the standard partial regression coefficient showed that humidity is the factor creating more variation in population as compared to temperature. The population of weevils was highest during monsoon with peak during September (14.97 ± 0.7 weevils/plant) (mean ± standard error) due to congenial climatic conditions with temperature ranging from 18.9 to 30.6^o C while average humidity was 68 to 90%. The population of weevils in September was at par with that in October (12.6 ± 0.94 weevils/plant) followed by the population in August (10.61 ± 0.17 weevils/plant) and July (9.03 ± 0.60 weevils/plant). The population of the weevils was recorded low during winter with lowest in January (2.49 ± 0.48 weevils/ plant), followed by December (3.4 ± 0.70 weevils/plant) and February (3.82 ± 0.62 weevils/plant). Low population in winter especially in January can be attributed to low temperature (maximum= 24.2^o C and minimum 8.9^o C) inspite of appreciable rainfall (35.5 mm) and humidity (40.5 to 92%).

Further in March (maximum and minimum temperature 33 and 15.8^o C, relative humidity 26.3 to 72.8% and average rainfall 27.5 mm) there was an increase in weevil population (7.5 weevils/plant) while high temperature and low humidity in summer caused the population to decrease. During May, the temperature went up to more than 40^o C and relative humidity ranging from 16.8 to 42.3% and average rainfall 15.9 mm. The consequences of such climatic condition could be seen in the population of June where there is a decrease in weevil population (6.9 weevils/plant).

The population of *N. bruchi* (Fig. 1a) predominated that of *N. eichhorniae* (Fig. 1b) throughout the study period with a ratio of 1: 0.04 respectively. The population of *N. bruchi* (F= 13.10; df= 11, 36; p=0.000) was highest in monsoon with peak in September (12.15 ± 0.78 weevils/plant) while

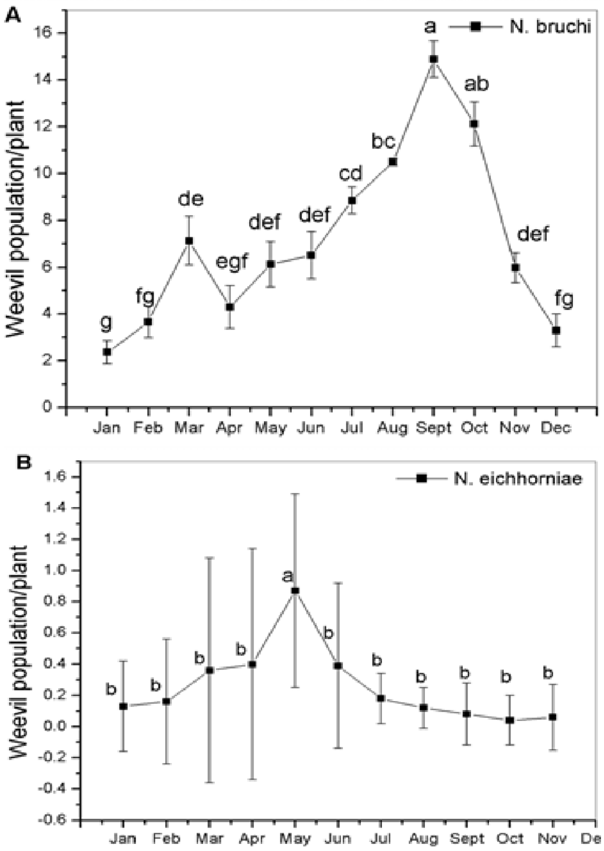

Fig. 1. Mean comparison of population of two species of water hyacinth weevil, (A) *N. bruchi* and (B) *N. eichhorniae* during different months years 2004-2008. DMRT: for each species, mean marked by same letter(s) are not significantly different from each other (P=0.05). Vertical bars indicate standard error of the mean.

the population of *N. eichhorniae* ($F= 2.97$; $df= 11, 36$; $P=0.007$) was slightly higher in summer compared to its own occurrence in other seasons with maximum in May (0.08 ± 0.8 weevils/plant).

In the present study, there was high eutrophication in the water bodies from which the weevils were collected (Table 2). The DO measured during the fourth year of study, was found to range from 3.6 to 10.2 mg/L. The pH ranged from 7.2 to 8 while TDS ranged from 200 to 600 mg/L. Nitrate-nitrogen ranged from 3.2 to 4 mg/L while phosphate-phosphorus was found between 0.3 to 0.6 mg/L.

Alike many insect species, the population of the female weevils was higher than that of male throughout the study period. The sex ratio of *N. bruchi* throughout the study period was highly significant ($p=0.000$) while the difference between sex ratio of *N. eichhorniae* was non-significant ($p=0.0536$). The mean female: male sex ratio of *N. bruchi* per plant was found to be 1:0.52 and that of *N. eichhorniae* was 1: 0.75 (Table 3). The highest number of *N. bruchi* was found in September with 9.41 ± 0.59 female and 5.48 ± 0.59 male weevils/ plant. Similarly highest number of females (0.59 ± 0.56 weevils/plant) and males (0.28 ± 0.30 weevils/ plant) of *N. eichhorniae* was found in May (Table 4). Least number of *N. bruchi* were found in January (1.47 ± 0.30 female and 0.89 ± 0.45 males per plant) while though lowest number of *N. eichhorniae* were found in October, there was no significant difference in the two sexes of *N. eichhorniae* during various months ($p> 0.05$).

The growth and development of the weevils have been found to be dependent on several ecological factors including the combined interaction between humidity and temperature (Khaliq *et al.* 2014). The humidity exerts a relatively greater effect on insects at the extreme temperatures and *vice-versa*. The temperature has significant influence on the biochemical activities like hormone secretion, which subsequently influences the insect growth (Fenemore and Prakash 1992). In this present study, humidity had a greater impact on the population dynamics of the two weevil species, as compared to temperature. High humidity and congenial temperature during the monsoon helped in higher population build up of the weevils.

Deloach and Corodo (1976) also observed that *N. bruchi* survived better at low temperature and laid more eggs as compared to *N. eichhorniae*. Contrary to this, Coulson (1978) reported that *N. bruchi* adults are much more abundant than *N. eichhorniae* throughout the spring and summer and early fall, but *N. eichhorniae* is most abundant in late fall and winter**.** This increase in population can be attributed to the fact that *N. bruchi* develops better under eutropic conditions (Heard and Winterton 2000).

Table 1. Influence of weather parameters on population of *Neochetina* spp.

Month	Weevil population/ per plant	Avg. temp. (° C)		Avg. humidity (%)		Avg. rainfall (mm)
		Max.	Min.	Max.	Min.	
January	2.5^{e}	24.2	8.9	92.0	40.5	35.5
February	3.8^{de}	28.1	11.9	87.0	35.5	11.0
March	7.5^{bcde}	33.0	15.8	72.7	26.2	27.5
April	4.7^{bcde}	38.5	21.3	47.2	15.2	2.0
May	7.0^{bcde}	40.8	25.9	42.2	16.7	15.9
June	6.9^{bcde}	38.4	27.4	56.5	36.0	141.4
July	9.0^{bcd}	30.5	24.6	88.5	73.7	486.9
August	10.6^{abc}	29.0	23.9	91.2	78.5	423.3
September	15.0^{a}	30.6	23.7	90.0	68.5	467.6
October	12.2^{ab}	30.5	18.9	88.5	47.2	28.8
November	6.0^{ade}	29.0	16.5	79.0	33.5	12.6
December	3.4^{e}	25.5	12.8	79.2	35.2	3.5

One-way ANOVA: Mean number of *Neochetina* spp. per plant is replicated over 4 years ($F=12.35$; $df= 11, 36$; $P= 0.00$). Mean population bar marked by same letter(s) are not significantly different at P=0.05 as determined by DMRT.

Correlation matrix of average population (Y), temperature (X_1) and humidity (X_2) - Humidity: Temperature = - 0.415; Y: X_1 = 0.289; Y: X_2 = 0.445. Regression equation: $Y= -12.764 + 0.445 X_1 + 0.445 X_1 + o.149 X_2$; $R^2=0.469$; $R=0.685$.

Table 2. Water quality parameters taken to show the condition of the water hyacinth infested water bodies

Parameter	pH	DO (mg/L)	Water temperature (° C)	TDS (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)
Range	7.2 – 8.0	3.6 – 10.2	20.2 – 27.5	200 - 600	3.2 - 4	0.3 – 0.6

Table 3. Sex ratio of *N. bruchi* in different months

Month	Weevil population/plant		Mean*	Sex ratio (female: male)
	Female	Male		
January	1.47	0.89	1.18^{g}	1:0.61
February	2.32	1.34	1.83^{fg}	1:0.57
March	4.92	2.21	3.57^{de}	1:0.45
April	2.85	1.44	2.15^{efg}	1:0.51
May	4.01	2.12	3.07^{def}	1:0.53
June	4.48	2.04	3.26^{def}	1:0.46
July	5.85	3.00	4.40^{cd}	1:0.52
August	6.99	3.50	5.25^{bc}	1:0.50
September	9.41	5.48	7.44^{a}	1:0.58
October	8.00	4.12	6.06^{ab}	1:0.52
November	3.75	2.23	2.99^{def}	1:0.59
December	2.25	1.04	1.65^{fg}	1:0.46
Mean	4.69	2.45	-	1:0.52

2- way ANOVA:
Month- $LSD_{(p=0.05)}$ =1.55; SEm± = 0.41
Sex- $LSD_{(p=0.05)}$ =0.47; SEm± = 0.17
Month x Sex- $LSD_{(p=0.05)}$ = (NS); SEm± = 0.59
*Mean value superscripted by common letter(s) indicate no significant difference (p=0.05) between weevil population in different months as determined by DMRT.

Table 4. Sex ratio of *N. eichhorniae* in different months

Month	Weevil population/plant		Mean*	Sex ratio (Female: Male)
	Female	Male		
January	0.07	0.06	0.07^{b}	1:0.86
February	0.08	0.08	0.08^{b}	1:1
March	0.18	0.18	0.18^{ab}	1:1
April	0.27	0.13	0.20^{ab}	1:0.48
May	0.59	0.28	0.44^{ab}	1:0.47
June	0.27	0.12	0.19^{ab}	1:0.63
July	0.11	0.08	0.09^{a}	1:0.09
August	0.06	0.06	0.06^{b}	1:1
September	0.05	0.03	0.04^{b}	1:0.60
October	0.02	0.02	0.02^{b}	1:1
November	0.04	0.02	0.03^{b}	1:0.50
December	0.05	0.06	0.06^{b}	0.83:1
Mean	0.15	0.09	-	1:0.75

2- way ANOVA:
Month- $LSD_{(p=0.05)}$ = (NS); SEm± = 0.13
Sex- $LSD_{(p=0.05)}$ = (NS); SEm± = 0.05
Month x Sex- $LSD_{(p=0.05)}$ = (NS); SEm± = 0.19
*Mean value superscripted by common letter(s) indicate no significant difference (p=0.05) between weevil population in different months as determined by DMRT.

High nutrient in the water bodies resulted in better plant quality which aided the high population of *N. bruchi* as compared to *N. eichhorniae*. Studies by Julien *et al.* (1999) have shown that sites of poor plant quality, reflected by lower average tissue nitrogen concentration tend to have more *N. eichhorniae* while those of higher plant quality contain a higher proportion of *N. bruchi.*

Moorehouse *et al.* (2001) reported that weevils collected in September from Uganda had ratio of 0.92 female: 1.0 male in *N. bruchi* and 1.0 female: 0.84 male in *N. eichhorniae* population. Center and Durden (1986) reported that water bodies with poor quality water hyacinth had twice as many male as female (2.12:1) while water bodies with plants in good condition favoured female ratio (0.75:1). This could be attributed to the fact that females required more nutritious supplements to lay eggs.

The high female ratio of *N. bruchi* seems to be in favour of quick population build up of this biological control agent. Therefore, early control of water hyacinth by this species can be expected over *N. eichhorniae* in Indian climatic conditions. The present studies have focused mainly on influence of climatic conditions on population structure of the two species water hyacinth weevils. The further prospect lies in understanding the influence of water and plant quality on the population dynamics of the two species of weevils.

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Leaching behaviour of four herbicides in two soils of Kerala

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ABSTRACT

The present study was conducted to find out the extent of leaching of butachlor, pretilachlor, 2,4-D and oxyfluorfen in two soil types, *viz*. Type I [coarse textured low organic matter soil (Mannuthy–Ultisol] and Type II [fine textured high organic matter soil (Alappad-Inceptisol]. Intact soil columns were collected from the paddy fields after the harvest of second crop. Butachlor, pretilachlor, 2,4-D and oxyfluorfen were applied in moist soil columns at the recommended rate of application. Soil samples from different depths up to 10 cm (top 5 segments of 2 cm each) and the leachate at 30 and 60 cm depths were analyzed for herbicide residues using gas chromatography. Among the four herbicides tested, 2,4-D registered highest level of residue in the leachate (0.20 ppm at 60 cm depth). Pretilachlor and butachlor followed the same trend in the pattern of movement of residue through the soil columns. However, the leachate of pretilachlor registered much lower quantity of residue (0.006 ppm). Fine textured organic matter rich soil recorded lower residue levels compared to the soil with coarse texture and poor organic matter. It could be attributed to the high adsorptive power of the soil, especially at the top layers with high organic matter content. Oxyfluorfen residues could not be detected in the leachate, because of its poor water solubility.

Key words: 2,4-D, Butachlor, Leaching, Oxyfluorfen, Pretilachlor

Among the different pre-emergence herbicides in rice, butachlor, pretilachlor and oxyfluorfen are more popular in the paddy fields of Kerala. Sodium salt of 2, 4-D is the most common post-emergence herbicide in the major rice bowls of the state, *viz.* Kole and Kuttanad. Herbicide movement in soils is of major concern in tropical soils with heavy rainfall. Since these herbicides are applied to the soil surface without incorporation, heavy rainfall soon after application may cause excessive leaching of the herbicide from the surface zone, resulting in poor weed control. In the case of herbicides with high soil mobility, leaching may lead to injury of deeper-rooted desirable species. In addition, herbicide leaching may result in contamination of ground and surface water (Anderson 1983). Movement of herbicide within the soil profile is influenced by many factors such as chemical nature of herbicide, the adsorptive capacity of soil and the amount of water available for downward movement through the soil. Butachlor, pretilahlor, oxyfluorfen and 2,4-D differ much in their water solubility (RSC 1987). Considering these factors, studies on leaching pattern of three pre-emergence herbicides and one post-emergence herbicide were conducted in two soil types of Kerala, under All India Coordinated Research Programme on Weed Control during the period from 2007-08 to 2010-11.

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MATERIALS AND METHODS

Intact soil columns were collected from two soil types, *viz*. Type I (sandy loam low organic matter soil of Ultisol order at Rice field of Agricultural Research station, Mannuthy) and Type II (high organic matter clayey soil of Inceptisol order, Kole Lands, Alappad) after the harvest of second crop. Long PVC tubes (60 cm) of 16 cm diameter were taken for Type I soil. Tubes of only 30 cm and 16 cm diameter were taken for Type II soil because the area is below mean sea level and hence collection of intact soil columns below 30 cm was not possible. The tubes were cut vertically and the two halves were pressed onto the lateral sides of the soil pit of 60 cm deep, dug in the rice field. The soil corresponding to the different depths were transferred as such to the two halves of the PVC column and they were joined together using adhesive tape. The tube was kept on an iron stand after tying the lower end with a muslin cloth. After adding water continuously to attain constant percolation rate, the herbicides were added at the recommended rate of application, *viz.*1.25 , 0.75, 1.0 and 0.2 kg/ha for butachlor (Machete®), pretilachlor (Rifit®), 2,4-D (Fernoxone®) and oxyfluorfen (Goal®), respectively using a spray volume of 500 L/ha. The quantity of solution required for spraying was calculated based on the surface area.

Water was added frequently to the top of the column at one day after spraying. A total of 1000 mL water was added through the column (200 mL x 5 times) so as to simulate the normal rainfall receiving in the area. Methods were standardized for estimation residues in soil and water samples using the gas chromatograph. Soil samples from different layers (top 5 segments of 2 cm each) leachate were analysed for herbicide residues. Average values of residues from three replications were worked out for comparison of data.

Extraction and estimation of 2,4-D residues

Water samples were filtered out of any particulate matter. A 50 mL portion of the sample was taken and saturated with sodium chloride. The pH was adjusted to <2 with HCl. It was then extracted with (5 x 25 mL) portions of acetonitrile. The pooled extract was then concentrated to 15 mL. Fifteen mL 10% NaOH was added and the pH was adjusted to > 13. The organic phase was evaporated off in presence of the alkali. The aqueous alkaline solution was refluxed for 20 min. It was then cooled and extracted with equal volume of hexane (x3). The hexane fraction was discarded and the aqueous portion was acidified with HCl to pH<2. It was then extracted with equal volumes of diethyl ether (x3)

Twenty five gram of wet soil sample after draining excess water by spreading over a filter paper was shaken on a shaker with 80 m. extracting mixture (acetonitrile: water: glacial acetic acid in the ratio 80:20:25) for a period of 30 minutes at 220 rpm and filtered through Whatman No.1 filter paper. The filtrate was acidified with concentrated HCl (15 mL) and separated by extracting thrice each with 50 mL diethyl ether.

From the combined diethyl ether extract, the organic phase was evaporated off and the residue was dissolved in 3 mL of methanol. Added a 3ml portion of boron tri fluoride methanol reagent and refluxed for 10 minutes on a water bath. After reaction, excess alcohol was evaporated off and 20mL water was added, shaken vigorously for 5 min. and extracted with hexane (3x10mL). The hexane portions were combined, the organic phase evaporated off and the residue was concentrated

A 5 cm bed of activated silica gel Pyrex glass column packed at the two ends each with 1g of anhydrous sodium sulfate was used. The column was washed with 25 mL hexane. The extract obtained after derivatisation as given in step II was placed on the column. The residue in the column was washed with 100 mL solvent system containing (70% hexane/ 30% dichloromethane). It was then eluted with 100 mL of (70% dichloromethane/30% hexane) solvent mixture. First 20 mL was discarded and next 80 mL was collected. The solvent was then evaporated off and the residue was dissolved in 1 mL n-hexane.

One micro litre of n- hexane extract was injected in to the GC 2010 fitted with a ^{63}Ni electron capture detector, a DB-17 capillary column and a split injector. The temperature of the injector, column and detector were 180, 210 and 300^0 C, respectively with a split ratio of 3:1. The residue content was calculated from the standard curve obtained with the reference standard.

Air dried soil sample (15 g, 2 mm sieved) was thoroughly mixed with 10g of anhydrous sodium sulphate, 2 g of florisil (60-100 mesh size) and 0.3g of activated charcoal. A glass column of 30 cm length and 2 cm internal diameter was taken. Anhydrous sodium sulphate of 3 cm layer was put on the non adsorbent cotton kept at the lower end of the column. Then the soil sample mixture (prepared as above) was added to the column and another layer of anhydrous sodium sulphate of 1 cm was put over this layer. The herbicide was extracted with 100 mL of hexanes: acetone mixture (9:1) and excess solvent was evaporated under vacuum to one mL. The evaporated sample was made up to 5 mL with n-hexane. One micro litre portion of the n- hexane extract was injected in to the GC 2010 fitted with a ^{63} Ni electron capture detector, a BPX-5 capillary column and a split injector. The temperature conditions for butachlor and petilachlor were the same (250, 220 and 300^{0}C for injector, column and the detector were respectively). For oxyfluorfen, optimum temperature conditions were 220, 210 and 240^{0}C for injector, column and the detector respectively). The residue content was calculated from the standard curve obtained with the reference material (97% pure reference standards obtained from Dr. Ehrenstorfer, GmbH, Germany)

Gas chromatographic technique (KAU 2008) was used for estimation of butachlor, pretilachlor and oxyfluorfen residues in the leachate.

RESULTS AND DISCUSSION

Physicochemical characteristics of the soil

The major physico-chemical characteristics of soil, *viz.* soil texture, pH, cation exchange capacity (CEC), anion exchange capacity (AEC) and organic carbon content of the soil sample taken from the rice field before conducting experiment are presented in (Table 1).

Table 1. Major physico chemical characteristics of the soil columns collected for the study

Characteristics	Soil type (average values)	
	Type I (Mannuthy) coarse textured low organic matter soil sandy loam-ultisol	Type II (Alappad) fine textured high organic matter soil-clay- inceptisol
Clay %	26.0	64.0
Organic carbon, %	0.90	1.87
pH	5.09	5.1
C.E.C, C mol(+)/kg	9.25	15.7
A.E.C, C mol(-)/kg	12.4	9.38
Sesquioxide, %	4.6	3.0

The soils showed wide differences in their textural characteristics. The mean clay content varied from 25.98% (Type I) to 64.00% (Type II). The organic carbon content of Type I soil (Mannuthy) was 0.90% and that of Type II (Alappad) was 1.87%. The soils were uniformly acidic in nature (5.1). Cation and anion exchange capacities showed variations between the soil types (9.25 to 15.75. mol (+)/kg and 9.38 to 12.4 C mol (-)/kg respectively). Sesquioxide content varied from 3.0 to 4.60 per cent between the soil types.

Herbicide residues at different soil depths

All the herbicides registered maximum quantity of residue in the upper 2 cm of the soil column.

Maximum value was registered by butachlor treatment (2.43 µg/g) in Type II soil and oxyfluorfen registered lowest value in both the soil types (0.55 and 0.61µg/g for Type I and Type II, respectively). This could be attributed to the differences in the levels of application of herbicides to the columns. The recommended level of application of butachlor was1.25 kg/ha and that of oxyfluorfen was 0.20 kg/ha (KAU 2011). Higher proportion of applied pretilachlor compared to butachlor observed in the upper layer of soil column could be attributed to higher Kd (distribution coefficient) values for pretilachlor as reported by Hasna (2011).

There was considerable decrease in the residue with increasing depth of the soil. Fine textured organic matter rich soil recorded lower residue levels

Table 2. Leaching pattern of butachlor, pretilachlor oxyfluorfen and 2,4-D, in different soil types

Herbicide and level of application (kg/ha)	Depth of soil (cm)	Concentration of herbicide (µg/g or µg/ mL)	
		Coarse textured low organic matter soil	Fine textured high organic matter soil
Butachlor (1.25)	0-2	1.47 (35.28)	2.43 (58.32)
	2-4	0.25 (6.0)	0.77 (18.48)
	4-6	0.15 (3.6)	0.14 (3.36)
	6-8	0.05 (1.2)	0.02 (0.48)
	8-10	0.05 (1.2)	0.02 (0.48)
	Leachate	0.16 (3.84) (>60 cm depth)	0.04 (0.96) (>30 cm depth)
Pretilachlor (0.75)	0-2	1.56 (62.4)	1.85 (74.0)
	2-4	0.19 (7.6)	0.21 (8.4)
	4-6	0.09 (3.6)	0.09 (3.6)
	6-8	0.06 (2.4)	0.03 (1.2)
	8-10	0.03 (1.2)	0.01 (0.4)
	Leachate	0.006 (0.24) (>60 cm depth)	0.004 (0.16) (>30 cm depth)
Oxyfluorfen (0.20)	0-2	0.55 (82.5)	0.61 (91.5)
	2-4	0.005 (0.75)	0.004 (0.6)
	4-6	0.005(0.75)	0.002 (0.3)
	6-8	0.003 (0.45)	BDL
	8-10	0.003(0.45)	BDL
	Leachate	BDL(>60 cm depth)	BDL(>30 cm depth)
2,4-D (1.0)	0-2	1.44 (43.2)	1.83(54.9)
	2-4	0.17(5.1)	0.19 (5.7)
	4-6	0.10 (3.0)	0.16(4.8)
	6-8	0.08 (2.4)	0.10 (3.0)
	8-10	0.05(1.5)	0.09(2.7)
	Leachate	0.20 (6.0) (>60 cm depth)	0.05 (1.5) (>30 cm depth)

Percentage of the applied herbicide remaining at different depths is given in parentheses; BDL: Below detectable level compared to the soil with coarse texture and poor organic matter. It could be attributed to the high adsorptive power of the soil, especially at the top layers with high organic matter content.

Based on the quantity sprayed over the soil column, percentage of applied herbicide remaining in each layer of soil was calculated (Table 2). It could be noticed that oxyfluorfen is more strongly adsorbed in the first soil layer of 0-2 cm (82.5% and 91.5% of the applied herbicide in Type I and Type II soil, respectively) followed by pretilachlor (62.4 and 74.0%, respectively), 2,4-D (43.2% in Type I soil) and butachlor (35.28% in Type I soil). In Type II soil, butachlor (58.32%) adsorption was higher than that of 2,4-D (54.9%). As reported by Hasna (2011), higher quantity of organic matter resulted in considerable increase in the adsorption of butachlor in the lateritic soil of Kerala.

Herbicide residues in the leachate

Among the four herbicides tested, 2,4-D residue was the maximum in the leachate (Table 2) followed by butachlor, pretilachlor and oxyfluorfen. The leachate collected at 30 cm depth in Type II soil registered 2,4-D residues to an extent of 0.05 µg/mL (1.50% of the applied herbicide). In the case of Type I soil 2,4 D residues registered in the leachate at 60 cm depth was 0.2 µg/mL (6.0%). Oxyfluorfen residues in the leachate collected from both the soil types were below the detectable level. The results indicated that the mobility of oxyfluorfen was very low in both the soil types and may not contaminate groundwater under recommended rate of application of the herbicide. Similar findings were reported by Yen *et al.* (2003) after evaluating the possible contamination of oxyfluorfen using the behavior assessment model and the groundwater pollution-potential (GWP) model. The present study also revealed that the solubility of herbicide in water is the major factor determining the movement of herbicides in the soils of Kerala. The extent of leaching followed the order: 2,4-D (620 mg/L) >butachlor (50 mg/L) > pretilachlor(20 mg/L) > oxyfluorfen (0.114mg/L).

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Knowledge based system for weed seed identification

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ABSTRACT

The term 'weed' always has a negative connotation not only by its presence as a plant but as a seed also. The movement of most of the weeds from one location to the other is mainly through their seeds. Correct identification of weed seeds is therefore necessary for strict quarantine to check the spread of weed seeds from one place to another. Accurate identification of weed seeds requires skill and good judgment on the part of the examiner and it is a difficult task for a layman. Therefore, availability of a state of art technology for identification of weed seeds is very much needed. For identification of weed seeds, a Knowledge Based System (KBS) contains information about 120 weed seeds with 11 parameters each has been developed at the Directorate of Weed Research, Jabalpur (India) using Visual Basic. Net as front-end application and MS Access as back-end application with user-friendly menus**.** In this study, a rule based system for identification of weed seeds was developed that helps the stakeholder in identifying the weed seeds.

Key words: Identification, Knowledge Base, Software, System, Weed seed

All definitions of "Weed" usually reflect the damage or loss caused by weed as a plant. But actual weed problems start with weed seeds. Weed seeds serve as a primary source of new populations on the site of their production or elsewhere. The weed seed contaminants in the crop produce cause quality deterioration and weed seeds in grain crops perpetuate when the seed is used to raise the crop. On occasions, the agricultural producers or other professionals will be challenged to identify a weed by the features of its seed. Accurate identification of weed seeds is necessary for the correct labeling of seeds moving in commercial channels which require skill and knowledge.

The task of identifying weed seeds is difficult due to smaller size of many seeds, the differences in maturity, the loss of certain parts and the changes in surface appearance caused by processing or handling and difference in size and colour which occur under different soil and climate conditions. Some of the difficulties in identifying the weed seeds is lack of familiarity with the terms, failure to observe closely important features of the seed, lack of general knowledge in that area, and the fact that description of one observer does not always convey the intended information to another observer. The Knowledge Based System (KBS) for weed seed identification were developed to assist persons involved in identification of weeds by their seed.

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KBS can be defined as a tool for information generation from knowledge. Information is either found in various forms or generated from data and/or knowledge. Text, images, video, audio are forms of media on which information can be found, and the role of information technology is to invent, and devise tools to store and retrieve this information.

Agricultural KBS is a Decision Support System that helps the Agricultural Extension agents, who have to identify the problem and advice the farmers to take action, based on the observations from the fields or from the expert systems (Prasad and Vinaya Babu 2006). It is one of the most efficient extension tools to take the technology from scientists to the farmers directly without any dilution of content which normally creeps in because of the number of agencies involved in normal technology transfer systems.

Most of the institutes under Indian Council of Agricultural Research (ICAR) developed the KBSs for various aspects including crop production, disease management, farming system research, poultry management, animal husbandry, *etc.*

KBS for field crops are implemented for: identification of weed seedlings (Naidu *et al.* 2013), rainfed natu tobacco germplasm (Ravisankar *et al.* 2009), identification of weeds in cereals (Gonazalez *et al.* 1990), wheat crop management (Kamel *et al.* 1994), diagnosis of soybean diseases (Michalski *et al.*

1983), crop management for cotton (Lemon 1986) and (Plant 1989) and weed identification for wheat (Schulthess *et al.* 1996). KBSs were also implemented for horticulture crops: apple orchid management (Roach *et al.* 1985, Gerevini *et al.* 1992) and cucumber production management (Rafea *et al.* 1995). In the present study, a rule based system (Ajith Abraham 2005) for identification of weed seeds was developed which enables the extension personnel, researchers and farmers in identification of weed seeds and there by managing weeds in crops and maintenance of quality of crop produce.

MATERIALS AND METHODS

KBS on weeds seeds was developed with the combined effort of domain experts and software professionals. Based on the information collected on different weed seeds, a data sheet has been prepared with 11 characters and 'Scientific name' is considered as a primary key for managing the records. Using this datasheet, a knowledge base was developed which contains information about 120 weed seeds with 11 parameters each. This system was developed using Visual Basic .Net (Balena 2005) as front-end applications and MS Access (Teresa *et al.* 2010) as back-end applications with user-friendly menus.

System design (Kiong 2005) composed of several basic components: a user interface, database, knowledge base and an inference mechanism (Figure 1). System development usually proceeds through several phases including problem selection, knowledge acquisition, knowledge representation, programming, testing and evaluation. In the knowledge base, information on weed seed can be stored as rules of inference that are used during the reasoning process for knowledge extraction of weed seed characteristics. These rules may be if…then…else nature or any other valid form. The inference mechanism guides the Fig. 1.

KBS Design Architecture reasoning process through knowledge base by attempting to match the facts in the database to other rule conditions. Inferences are identified to meet the user requests to find availability of the data in weed seed knowledge base. The transactional data from operational sources are fed into the database which in turn converts into facts and rules.

To use the system easily, the user friendly interface was developed with Graphical User Interface (GUI). The three major activities considered in designing the system are 'Weed-seed information, Search–Query, Weed thumbnail'. These three options allow the user to identify the weed seed characteristics by selecting family name (or) scientific name (or) seed photo. These fields were created with text boxes for data entry / modification and label boxes for title of the text. Image(s) of seed and plant photograph are embedded in the knowledge base itself. Based on the knowledge base, application software has been developed which consists of 4 modules. The multiple document interface (MDI) form of the software (Figure 2) consists of 4 options, *viz.* 'Masters, 'Details', 'Reports', and 'Help'. At present, data related to 120 weed seed were fed into the software system, for storage and accessing. Open Data Base Connectivity (ODBC) has been provided to access the data from the database with the developed application.

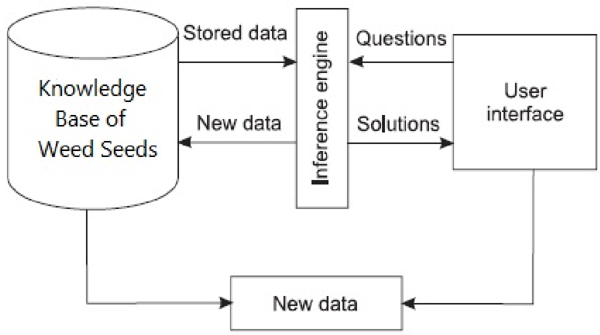

Fig. 1. KBS Design Architecture

RESULTS AND DISCUSSION

The main menu of this software consisted of 4 modules, *viz*. Weed-seed information, Search – Query, Weed thumbnail, About e-module and Exit (Fig. 2). The scientific names of plants were considered as primary key for identifying the characteristics of weed seeds.

Weed-seed information: It was a simple search mechanism which allows the user to search for a particular weed seed by its scientific name. For easy searching, all the scientific names are arranged alphabetically and placed into different subgroups, *viz.* A-D, E-H, I-L, M-P, Q-T, U-X, Y-Z. For example if the user is searching for the weed seed characteristics of a plant with scientific name as "*Cleome viscose* L." then user has to select the subgroup A-D, then a list of scientific names gets displayed. By selecting '*Cleome viscose* L.' from the list, the information, *viz.* Bayer code, family name, common name, seed photograph and plant photograph along with seed characteristics, *viz.* size, color, shape, surface and remark gets displayed as shown in (Fig. 3). Search-query: Through this

Fig. 2. Main menu

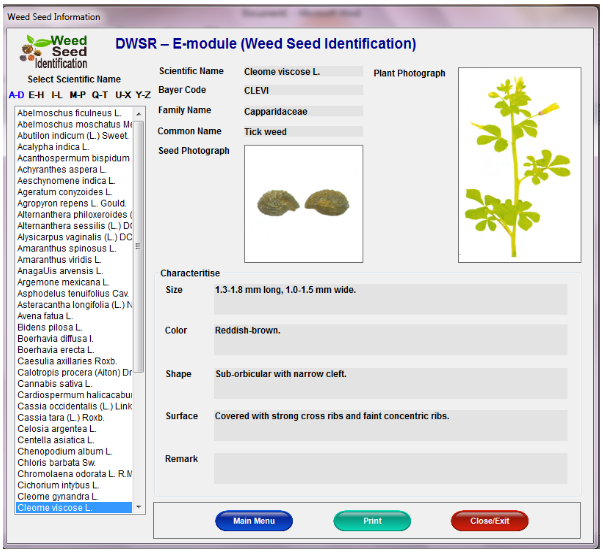

Fig. 3. Weed seed information menu

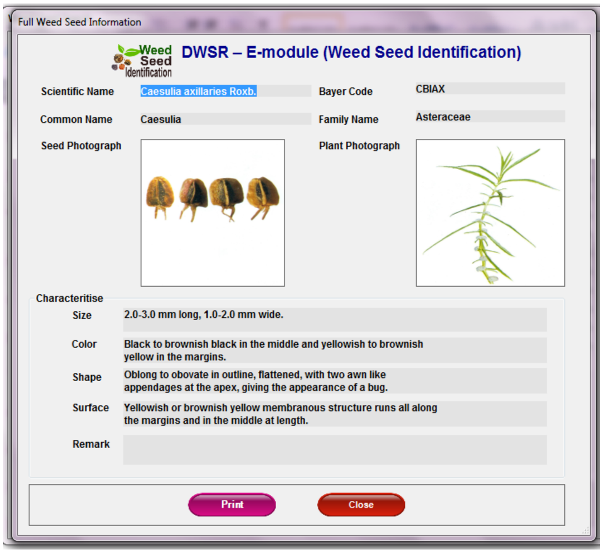

Fig. 4. Search by family name

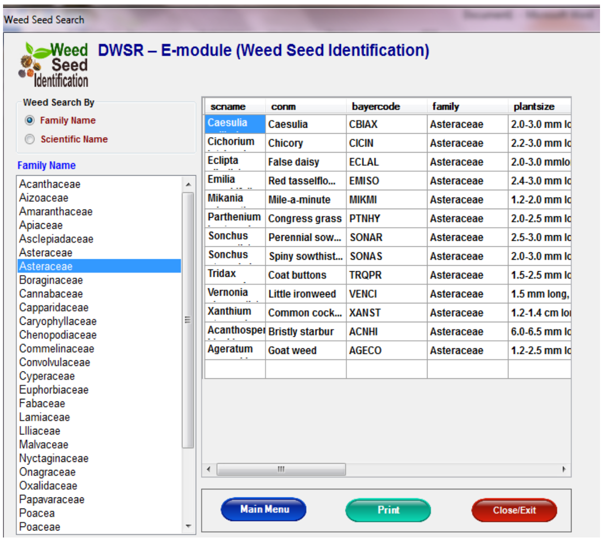

Fig. 5. Weed seed identification - output

option, the user can make a query for a particular weed seed by selecting either ‘family name’ or ‘scientific name’ of the weed. If user selects the ‘family name’ then list of names will be displayed in alphabetical order. In each ‘family name’ list of ‘scientific names’ of weed plants are stored which belong to that family. For example, if the user selects the ‘family name’ as *Asteraceae*, then list of ‘scientific names’ of that family with other parameters, *viz*. Common Name, Bayer Code, Family, Seed size, Shape, Color, Surface, Remark along with Seed image, Plant image’ gets displayed on the leaf pane of the menu as shown (Fig 4). Then the user can select one of the scientific name like *Caesulia axillaries* Roxb whose characteristics gets displayed in a new windows as shown (Fig. 5).

Similarly by selecting the ‘Scientific name’ in ‘Weed search’ option under ‘Search-Query’ menu, list of scientific names of the weed plants gets displayed on the left pane of the menu. By selecting one of the names, its characteristics get displayed in new window.

Weed thumbnail: The third module allows the user to perform the search by viewing the list of seed photos. A list of seed photos with their scientific names gets displayed after selecting this option from the ‘main menu’ (Fig. 6). By choosing one of these ‘photographs’ from the list it will display the characteristics of that weed seed in the new window.

About e-module: This option is self-explanatory that includes the information for step-by-step execution

Fig. 6. Search by seed photograph

of this software. This is portable software, which makes possible to execute this software in any system. For this, a 'SETUP' program is created (executable file) including all the files and data. Any user can install this software by running this 'SETUP' program and the execution of the software is self-explanatory. In all menus, three navigation toolbars were created, *viz.* 'Main menu, Print and Close/Exit' option. The user is allowed to take the hard copy of the selected report in any menu, switch to 'main menu' from the current window and close the current window.

From the researchers point of view, knowledge based systems have a potential to help to organize and synthesize knowledge and information of different types. It is possible to focus and apply diverse avenues of research to solve difficult problems, link together quantitative data, simulation models and basic research results into knowledge base. The idea of a KBS is shifting the focus of the research community to knowledge dissemination in contrast to knowledge accumulation. This system serves as a delivery system for extension information and management of decision makers. It also plays an important role for accessing instant information in an easily understood form with embedded images in the database itself for identification of weed seeds. Further modification to the existing system is a continuous process based on the information and suggestions received from various users / researchers.

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Short communication

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Bio-efficacy of sequential application of herbicides on weed control, growth and yield of wet-seeded rice

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Key words: Sequential application, Weed control, Wet seeded rice, Yield attributes

Due to shortage of labour and increased wages, transplanting is becoming difficult and farmers are resorting to wet-seeded rice in Krishna, Godavari zones of Andhra Pradesh, as it saves labour, time and energy, early crop maturity, ensures efficient water use and increased benefit cost ratio (Ravi Shankar *et al.* 2008). However, in wet-seeded rice, weeds are the major limiting factor in obtaining higher yields and uncontrolled weed growth may cause yield reduction to the extent of 64% (Rao *et al.* 2007). Use of pre-emergence herbicides such as butachlor, pretilachlor has been found effective in early stages but the second flush of weeds at later stages has become problematic. In such situations, sequential application of herbicides is the only alternative, in order to achieve broad spectrum and season long control during the critical period of the crop. The present experiment was under taken to evaluate the performance of various new herbicides alone and in sequential applications.

A field experiment was conducted during *Kharif* 2010-11 at Agricultural College Farm, Bapatla, Andhra Pradesh. The soil of the experimental plot was sandy clay loam in texture with low in available nitrogen, phosphorus and high in available potassium with a soil pH of 8.1. The experiment consisting of ten treatment was laid out in a randomized block design with three replications. The rice variety *'Jagitial Mashuri'* was sown in solid rows in the furrows opened by line marker at 25 cm interval. The pre emergence herbicides were applied uniformly at 3 days after sowing (DAS) by mixing the herbicide with dry sand at 50 kg/ha and broadcasted uniformly under thin film of water. Whereas, post-emergence herbicides were sprayed at 20 DAS with knapsack sprayer using a spray volume of 500 L/ha. All the recommended package of practices except weed control were adopted to raise the crop. The data on weed density and dry weight were subjected to square root transformation before statistical analysis to normalize their distribution.

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The experimental plot was largely infested with *Echinochloa colona, Cynodon dactylon, Paspalum conjugatum, Leptochloa chinensis* (grasses), *Cyperus rotundus, Scirpus articulatus* (sedges), *Eclipta alba, Ludwigia parviflora, Ammania baccifera, Bergia capensis* and *Euphorbia hirta* (broad-leafved weeds). All the weed control treatments significantly reduced the density and dry weight of weeds compared to unweeded check at 60 DAS (Table 1). Among the treatments, the lowest density, weeds dry weight and higher weed control efficiency of 86% was observed in the sequential treatment, with pre-emergence application of oxadiargyl 100 g/ha *fb* post-emergence application of penoxsulam 25 g/ha and was at par with other sequential treatments and hand weeding at 20 and 40 DAS but significantly superior to herbicides applied as one time. The lower weed growth in this treatment was mainly due to effective control of weeds in the early stage by pre-emergence herbicide and at later stages by post-emergence herbicides. Maximum weed growth was observed in unweeded check. In general, sequential treatments were found to be superior to alone application of herbicides.

All the herbicides under study were found to be selective to rice crop without any injury. All the weed management practices exhibited profound influence on growth (plant height, number of tillers and crop dry weight) and yield parameters (number of panicles per square metre, filled grains per panicle, except hundred seed weight), grain and straw yield (Table 1 and 2). Among the herbicide treatments, significantly the highest grain yield (5.19 t/ha) was observed in sequential application of oxadiargyl 100 g/ha *fb* penoxsulam 25 g/ha over single application of herbicides and was at par with sequential treatment and also with hand weeding. The increased yield in these treatments might be due to cumulative effect of lower weed density, dry weight, higher weed control efficiency and increased number of panicle bearing tillers per unit area, filled grains per panicle. The lowest grain yield (1.89 t/ha) was observed in weedy

Table 1. Effect of different treatments on weed and crop growth parameters

Treatment	Dose (g/ha)	Time of application (DAS)	Weed density (no./m^2) at 60 DAS	Weed dry weight (g/m^2) at 60 DAS	WCE at 60 DAS (%)	Plant height at 60 DAS (cm)	No. of tillers/m^2 at 60 DAS	Crop dry weight at 60 DAS (t/ha)
Oxadiargyl	-	3	6.4 (40.5)	10.9 (118.3)	61	65	386	1.43
Pyrazosulfuron-ethyl	20	3	7.1 (49.9)	11.8 (138.7)	55	64	372	1.35
Penoxsulam	25	20	6.8 (45.7)	11.3 (127.2)	58	64	379	1.41
Azimsulfuron	35	20	7.5 (55.8)	12.1 (145.9)	52	63	358	1.28
Oxadiargyl *fb* penoxsulam	100 *fb* 25	3 *fb* 20	4.2 (17.1)	6.6 (43.1)	86	71	479	1.86
Oxadiargyl *fb* azimsulfuron	120 *fb* 35	3 *fb* 20	4.5 (19.8)	6.8 (45.7)	85	69	451	1.80
Pyrazosulfuron-ethyl *fb* penoxsulam	20 *fb* 25	3 *fb* 20	4.8 (22.5)	7.4 (54.3)	82	68	434	1.75
Pyrazosulfuron-ethyl *fb* azimsulfuron	20 *fb* 355	3 *fb* 20	5.0 (24.8)	7.6 (57.3)	81	68	426	1.70
Weedy check	-	-	10.6 (111.9)	17.5 (305.8)	-	56	248	0.96
Hand weeding	-	20 & 40	4.2 (17.1)	6.0 (35.5)	88	74	545	1.89
LSD (P=0.05)			1.1	2.2	16	12	59	0.24

The data shown on weed density and dry matter follows square root ($\sqrt{x+0.5}$) transformation. The figures in parentheses are original values.

Table 2. Effect of different treatments on yield attributes, yield and economics of wet seeded rice

Treatment	Dose (g/ha)	Time of application (DAS)	No. of panicles/ m^2	No. of filled grain/ panicle	100 seed weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Net return (x10^3 `/ha)	Benefit cost ratio (`/ha)
Oxadiargyl	-	3	372	95	14.0	3.86	4.92	45.49	2.9
Pyrazosulfuron-ethyl	20	3	361	94	13.9	3.56	4.60	42.06	2.7
Penoxsulam	25	20	366	92	13.8	3.63	4.69	42.84	2.7
Azimsulfuron	35	20	339	92	13.8	3.39	4.41	40.11	2.5
Oxadiargyl *fb* penoxsulam	100 *fb* 25	3 *fb* 20	441	109	14.5	5.18	5.72	60.21	3.6
Oxadiargyl *fb* azimsulfuron	120 *fb* 35	3 *fb* 20	435	104	14.4	5.04	5.71	58.69	3.4
Pyrazosulfuron-ethyl *fb* penoxsulam	20 *fb* 25	3 *fb* 20	419	103	14.2	4.97	5.67	57.91	3.5
Pyrazosulfuron-ethyl *fb* azimsulfuron	20 *fb* 355	3 *fb* 20	423	102	14.2	4.91	5.50	57.91	3.4
Weedy check	-	-	339	78	13.4	1.89	3.92	23.73	1.6
Hand weeding	-	20 & 40	521	114	14.5	5.23	5.80	60.75	2.4
LSD (P = 0.05)			56	13	NS	0.86	0.87	-	-

Note: Sale price of: paddy ` 10.5 /kg, Straw: ` 1/kg,

check with an yield loss of 64% as compared to hand weeding because of severe weed competition, which effected crop growth and ultimately yield. The results are similar to those reported by Kumar and Kumar (2003). Regarding economics, the same treatment recorded higher net returns (` 60, 213/ha) and benefit cost ratio of 3.6. The next best treatment was pyrazosulfuron-ethyl 20 g/ha *fb* penoxsulam 25 g/ha. Thus, it can be summarized that in wet-seeded rice, pre-emergence application of oxadiargyl g/ha *fb* penoxsulam 25 g/ha was found to be effective and economical.

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Short communication

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Weed management under different planting geometry in dry direct-seeded rice

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Rice (*Oryza sativa* L.) is the leading cereal of the world and more than half of the human race depend on rice for their daily sustenance. World's rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al*. 2002), and therefore, meeting ever increasing rice demand in a sustainable way with shrinking natural resources is a great challenge. Weeds are the greatest yield-limiting constraint to rice. The risk of yield loss from weeds in direct- seeded rice is greater than transplanted rice. Ramzan (2003) reported yield reduction up to 48, 53 and 74% in transplanted, direct-seeded flooded and direct-seeded aerobic rice, respectively. Aerobic rice is subject to much higher weed pressure with a broader weed spectrum than flood-irrigated rice (Balasubramanian and Hill 2002). Season-long weed competition in direct-seeded rice may cause yield reduction up to 80% Sunil *et al*. (2010).

The development and adoption of DSR may enable good crop growth but the lack of sustained flooding will greatly increase potential losses from weeds. These systems may integrate direct-seeding and herbicide use, yet, to be sustainable, effective weed management strategies are required. A multitude of prerequisites, including level land, effective weed control, efficient water management, and timely water supply in relation to crop water demand, need to be met to ensure a successful DSR crop. When weed control in rice is neglected, there is a decrease in yield because of weeds, even if other means of increasing production, including application of fertilizers are practiced. In the NW-IGP, DSR is an emerging production system. The transition from the puddle transplanted rice to DSR can therefore only be successful, if accompanied by effective integrated weed management practices.

A field experiment was conducted during *Kharif* 2013 at Borlaug, Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The soil was calcareous, medium to moderately coarse textured, with pH 7, high in organic carbon (0.81%) and medium in available nitrogen (215.61 kg/ha) and available phosphorus (21.62 kg/ha) and available potash (141.92 kg/ha). The experiment was laid out in factorial randomized block design with four replications. A set of twelve treatment combinations consisting of three planting geometries, *viz.* 20 cm at regular sowing, 20 x 10 cm and 25 x 25 cm and four weed control treatments consisted of weedy check, pre-emergence application of pendimethalin 1 kg/ha *fb* hand weeding at 30 days after sowing, post-emergence application of bispyribac–Na 25 g/ha *fb* hand weeding at 45 days after sowing and pre-emergence application of pendimethalin 1 kg/ha *fb* post-emergence application of bispyribac–Na 25 g/ha supplemented with one hand weeding at 45 DAS. Rice variety "*Pant dhan - 12*" was sown on 22 June, 2013 with 40, 26 and 8.5 kg/ha seed rate. A common dose of fertilizer at 150:60:40 kg N:P:K/ha was supplied through DAP, urea and muriate of potash. The 25% nitrogen and full dose of phosphorus and potash were applied as basal while remaining nitrogen was applied into two equal *i.e.* 50% nitrogen was given at active tillering and 25% at panicle initiation stage. Weeds were collected four times for count and dry weight through 0.25/m^2 quadrate.

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Weed flora

The major weed flora observed in the experimental field included *Echinochloa crusgalli* (15.8%), *Ecinochloa colona* (23.8%), *Leptochloa chinensis* (18.4%), *Ammania baccifera* (14.8%), *Caesulia axillaris* (10.3%), *Cyperus rotundus* (8.9%) and others (8.7%) in rice crop.

Effect on weed density

Different planting geometries and weed control treatments significantly influenced the density of different species of weeds in rice crop while interaction was found non-significant in all. The planting geometry 20 cm at regular spacing had lesser weed density compared to 20 x 10 cm and 25 x 25 cm. The reason behind this could be mutual competition between weed species. Narrow row planting with increased crop density would have shifted the competitive balance in favour of the crop. All planting geometries had almost same population of broad-leaved weeds while *C. iria* among the sedges and *E. colona* among the grassy weeds were more effectively controlled (Table 1). Among the weed control treatments, pre-emergence application of pendimethalin 1 kg/ha followed by post-emergence application of bispyribac-Na 25 g/ha followed by one hand weeding at 45 days after sowing was at par-with pre-emergence application of pendimethalin 1 kg/ha *fb* hand weeding at 30 days after sowing and post-emergence application of bispyribac-Na 25g/ha *fb* hand weeding at 45 days after sowing in *E. colona* among grassy, *C. axillaris* and *Alternanthera sessilis* among broad leaf weeds and *C. iria* and *C. rotundus* among the sedges. Rao *et al*. (2007) reported that the grasses persist in all of principal crops and have greatest weed pressure and crop-weed competition in aerobic rice.

Effect on weed dry weight

Dry weight was found significant except some species both among planting geometry and weed control practices while interaction was found non-significant. Continuous drilling at 20 cm recorded minimum dry weight of the weeds which is at par with 20 x 10 cm spacing. This might be due to lesser space in narrow spacing which reduces the weed dry weight. Among weed management practices, lowest weed density was observed in both pre- and post-

Table 1. Effect of planting geometry and weed management practices on weed density at 60 DAS in dry direct-seeded rice

Treatment	Weed density							Total weed density (no./m^2)
	Grassy weeds		Broad-leaved weeds			Sedges		
	E. colona	*L. chinensis*	*A baccifera*	*C. axillaris*	*A. sessilis*	*C. iria*	*C rotundus*	
Planting geometry								
Continous drilling at 20 cm	3.1(13.5)	3.7(17.5)	3.5(12.3)	1.3(1.25)	1.7(2.6)	1.5(2.0)	4.0(22.7)	6.1(47)
20 x 10 cm	2.1(7.7)	3.0(9.1)	4.8(22.6)	1.6(1.8)	1.3(1.1)	1.5(2.5)	5.7(36.5)	6.7(56)
25 x 25 cm	2.6(8.9)	2.3(6.6)	3.5(14.2)	1.8(2.7)	1.7(2.6)	2.0(6.0)	5(35.7)	7.0(62)
LSD (P=0.05)	0.3	0.3	0.3	0.3	NS	0.13	NS	0.4
Weed management								
Pendimethalin *fb* hand weeding (30 DAS)	1.5(1.58)	2.3(4.6)	3.2(11.3)	1.5(1.7)	1.2(1.0)	1.0(0.0)	5.0(28.3)	5.7(31.7)
Bispyribac *fb* hand weeding (45 DAS)	2.1(4.6)	2.1(4.3)	3.3(13.5)	1.0(0.0)	1.1(0.3)	1.0(0.0)	3.0(13.0)	4.8(22.6)
Pendimethalin *fb* bispyribac *fb* hand weeding (45 DAS)	1.1(0.3)	1.8(2.7)	4.4(18.3)	1.4(1.3)	1.3(1.0)	1.0(0.0)	4.6(27.7)	3.7(12.9)
Weedy check	5.9(33.6)	5.6(32.7)	4.8(22.5)	2.4(4.8)	2.6(6.0)	3.7(14)	7(57.7)	12.3(153.1)
LSD (P=0.05)	0.34	0.33	0.38	0.34	0.4	0.16	1.9	0.5

Original values are given in parentheses

Table 2. Effect of planting geometry and weed management practices on weed dry weight (g/m^2) at 60 DAS in direct dry seeded rice

Treatment	Weed dry weight							Total weed dry weight (g/m^2)
	Grassy weeds		Broad-leaved weeds			Sedges		
	E. colona	*L. chinensis*	*A baccifera*	*C. axillaris*	*A. sessilis*	*C. iria*	*C rotundus*	
Planting geometry								
Continous drilling at 20 cm	3.5(19.8)	3.9(19.8)	2.3(4.8)	1.1(.26)	1.9(4.1)	1.5(2.1)	1.7(2.6)	7.4(71.8)
20 x 10 cm	2.4(10.7)	3.2(10.7)	3.6(12.6)	1.3(0.73)	1.4(1.6)	1.5(2.1)	2.2(4.4)	8.0(80.7)
25 x 25 cm	2.9(12.5)	2.7(10.1)	2.9(9.2)	1.9(7.1)	1.8(3.4)	1.9(5.0)	2.5(9.8)	7.9(77.8)
LSD (P=0.05)	NS	0.3	0.27	NS	NS	0.7	NS	0.4
Weed management								
Pendimethalin *fb* hand weeding (30 DAS)	1.5(1.8)	2.5(5.2)	2.4(6.0)	1.3(0.8)	1.3(1.4)	1.0(0.0)	2.8(12.0)	6.4(40.9)
Bispyribac *fb* hand weeding (45 DAS)	2.3(6.7)	2.3(4.8)	2.8(9.4)	1.0(0.0)	1.1(0.49)	1.0(0.0)	1.3(1.0)	5.5(29.9)
Pendimethalin *fb* bispyribac *fb* hand weeding (45 DAS)	1.1(0.4)	1.9(2.9)	3.2(9.8)	1.8(8.5)	1.3(1.5)	1.0(0.0)	2(3.4)	4.5(19.6)
Weedy check	6.8(48.3)	6.4(41.2)	3.2(10.3)	1.6(1.5)	3(8.8)	3.6(12.4)	2.4(5.8)	14.7(216.8)
LSD (P=0.05)	1.0	0.33	0.3	NS	0.5	0.8	NS	0.5

Original values are given in parentheses

Table 3. Effect of planting geometry and weed control practices on yield and harvest index

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Planting geometry				
Continous drilling at 20 cm	3.47	6.77	10.4	32.7
20 x 10 cm	3.41	6.37	10.2	32.9
25 x 25 cm	2.89	4.59	7.87	34.6
LSD (P=0.05)	0.40	1.05	1.25	NS
Weed management				
Pendimethalin *fb* hand weeding (30 DAS)	3.72	6.51	10.5	33.2
Bispyribac *fb* hand weeding (45 DAS)	3.66	6.53	10.7	34.9
Pendimethalin *fb* bispyribac *fb* hand weeding (45 DAS)	4.79	7.97	13.7	36.7
Weedy check	0.8.5	2.63	2.9	28.8
LSD (P=0.05)	0.46	1.21	1.45	3.7

Original values are given in parentheses

emergence herbicide application along with one hand weeding at 45 days after sowing (Table 2). Rao *et al.* (2007) reported that the grasses persist in all of principal crops and have gratest weed pressure and crop-weed competition in aerobic rice.

Effect on yield

The grain yield of rice was influenced significantly due to different planting geometry and weed management practices. The planting geometry continuous drilling at 20 cm spacing produced the highest grain yield which was at par with 20 x 10 cm plant spacing and significantly superior than the wider (25 x 25 cm) spacing. The reason may be closer spacing which resulted in mutual competition between the weeds and rice plants which cause lower weed population under 20 x 10 cm spacing (Table 3).

While among the herbicidal treatments, pre-emergence application of pendimethalin (1 kg/ha) *fb* post-emergence application of bispyribac –Na (25 g/ ha) supplemented with one hand weeding 45 days after sowing recorded the highest grain yield which was significantly superior than both pre and post emergence herbicide application along with one hand weeding (Table 3). The integrated approaches of the chemicals along with hand weeding resulted in higher grain yield and this might be attributed due to effective weed control due to both pre- and post-herbicide which control both early and later weeds in the treatment which resulted in optimum tiller density, more panicle bearing tillers (m^2), more number of grains per panicle and more 1000- grain weight as reported by several workers (Hasanuzzaman *et al.* 2008). The higher grain yield in planting geometry continuous drilling at 20 cm and sequential application of pre- and post-emergence herbicide application along with hand weeding might be attributed to long term effective control of weeds by both herbicides during the growing period of crop.

SUMMARY

A field experiment was conducted during *Kharif* 2013 at Pantnagar, Uttrakhand, to find out the effect of planting geometry in direct-seeded rice by different weed management practices. The experiment comprised of twelve treatments with four replications in factorial randomized block design of which main factor was three different planting geometry and sub-plots have four factors with three different weed control treatments with one weedy check. The treatment pre-emergence application of pendimethalin 1 kg/ha *fb* post-emergence application of bispyribac–Na 25 g/ha supplemented with one hand weeding along with planting geometry 20 cm at regular spacing increased the grain yield, weed control efficiency and net returns over all the other treatments of rice .

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Short communication

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Effect of weed management on growth, yield and nutrient uptake of greengram

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Greengram is one of the major pulse crops in India which is cultivated in arid and semi-arid region. It is cultivated in nearly 3.35 million hectare area with the production of 1.82 million tones and average productivity of 512 kg/ha. Lack of improved cultural practices, cultivation on marginal and sub marginal lands of poor fertility, inadequate fertilization, monsoon dependent cultivation, high sensitivity to pests and diseases and non-availability of suitable varieties are the major factors responsible for low yield of greengram. Along with these, weed infestation is one of the major constraints in greengram cultivation. Being a rainy season crop, it is invaded by a large number of fast growing weeds. The critical period of weed competition in greengram is during the first 30–40 days after sowing. Weeds grow quickly during this time taking the advantage of crops' slow initial growth.

Weeding and hoeing are common cultural and manual weed management methods for greengram. Manual weeding at right stage is difficult, time consuming and expensive due to intermittent rainfall during rainy season and scanty labour, therefore, farmers rarely adopt manual weeding for weed control. Under such situation, herbicides use with suitable dose remains the pertinent choice for controlling the weeds. Herbicides in isolation, however, are unable do complete weed control because of their selective kill. Their use can be made more effective, if supplemented with hand weeding or hoeing *etc*. A judicious combination of chemical and cultural methods of weed control would not only reduce the expenditure on herbicides but would benefit the crop by providing proper aeration and conservation of moisture (Prakash *et al.* 1991). Thus, an experiment was conducted with an objective to identify a judicious combination of chemical and cultural methods for controlling weeds in greengram.

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The experiment was conducted during *Kharif* season of 2013 at Agriculture Research Station, SK Rajasthan Agricultural University, Bikaner, Rajasthan to identify the suitable integrated weed management method for managing weeds in greengram. The experiment was laid out in randomized block design with 16 treatments replicated thrice. The soil of the experimental field was loamy sand (84.1% sand, 7.5% silt and 8.0% clay) with poor in organic carbon (0.08), low in available nitrogen (78.0 kg/ha), medium in available phosphorus (22.0 kg/ha) and potassium (210.0 kg/ha). The soil was slightly alkaline in reaction with pH 8.22.

Experimental treatments comprised weedy check, weed free, pendimethalin 0.75 kg/ha as pre-emergence, pendimethalin 0.75 kg/ha as pre-emergence + one hand weeding at 30 DAS, imazethapyr 40 g/ha at 20 DAS as post-emergence, imazethapyr 50 g/ha at 20 DAS as post-emergence, imazethapyr 60 g/ha at 20 DAS as post-emergence , imazethapyr 40 g/ha at 20 DAS as post-emergence + one hand weeding at 40 DAS, imazethapyr 50 g/ha at 20 DAS as post-emergence + one hand weeding at 40 DAS, imazethapyr 60 g/ha at 20 DAS as post-emergence + one hand weeding at 40 DAS, imazethapyr + imazamox 40 g/ha at 20 DAS as post-emergence, imazethapyr + imazamox 60 g/ha at 20 DAS as post-emergence, pendimethalin 0.75 kg/ha as pre-emergence + imazethapyr 40 g/ha at 20 DAS as post-emergence, imazethapyr + imazamox 40 g/ha at 20 DAS as post-emergence + one hand weeding at 40 DAS, imazethapyr + imazamox 60 g/ha at 20 DAS as post-emergence + one hand weeding at 40 DAS and pendimethalin 0.75 kg/ha as pre-emergence + imazethapyr + imazamox 40 g/ha at 30 DAS as post-emergence.

Greengram variety '*SML-668*' was sown with seed rate of 20 kg/ha and plant spacing of 30 × 10 cm. The recommended dose of fertilizer 20:40:40 kg/ha N, P_2O_5 and K_2O was applied as basal dose through urea, single super phosphate and muriate of potash respectively. Protective irrigations were applied whenever it was necessary during the crop growth. Pendimethalin was applied one day after sowing as pre emergence whereas imazethapyr was applied 20 and 30 DAS as post emergence as per the treatment with knapsack sprayer. Weed free was achieved by two hand weedings at 20 and 40 DAS. Randomly five plants were selected from each plot and regular biometric observations of crop and weed parameters were recorded from 30 DAS upto harvest. Weed density(no./m^2) was recorded by putting a quadrate of 0.25 m^2 at two random spots in each plot and after drying them in hot air oven (65^0 C for 48 hours) weed dry weight (g/m^2) was recorded. Weed density was subjected to $\sqrt{x+0.5}$ transformation. Weed control efficiency was estimated on the basis of reduction in weed weight in comparison with unweeded control and expressed as an index taking weed free as 100% efficiency. Weed index refers to reduction in yield due to presence of weeds in comparison to the weed free treatment plot yield. The experimental plot size was 3.40 x 2.40 m^2. Yields were harvested from net plot. For economic study, prevailing market price was used for different outputs and inputs.

Weed flora

Predominant weeds in experimental greengram field were: *Amaranthus spinosus*, *Digera arvensis*, *Trianthema portulacastrum*, *Gisekia poredious*, *Euphorbia hirta*, *Aristida depressa*, *Portulaca oleracea*, *Cenchrus biflorus*, *Cleome viscosa*, *Tribulus terrestris*, *Corchorus tridense*, *Cyperus rotundus*, *Eleusine verticillata*, *Eragrastris tennela* and *Aerva tomentosa*.

All the treatments were responsible for significant reduction in weed density and dry weight of weeds over control. Weed free treatment resulted in lowest weed density and dry weight of weeds. However, treatment pendimethalin 0.75 kg/ha as pre emergence + imazethapyr + imazamox 40 g/ha at 30 DAS as post-emergence and imazethapyr + imazamox 60 g/ha at 20 DAS as post-emergence + hand weeding at 40 DAS were found to be at par with each other and recorded significantly least number of weed and weed dry matter. Pendimethalin 0.75 kg/ha as pre emergence + imazethapyr + imazamox 40 g/ha at 30 DAS as post-emergence was found next superior treatment after weed free in respect of all weed parameters. This might be due to control of weeds during early growth stage by pre-emergence application of pendimethalin which prevented emergence of monocot and grassy weeds by inhibiting root and shoot growth, while post emergence application of imazethapyr + imazamox was responsible for inhibition of acetolactate synthase (ALS) or acetohydroxy acid synthase (AHAS) in broad-leaved weeds which caused destruction of these weeds at 3-4 leaf stage.

The treatment combination of pre- and post-applied herbicide after sowing and 30 DAS was able

Table 1. Effect of different weed management practices on weed parameters in greengram at harvest

Treatment	Weed density (no/m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)	Weed index (%)
Pendimethalin 0.75 kg/ha	2.81 (7.42)	6.33	89.0	14.1
Pendimethalin 0.75 kg/ha + HW 30 DAS	1.04 (0.59)	0.54	98.8	2.40
Imazethapyr 40 g/ha 20 DAS	1.90 (3.15)	5.60	93.8	19.1
Imazethapyr 50 g/ha 20 DAS	1.88 (3.09)	5.70	94.0	16.4
Imazethapyr 60 g/ha 20 DAS	1.87 (3.00)	5.72	94.1	16.8
Imazethapyr 40 g/ha 20 DAS + HW 40 DAS	1.10 (0.71)	1.49	98.3	12.1
Imazethapyr 50 g/ha 20 DAS + HW 40 DAS	1.00 (0.50)	1.15	98.5	10.3
Imazethapyr 60 g/ha 20 DAS + HW 40 DAS	1.17 (0.86)	2.13	98.6	9.82
Imazethapyr + issmazamox 40 g/ha 20 DAS	0.96 (0.43)	0.29	99.4	15.4
Imazethapyr + imazamox 60 g/ha 20 DAS	0.91 (0.32)	0.21	99.5	14.6
Pendimethalin 0.75 kg/ha + imazethapyr 40 g/ha 20 DAS	0.90 (0.31)	0.30	99.5	2.88
Imazethapyr + imazamox 40 g/ha 20 DAS + HW 40 DAS	0.83 (0.19)	0.39	99.6	7.51
Imazethapyr + imazamox 60 g/ha 20 DAS + HW 40 DAS	0.75 (0.06)	0.15	99.8	6.07
Pendimethalin 0.75 kg/ha + imazethapyr + imazamox 40 g/ha 20 DAS + HW 40 DAS	0.75 (0.06)	0.06	99.8	4.79
Weedy check (W_1)	8.14 (65.8)	46.9	-	50.6
Weed free (W_2)	0.71 (0.00)	0.00	100.0	-
LSD (P=0.05)	0.17	0.46		

HW= Hand weeding; DAS=Day after sowing

to control the further infestation of weeds in greengram crop. Further the crop covers the soil surface and smothers the growth of weeds results into least number of weeds at harvest.

Highest weed control efficiency and lowest weed index percentage were observed in weed free treatment. Besides weed free, treatments pendimethalin 0.75 kg/ha as pre-emergence + imazethapyr + imazamox 40 g/ha at 30 DAS as post-emergence, imazethapyr + imazamox 60 g/ha at 20 DAS as post-emergence + one hand weeding at 40 DAS and imazethapyr + imazamox 40 g/ha at 20 DAS as post-emergence + one hand weeding at 40 DAS recorded lower weed index 4.79, 6.07 and 7.51 and

Table 2. Effect of different weed management practices on growth and yield parameters in greengram

Treatment	Plant height (cm)	Branches /plant	Dry matter accumulation (g/plant)	Dry weight of nodules at 50 DAS (mg/plant)	Pods/ plant (no.)	Seeds / pod (no.)
Pendimethalin 0.75 kg/ha	64.5	4.16	14.4	25.5	26.1	5.61
Pendimethalin 0.75 kg/ha + HW 30 DAS	64.7	4.17	14.5	27.4	27.5	5.89
Imazethapyr 40 g/ha 20 DAS	59.1	3.77	12.8	25.6	25.4	5.50
Imazethapyr 50 g/ha 20 DAS	59.2	3.80	13.2	26.2	25.5	5.65
Imazethapyr 60 g/ha 20 DAS	59.6	3.81	13.0	26.4	25.7	5.57
Imazethapyr 40 g/ha 20 DAS + HW 40 DAS	61.0	3.98	13.4	26.5	26.4	5.65
Imazethapyr 50 g/ha 20 DAS + HW 40 DAS	61.4	4.01	13.8	26.5	26.6	5.69
Imazethapyr 60 g/ha 20 DAS + HW 40 DAS	61.5	4.03	14.1	27.0	26.6	5.71
Imazethapyr + issmazamox 40 g/ha 20 DAS	60.2	3.87	13.3	27.7	25.9	5.59
Imazethapyr + imazamox 60 g/ha 20 DAS	60.5	3.90	13.2	27.8	26.0	5.60
Pendimethalin 0.75 kg/ha + imazethapyr 40 g/ha 20 DAS	60.7	3.93	13.2	25.8	27.5	5.87
Imazethapyr + imazamox 40 g/ha 20 DAS + HW 40 DAS	62.1	4.06	14.1	28.1	27.0	5.75
Imazethapyr + imazamox 60 g/ha 20 DAS + HW 40 DAS	62.3	4.10	14.2	28.2	27.1	5.81
Pendimethalin 0.75 kg/ha + imazethapyr + imazamox 40 g/ha 20 DAS + HW 40 DAS	63.4	4.12	14.3	27.2	27.1	5.83
Weedy check (W_1)	46.6	2.97	7.90	20.2	19.2	4.52
Weed free (W_2)	65.2	4.21	14.8	29.5	27.8	5.94
LSD (P=0.05)	7.40	0.50	2.62	3.05	3.24	0.50

HW= Hand weeding; DAS=Day after sowing

Table 3. Effect of different weed management practices on yield and economics in greengram

Treatment	Seed yield (t/ha)	Straw yield (t/ha)	Gross return ($x10^3$ `/ha)	Net returns ($x10^3$ `/ha)	B:C ratio
Pendimethalin 0.75 kg/ha	1.08	2.82	64.15	40.70	2.74
Pendimethalin 0.75 kg/ha + HW 30 DAS	1.22	3.11	72.76	47.99	2.94
Imazethapyr 40 g/ha 20 DAS	1.01	2.74	60.48	37.82	2.67
Imazethapyr 50 g/ha 20 DAS	1.05	2.81	62.43	39.69	2.74
Imazethapyr 60 g/ha 20 DAS	1.04	2.76	62.16	39.32	2.72
Imazethapyr 40 g/ha 20 DAS + HW 40 DAS	1.10	2.90	65.60	41.62	2.74
Imazethapyr 50 g/ha 20 DAS + HW 40 DAS	1.12	2.95	66.96	42.88	2.78
Imazethapyr 60 g/ha 20 DAS + HW 40 DAS	1.13	2.95	67.30	43.13	2.78
Imazethapyr + imazamox 40 g/ha 20 DAS	1.06	2.82	63.18	40.69	2.81
Imazethapyr + imazamox 60 g/ha 20 DAS	1.07	2.83	63.76	41.17	2.82
Pendimethalin 0.75 kg/ha + imazethapyr 40 g/ha 20 DAS	1.22	3.11	72.43	48.11	2.98
Imazethapyr + imazamox 40 g/ha 20 DAS + HW 40 DAS	1.16	3.01	69.01	45.19	2.90
Imazethapyr + imazamox 60 g/ha 20 DAS + HW 40 DAS	1.18	3.03	70.06	46.14	2.93
Pendimethalin 0.75 kg/ha + imazethapyr + imazamox 40 g/ha 20 DAS + HW 40 DAS	1.19	3.08	71.02	46.86	2.94
Weedy check	0.62	1.69	36.97	15.19	1.70
Weed free	1.25	3.18	74.54	50.10	3.05
LSD (P=0.05)	0.24	0.58		10.40	0.53

HW= Hand weeding; DAS=Day after sowing

higher weed control efficiency 99.8, 99.8, 99.6 and 98.6%. This might be due to elimination of weeds by manual weeding and interculturing or by herbicides. The integrated effect on dry weight of weeds and seed yield under these treatments might have been responsible for excellent weed indices. These findings are akin to report of Bhandari *et al.* (2004). Lowest weed control efficiency and highest weed index percentage were recorded in weed free.

Weed free treatment recorded significantly taller plants and higher dry matter production and seed yield/ha over all the other treatments (Table 2 and 3). This was followed by treatment pendimethalin 0.75 kg/ha as pre-emergence + hand weeding at 30 DAS. However in respect of pods/plant and seed/pod weed free and pendimethalin 0.75 kg/ha as pre-emergence + hand weeding at 30 DAS were found at par with each other. This might be due to minimizing the competition of weeds with main crop for resources *viz.* space, light, nutrients and moisture with adaption of effective weed control methods. Thus, reduced crop- weed competition resulted into overall improvement in crop growth as reflected by plant height and dry matter accumulation consequently resulted into better development of reproductive structure and translocation of photosynthates to the sink. The results corroborate with the findings of Singh *et al.* (1994) and Yadav *et al.* (2014). Significantly lower value of growth parameters *viz.* plant height, dry weight of nodules and number of branches/plant and yield attributing characters *viz.* pods/plant, seeds/pod seed yield and straw yield were recorded in treatment weed free. This might be due to severe competition by weeds for resources, which made the crop plant inefficient to take up more moisture, nutrients and ultimately growth was adversely affected due to less supply of carbohydrates. Similar findings was observed by Panwar *et al.* (1982), Singh and Chaudhary (1992) and Malliswari *et al.* (2008).

The monetary returns were found to be significantly influenced by different weed control treatments (Table 3). The maximum gross returns of ` 74,544/ha, net returns of ` 50,102/ha and benefit: cost ratio (3.05) was obtained with weed free treatment. Among herbicide weed control treatments maximum gross return (` 72,764/ha) was recorded with treatment pendimethalin 0.75 kg/ha as pre-emergence + hand weeding at 30 DAS whereas maximum net returns (` 48,108/ha) and benefit : cost ratio (2.98) were recorded with treatment pendimethalin 0.75 kg/ha as pre-emergence + imazethapyr 40 g/ha at 30 DAS as post-emergence. This might be due to the cost of cultivation of greengram crop was increased in treatment pendimethalin 0.75 kg/ha as pre-emergence + hand weeding at 30 DAS due to the higher need of human labours and their higher wages. This cost was reduced in treatment pendimethalin 0.75 kg/ha pre-emergence + imazethapyr 40 g/ha at 30 DAS as post-emergence by using herbicides to effective control of weeds with minimizing human labours. These

Table 4. Effect of different weed management practices on nutrient uptake by crop and weeds in greengram

Treatment	Nutrient uptake (kg/ha)					
	Crop			Weeds		
	N	P	K	N	P	K
Pendimethalin 0.75 kg/ha	79.5	10.5	79.7	8.68	1.68	7.01
Pendimethalin 0.75 kg/ha + HW 30 DAS	94.2	12.1	91.6	0.73	0.14	0.59
Imazethapyr 40 g/ha 20 DAS	74.2	9.86	75.8	6.73	1.33	5.60
Imazethapyr 50 g/ha 20 DAS	76.9	10.2	78.3	6.84	1.36	5.66
Imazethapyr 60 g/ha 20 DAS	76.4	10.1	77.2	6.85	1.24	5.13
Imazethapyr 40 g/ha 20 DAS + HW 40 DAS	81.8	10.8	82.0	1.76	0.37	1.53
Imazethapyr 50 g/ha 20 DAS + HW 40 DAS	84.3	11.0	84.1	1.36	0.29	1.21
Imazethapyr 60 g/ha 20 DAS + HW 40 DAS	85.2	11.1	84.7	2.55	0.54	2.29
Imazethapyr + imazamox 40 g/ha 20 DAS	78.4	10.3	78.9	0.39	0.08	0.32
Imazethapyr + imazamox 60 g/ha 20 DAS	79.3	10.5	79.5	0.28	0.05	0.22
Pendimethalin 0.75 kg/ha + imazethapyr 40 g/ha 20 DAS	94.0	12.2	90.9	0.37	0.07	0.31
Imazethapyr + imazamox 40 g/ha 20 DAS + HW 40 DAS	88.6	11.4	86.9	0.47	0.10	0.40
Imazethapyr + imazamox 60 g/ha 20 DAS + HW 40 DAS	90.4	11.6	87.8	0.17	0.04	0.17
Pendimethalin 0.75 kg/ha + imazethapyr + imazamox 40 g/ha 20 DAS + HW 40 DAS	91.1	11.8	89.3	0.08	0.02	0.07
Weedy check	45.0	6.02	46.3	61.9	12.1	51.3
Weed free	97.2	12.6	94.6	0.00	0.00	0.00
LSD (P=0.05)	19.1	2.36	16.7	0.62	0.12	0.64

HW = Hand weeding; DAS = Day after sowing findings are in close vicinity with those reported by Sardana *et al.* (2006), Kalhapure *et al.* (2013) and Yadav *et al.* (2014). Weedy check recorded lowest gross monetary return (` 36,974/ha), net monetary return (` 15,188/ha) and benfeit: cost ratio (1.70).

All weed control treatments were almost equally important in controlling weeds and improving crop yield. Weed free treatment was superior most with respect to yield (1.25 t/ha), yield attributes, quality and net profit (` 50,102/ha) and B: C ratio (3.05). The next best treatment with respect to net returns (` 48,108/ha) and B:C ratio (2.98) was found pendimethalin 0.75 kg/ha as pre-emergence + imazethapyr 40 g/ha at 20 DAS as post-emergence.

Significant decrease in total N, P and K uptake by weeds were recorded due to all weed management practices over weedy check (Table 4). The nil uptake of N, P and K by weeds was recorded with weed free which was at par with pendimethalin at 0.75 kg/ha as pre-emrgence + imazethapyr + imazamox at 40 g/ha at 30 DAS as post-emergence. Reduced nutrient uptake by weeds under the influence of different weed control measures had been also reported by Chhokar *et al.* (1995) and Chhodavadia *et al.* (2013)

All weed control treatments significantly increased N, P and K uptake by seed and straw of greengram over weedy check. Weed free treatment resulted in significantly highest total uptake of N (97.16 kg/ha), P (12.56 kg/ha) and K (94.56 kg/ha) by the crop compared to weedy check (44.97, 12.56 and 94.56 kg/ha), respectively.

SUMMARY

A field experiment was conducted during *Kharif* of 2013 at Agriculture Research Station, SK Rajasthan Agricultural University, Bikaner, Rajasthan, India with combination of 16 weed control treatments in three replications. Weed free check (two hand weeding at 20 and 40 DAS) was found most effective to control weeds in greengram and recorded lowest weed density, weed dry matter and weed index and highest weed control efficiency. It was also recorded significantly highest growth and yield attributes in greengram over all the other treatments, *viz*. plant height, dry weight of nodules, dry matter accumulation, number of pods/plant, seeds/pod and seed yield/ha. The maximum net return of ` 50,102/ha and B: C ratio (3.05) was recorded under weed free treatment. Among the different herbicides, pre-emergence application of pendimethalin 0.75 kg/ha + post-emergence application of imazethapyr 40 g/ha at 30 DAS recorded significantly higher net returns of ` 48,108/ha and B:C ratio (2.98).

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Short communication

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Bioefficacy of herbicides in blackgram and their residual effect on succeeding mustard

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Due to limited irrigation facilities, blackgram is the important *Kharif* season in Shivalik foot hills region of Panchkula, Ambala and Yamuna Nagar districts of Haryana state. Weed emergence in blackgram begins almost with the crop emergence leading to crop-weed competition from initial stages and reduce yields to the extent of 78% and sometimes lead to the total failure of crop (Gogoi *et al.* 1992). An initial period of crop-weed completion of 20-40 days is very critical (Saraswat and Mishra 1993) and a season long weed competition has been found to reduce blackgram yield to the extent of 87% depending upon type and intensity of weed flora (Singh *et al.* 2002). Thus, it is necessary to eliminate weeds from crop at proper time and with suitable methods. Chemical method of weed management offers good scope for harvesting a good crop of blackgram.

Imazethapyr and its ready mix combination with imazamox, new herbicides of imidazolinone group have been found promising to control weeds in blackgram. Imazethapyr being highly persistent in soil may cause residual toxicity in succeeding crops (Hollaway *et al.* 2006). Keeping it in view, the present study has been planned to study the bio-efficacy of different herbicides in blackgram and the residual effect of herbicides applied in blackgram on succeeding mustard crop.

Studies on evaluation of herbicides in blackgram and their residual effect on succeeding mustard crop were conducted at Research Area of Department of Agronomy, CCSHAU, Hisar during *Kharif* 2013 and *Rabi* 2013-14. The experimental soil was sandy loam (*Typic Ustochrepts*) with 61% sand, 22.1% silt and 19.1% clay, medium in fertility with 0.29% organic carbon and a pH of 8.2. Blackgram variety '*UH-1*' was drilled on July 16, 2013 in a plot size of 12 x 3.6 m, keeping row to row distance of 30 cm by using seed rate of 15 kg/ha. The study was arranged in randomized block design replicated thrice. To study the residual effect of herbicides applied in blackgram on succeeding crop, mustard var. '*RH-30*' was sown after slight disking the field without disturbing the original layout and crop was raised as per package of practices recommended by CCS HAU, Hisar. Visual injury ratings of weed control and phytoxicity to blackgram were estimated at 15, 30, 45 and 60 DAS on a scale of 0 to 100. Above ground weed biomass was sampled at 30 and 60 DAS using a quadrant of 0.5 x 0.5 m. Plant material was dried at 65^0C for 48 h before determining dry weight and this was used for calculating weed control efficiency (WCE). Data on weed density, per cent weed control, crop injury and seed yield of blackgram were analyzed by analysis of variance, and means were separated with least significant difference at 5% level of probability. To estimate the residual effect of herbicides applied in blackgram on succeeding mustard, data on plant height, number of leaves/plant, fresh weight/plant was recorded at 30 DAS and grain yield of mustard was recorded at maturity.

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Effect of herbicides in blackgram

The major weeds appeared in experimental field comprised of *T. portulacastrum*, *C. rotundus* and *Convolvulus arvensis*. At 30 DAS, *T. portulacastrum* was the dominant weed with relative density of 83% but at 60 DAS, *C. rotundus* dominated weed flora with relative density of 72%.

Pre-emergence application of imazethapyr + pendimethalin at 1000 g/ha provided excellent control (90%) of *T. portulacastrum* up to 30 DAS. At 60 DAS, per cent control with this treatment decreased to 73% which was at par with two hoeings employed at 20 and 40 DAS and pendimethalin at 1000 g/ha used pre-emergence. Post-emergence use of imazethapyr + imazamox at 60-80 g/ha exhibited 78-83% control of weeds with slight crop suppression in form of chlorosis, leaf crinkling and stunting, which mitigated within 15 days after spray resulting adverse effect on crop growth and yield. Early post-emergence application of imazethapyr at 50, 60 and

70 g/ha also caused mild injury to blackgram up to 30 DAS (Table 1), This is in agreement with results of Chandakar *et al.* (2014) who reported effectiveness of early post-emergence application (15-20 DAS) of imazethapyr at 40 g/ha and pendimethalin + imazethapyr at 1.0 kg/ha as pre-emergence against weeds in blackgram in clay textures soils of Raipur. Studies conducted by Patel *et al.* (2014) under Gujarat conditions are also in conformity with above results. The yield and yield attributing characters of blackgram were adversely affected in unweeded plots due to severe weed competition up to harvest. Seed yield of blackgram in the presence weeds through out crop season was reduced by 78%. Similar results were reported by Gogoi *et al.* (1992). Maximum seed yield (0.90 t/ha) of blackgram was obtained with two hoeings at 20 and 40 DAS which was at par with imazethapyr + pendimethalin at 1000 g/ha and pendimethalin at 1000 g/ha applied as pre-emergence.

Economics: The comparative economics showed that PRE application of pendimethalin at 1000 g/ha was most economical weed control treatment with net returns of ` 22,765/ha with benefit : cost ratio of 2.30 which was closely followed by pre-emergence application of imazethapyr + pendimethalin at 1000 g/ ha (` 22,390/ha) and B:C of 2.24. Chaudhary *et al.* (2012) reported that in blackgram pre-emergence application of pendimethalin at 1.5 kg/ha + one HW on 25 DAS was at par with 2 HW at 15 and 25 DAS in respect of seed yield, net returns and B:C ratio (Table 2).

Residual effect of herbicides applied in blackgram on succeeding mustard crop

No residual carry over effect of these herbicides applied in blackgram was visible on succeeding mustard crop as no. of plants/m.r.l., number of leaves/ plant and seed yield of mustard in untreated and herbicide applied treatments was same(Table 2). This may be due to enhanced microbial degradation of these herbicides with 477 mm of rainfall occurred between time of herbicide application and planting of mustard. Earlier findings of Tomar *et al.* (2014) and Patel *et al.* (2014) support above results where no residual effect of imazethapyr at 70 g/ha and its ready

Table 1. Effect of different herbicides on visual weed control, crop phytotoxicity and seed yield of blackgram (2013)

Treatment	Dose (g/ha)	Time of application	Weed density at 60 DAS (no./m^2)			WCE (%)	Visual weed control (%) *Trianthema*			Crop phytotoxicity (%)		
			T. portulacastrum	*C. rotundus*	*C. arvensis*		30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS
Pendimethalin	1000	PRE	3.0 (8.0)	10.2 (104.0)	3.9 (14.3)	40.3 (42.0)	65.9 (83.3)	55.7 (68.3)	51.7 (61.7)	0	0	0
Imazethapyr	50	3-4 leaf stage	3.0 (8.0)	7.8 (60.7)	3.8 (13.7)	44.2 (48.7)	27.7 (21.7)	49.8 (58.3)	46.8 (53.3)	0	0	0
Imazethapyr	60	3-4 leaf stage	2.5 (5.3)	7.6 (58.0)	3.8 (13.7)	47.7 (54.7)	29.9 (25.0)	52.7 (63.3)	49.7 (58.3)	0	12.2	0
Imazethapyr	70	3-4 leaf stage	2.5 (5.3)	7.5 (56.7)	3.8 (13.7)	51.8 (61.7)	34.2 (31.7)	55.7 (68.3)	50.7 (60.0)	0	19.8	0
Imazethapyr + pendimethalin	800	PRE	2.9 (7.3)	11.2 (124.0)	3.9 (14.7)	46.0 (51.7)	68.8 (86.7)	55.0 (66.7)	52.7 (63.3)	0	0	0
Imazethapyr + pendimethalin	900	PRE	1.5 (2.0)	10.5 (109.3)	3.9 (14.0)	48.1 (55.3)	70.1 (88.3)	57.8 (71.7)	54.7 (66.7)	0	0	0
Imazethapyr + pendimethalin	1000	PRE	1.0 (0)	9.6 (92.0)	3.7 (13.0)	54.1 (65.7)	71.5 (90.0)	62.3 (78.3)	58.9 (73.3)	0	0	0
Imazethapyr + imazamox	50	3-4 leaf stage	1.0 (0)	8.7 (74.0)	3.9 (15.3)	55.5 (68.0)	31.0 (26.7)	65.9 (83.3)	61.1 (76.7)	0	18.4	0
Imazethapyr + imazamox	60	3-4 leaf stage	1.0 (0)	8.7 (74.7)	3.9 (14.7)	58.3 (72.3)	32.0 (28.3)	68.8 (86.7)	62.2 (78.3)	0	21.3	0
Imazethapyr + imazamox	70	3-4 leaf stage	1.0 (0)	8.6 (72.7)	3.9 (14.0)	59.4 (74.0)	33.2 (30.0)	70.1 (88.3)	64.6 (81.7)	0	24.0	0
Imazethapyr + imazamox	80	3-4 leaf stage	1.0 (0)	7.9 (61.3)	3.9 (14.3)	60.4 (75.3)	34.2 (31.7)	71.5 (90.0)	65.9 (83.3)	0	25.3	0
Two hoeings		20 & 40 DAS	1.7 (2.0)	6.2 (38.0)	3.0 (6.7)	70.6 (89.0)	68.8 (86.7)	73.4 (91.7)	67.3 (85.0)	0	0	0
One hoeing	-	20 DAS	2.8 (6.7)	8.3 (68.7)	3.6 (12.3)	62.8 (79.0)	67.4 (85.0)	64.7 (81.7)	61.1 (76.7)	0	0	0
Weed free	-	-	1.0 (0)	1.0 (0)	1.0 (0)	90.0 (100.0)	90.0 (100.0)	90.0 (100.0)	90.0 (100)	0	0	0
Weedy check	-	-	5.2 (26.0)	10.5 (108.7)	4.2 (16.7)	0 (0)	0 (0)	0 (0)	0 (0)	0	0	0
LSD (P=0.05)			0.6	1.1	0.7	3.5	5.0	4.8	3.47	-	5.2	-

Table 2. Grass returns and residual carry over effect of different herbicides applied in blackgram on succeeding mustard crop (2013-14)

Treatment	Dose (g/ha)	Time of application	Blackgram Seed yield (t/ha)	Blackgram Gross returns (x10^3 `)	B:C ratio	Mustard No. of plants/ m. r. l.	Mustard Plant height (60 DAS)	Mustard No. of pods/ Plant	Mustard Seed yield (t/ha)
Pendimethalin	1000	PRE	0.86	40.16	2.30	11	20.5	299	2.48
Imazethapyr	50	3-4 leaf stage	0.69	32.03	1.88	10	20.1	306	2.47
Imazethapyr	60	3-4 leaf stage	0.70	32.83	1.91	11	20.3	306	2.50
Imazethapyr	70	3-4 leaf stage	0.75	34.95	2.01	11	19.8	303	2.52
Imazethapyr + pendimethalin	800	PRE	0.69	32.57	1.85	11	20.9	301	2.47
Imazethapyr + pendimethalin	900	PRE	0.85	39.32	2.12	11	20.2	298	2.50
Imazethapyr + pendimethalin	1000	PRE	0.87	40.34	2.24	11	19.8	306	2.50
Imazethapyr + imazamox	50	3-4 leaf stage	0.72	33.11	1.93	11	19.9	306	2.45
Imazethapyr + imazamox	60	3-4 leaf stage	0.78	36.34	2.11	11	19.8	306	2.48
Imazethapyr + imazamox	70	3-4 leaf stage	0.81	37.75	2.16	11	20.6	310	2.47
Imazethapyr + imazamox	80	3-4 leaf stage	0.82	38.01	2.16	12	20.6	323	2.45
Two hoeings		20 & 40 DAS	0.90	41.54	1.60	12	20.3	313	2.48
One hoeing	-	20 DAS	0.82	38.15	1.83	11	20.8	313	2.50
Weed free	-	-	1.02	47.31	2.38	12	21.2	306	2.52
Weedy check	-	-	0.23	10.76	0.68	11	19.9	303	2.47
LSD (P=0.05)			0.05			NS	NS	NS	NS

mixture with pendimethalin at 800 g/ha applied pre-emergence in blackgram was not observed on succeeding mustard and wheat crops. But findings of this experiment are not in agreement with earlier finding of Punia *et al.* (2011) who reported poor, stunted growth of mustard grown after imazethapyr used at 80-100 g/ha either PPI, pre- and post-emergence (21 DAS) in preceding clusterbean crop.

SUMMARY

Pre-emergence application of imazethapyr + pendimethalin at 1000 g/ha provided excellent control (90%) of *T. portulacastrum* up to 30 DAS. At 60 DAS, per cent control with this treatment decreased to 73% which was at par with two hoeings employed at 20 and 40 DAS and pendimethalin at 1000 g/ha. Post-emergence use of imazethapyr + imazamox at 60-80 g/ha exhibited 78-83% control of weeds with slight crop suppression which mitigated within 10-15 days after spray but with yield penalty. Early post-emergence application of imazethapyr at 50, 60 and 70 g/ha also caused mild injury to blackgram in terms of yellowing of leaves and stunted crop growth up to 30 DAS, but it diminished within two weeks. Maximum seed yield (0.90 t/ha) of blackgram was obtained with two hoeings at 20 and 40 DAS which was at par with imazethapyr + pendimethalin at 1000 g/ha and pendimethalin at 1000 g/ha applied as pre-emergence. All herbicides, irrespective of their dose and time of application, did not cause any injury to mustard planted as succeeding crop after harvest of blackgram.

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Short communication

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Weed management in transplanted ragi

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Finger millet is the most important small millet grown in India in an area of 1.26 M ha with a production of 1.89 M t and a productivity of 1.48t /ha (Ministry of Agriculture 2010). The production and productivity of finger millet is low because of inefficient irrigation, nutrient management, heavy weed infestation, incidence of blast disease *etc*. Among these, weed infestation is a serious threat to its production. Uncontrolled weed growth during crop period reduced the grain yield ranging from 34 to 61% (Ramachandra Prasad *et al*. 1991).The critical period for crop-weed competition is five weeks after planting (Nanjappa 1980). In order to increase the productivity, it is imperative to minimize weed competition particularly during the critical period of the crop. Although manual weeding is effective, it is time consuming and labour intensive. By the time it practiced, the crop will have been sufficiently damaged by weed competition. So, controlling weeds by the use of herbicides is receiving attention due to shortage of labour and increased labour wages. There is also a demand from farmers for the selective pre or post emergence herbicides which became cheaper when compared to manual weeding for timely control of weeds in ragi crop. Hence, this investigation was planned with an objective to find out the most suitable weed management practice for control of weeds in transplanted ragi.

A field experiment was conducted during *Kharif* 2011 at Agricultural College, Bapatla, Guntur, Andhra Pradesh. The soil of the experimental field was sandy soil in texture with low in available nitrogen but medium in available phosphorus and potassium with a pH of 7.6. The experiment consisting of ten treatments was laid out in a randomized block design with three replications. Ragi seedlings of 30 days old were transplanted with one seedling per hill with a spacing of 30 x 10 cm. The recommended dose of 30, 70 and 25 kg N, P_2O_5 and K_2O/ ha was applied as basal at the time of transplanting. Top dressing of N at 30 kg/ ha was also done. The source for nitrogen, phosphorous and potassium were urea, single super phosphate and muriate of potash, respectively. The crop was irrigated as and when needed. All the recommended package of practices except weed management was adapted to raise the crop during experimentation. Data on weed density and weed dry matter were recorded at harvest. The data on weed density was subjected to square root $\sqrt{x + 0.5}$ transformations before statistical analysis to normalize their distribution. Growth parameters like plant height, drymatter production, number of productive tillers, grains per finger and grain yield were recorded at harvest.

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Effect on weeds

The dominant weed flora of the experimental field was *Cynodon dactylon* and *Digitaria marginata* among grasses; *Cyperus bulbosus,* among sedges; *Sesamum ekamberi, Trianthema portulacastrum,* and *Portulaca oleracea* were broad-leaved weeds.

All the weed control treatments significantly reduced the weed growth over weedy check at harvest (Table 1). All the integrated treatments were significantly superior to alone application of herbicides but at par with sequential application of herbicides in reducing weed density and weed dry weight. Among the treatments, pre-emergence application of oxadiargyl 100g/ha *fb* inter-cultivation with weeder at 20 DAT recorded the lowest weed growth with higher weed control efficiency and was on par with all other treatments including hand weeding at 15 and 30 DAT. Among alone application of herbicides, pre-emergence application of oxadiargyl 100g/ha recorded the lowest weed growth but was at par with other alone application of herbicides.

Effect on crop

Slight phytotoxicity was observed with the post-emergence application of bispyribac sodium 25 g/ha but crop recovered subsequently within a week. All the weed control treatments significantly improved the growth, yield components and yield of ragi over weedy check (Table 2). Among the treatments, pre-emergence application of oxadiargyl 100 g/ha *fb* inter-cultivation at 20 DAT recorded higher plant height, crop dry weight, maximum number of productive tillers, grains per finger and highest grain yield of 2.47 t/ha and it was on par with all other treatments including hand weeding treatment which recorded the highest grain yield (2.63 t/ha) but significantly superior to alone application of

Table 1. Effect of weed management treatments on weed and crop growth parameters in transplanted ragi

Treatment	Dose (g/ha)	Time (DAT)	Weed density (no/m^2) at harvest	Weed dry weight (g/m^2) at harvest	WCE (%) at harvest	Plant height (cm)	Productive tillers (no./m^2) at harvest	Crop dry wt. at harvest (g/m^2)
Pendimethalin	750	3	7.88 (62.0)	74.33	45	94.6	80.7	637.3
Oxadiargyl	100	3	7.80 (60.3)	72.67	46	96.0	83.3	648.3
Bispyribac sodium	25	15	7.88 (61.6)	73.43	45	93.9	81.3	623.1
Pendimethalin *fb* bispyribac sodium	750 *fb* 25	20	5.94 (34.8)	58.43	57	98.1	98.0	780.1
Oxadiargyl *fb* bispyribac sodium	100 *fb* 25	3 *fb* 20	5.72 (32.3)	56.23	59	100.0	99.0	792.9
Pendimethalin *fb* intercultivation	750	3 *fb* 20	5.24 (26.9)	55.13	59	102.1	104.3	812.0
Oxadiargyl *fb* intercultivation	100	3 *fb* 20	4.84 (23.1)	49.27	63	106.8	105.3	837.1
Bispyribac sodium *fb* intercultivation	25	15 *fb* 30	5.12 (26.2)	50.23	63	96.5	101.3	809.7
Hand weeding	-	15 and 30	4.20 (17.6)	40.20	70	112.0	112.3	868.5
Weedy check	-	-	10.68 (113.6)	135.43	-	82.2	61.0	468.9
LSD (P=0.05)			0.88	12.47	9	12.8	16.8	147.7

DAT-Days After Transplanting, Data transformed to $\sqrt{x+0.5}$ transformation in case of weed density. Figures in parentheses are original values

Table2. Effect of different treatments on yield, yield parameters and economics of transplanted ragi

Treatment	Dose (g /ha)	Time (DAS)	Fingers per ear (no.)	No. of grains per finger (no.)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Net returns (x10^3 `/ha)	Returns per rupee investment (`)
Pendimethalin	750	3	7.10	99.7	2.82	1.77	5.60	12.40	1.98
Oxadiargyl	100	3	7.11	100.7	2.88	1.80	5.66	12.88	2.02
Bispyribac-sodium	25	15	7.07	97.7	2.86	1.75	5.54	11.40	1.86
Pendimethalin *fb* bispyribac- sodium	750 *fb* 25	20	7.23	122.3	2.88	2.33	6.42	17.97	2.25
Oxadiargyl *fb* bispyribac sodium	100 *fb* 25	3 *fb* 20	7.26	129.0	2.89	2.36	6.55	18.52	2.29
Pendimethalin *fb* inter-cultivation	750	3 *fb* 20	7.30	137.3	2.91	2.39	6.66	18.39	2.24
Oxadiargyl *fb* inter-cultivation	100	3 *fb* 20	7.34	141.3	2.92	2.46	6.85	19.44	2.31
Bispyribac sodium *fb* inter-cultivation	25	15 *fb* 30	7.23	136.3	2.89	2.38	6.57	17.50	2.12
Hand weeding	-	15 & 30	7.42	148.0	2.94	2.63	7.27	16.03	1.78
Weedy check	-	-	6.93	79.7	2.70	1.17	3.81	5.08	1.44
LSD (P=0.05)			NS	13.9	NS	0.30	0.84		

herbicides. Among the alone application of herbicides, oxadiargyl 100 g/ha recorded the highest grain yield (1.809 t/ha) followed by pendimethalin (1.77 t/ha). The increased yield in the inter-cultivation and sequential treatments might be due to better weed control at initial stages by pre-emergence application of herbicides and subsequently by inter-cultivation or sequential application of herbicides during critical period of crop-weed competition, which might have resulted in increased and translocation of photosynthates sufficient to the sink needs. The results are similar with those reported by Channa Naik *et al.* (2000) with the application of butachlor at 0.5 kg/ha along with hoeing. The lowest yield (1.17 t/ha) was observed in weedy check with a yield loss of 55% compared to two hand weedings.

Among the weed management treatments, the highest net returns (` 19,436/-) and the highest returns per rupee investment (2.31) were obtained with the treatment, pre-emergence application of oxadiargyl 100 g/ha *fb* inter-cultivation at 20 DAT. The higher net returns in this inter-cultivation treatment (T_8), when compared to hand weeding was not because of higher yield, but because of lower cost involved in herbicide application and in intercultivation than hand weeding.

SUMMARY

Among the treatments, pre-emergence application of oxadiargyl 100 g/ha *fb* intercultivation at 20 DAT should sinificanty higher growth and yield attributes.

From the results, it can be summarised that the highest grain yield and maximum economic returns in transplanted ragi were obtained with pre-emergence application of oxadiargyl 100 g/ha *fb* intercultivation at 20 DAT by obtaining season-long weed control .

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