Print ISSN
0253-8040

Online ISSN
0974-8164

Indian Journal of Weed Science

Volume 44 | Number 1 | January – March 2012

Available Online @ www.indianjournals.com

Indian Society of Weed Science
Directorate of Weed Science Research
Jabalpur - 482004
Website: www.isws.org.in

INDIAN SOCIETY OF WEED SCIENCE

(Founded in 1968)

Regd. S. No. SOR/BLU/DR/518/08-09

IJWS REGD. NO. MAG (5) PRB 249/82-83

Indian Journal of

Weed Science

Volume 44 **Number 1** **January-March, 2012**

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Indian Journal of Weed Science **44**(1): 1–5, 2012

Bioefficacy of tembotrione against mixed weed complex in maize

V. Pratap Singh*, S.K. Guru, A. Kumar, Akshita Banga and Neeta Tripathi
G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand 263 145

Received: 21 November 2011; Revised: 28 February 2012

ABSTRACT

A field experiment was conducted at the Norman E. Borlaug Crop Research Center, Pantnagar, during the rainy seasons of 2009 and 2010 to evaluate the efficacy of tembotrione (42% SC), a new post-emergence herbicide against mixed flora in maize as well as its residual effect on growth and yield of the succeeding mustard crop. The experimental field was highly infested with *Echinochloa colona, Digitaria sanguinalis* and *Cyperus rotundus*. Post emergence application of tembotrione 120 g/ha along with surfactant was found most effective to control the grassy as well as non-grassy weeds as compared to other herbicidal treatments either applied as pre or post emergence. This treatment also recorded highest grain yield during both the years which was at par with a lower dose (110 g/ha + surfactant) or even pre emergence application of the herbicide. Addition of surfactant (1000 ml/ha) increased the kernel yield significantly and reduced the density of weeds effectively as compared to the application of tembotrione without surfactant. No residual effects were observed on the growth and yield of succeeding mustard crop.

Key words: Herbicides, Maize, Tembotrione, Weed flora, Yield

Maize (*Zea mays* L.) is the most important cereal crop after wheat and rice, grown in virtually every suitable agricultural region of the globe. In India, it is cultivated as a food as well as feed crop under varying soil, topography, seasons and management practices throughout the country.

A wider row spacing and sowing of the crop with the onset of monsoon provides a favorable environment for weed growth. Apart from offering competition for light, space and moisture, it also helps the weeds to absorb more nutrients than the crop. A higher level of infestation combined with many weed species pose a major problem in *Kharif* maize. Almost all types of weeds *viz.*, grassy, BLWs and sedges infest the maize fields. The extent of nutrient loss varies from 30-40% of the applied nutrients (Mundra *et al.* 2002). Weeds being a serious negative factor in crop production are responsible for marked loss (28-100%) in crop yield (Pandey *et al.* 2001). Atrazine, recommended as a pre-emergence herbicide, is not effective against some of the weeds, both grassy and non grassy as well as the sedge *Cyperus rotundus*. Hence, there is need for some alternate post-emergence herbicide which can provide broad spectrum weed control in *Kharif* maize without affecting the crop growth and yield of crop.

Keeping in view the above facts, the present investigation was carried out for the evaluation of post-emergence herbicide tembotrione 42% SC with or without surfactants against mixed weed complex in maize at the G.B.P.U.A & T, Pantnagar during *Kharif* 2009 and 2010.

MATERIALS AND METHODS

A field experiment was conducted at the Norman E. Borlaug, Crop Research Center, Pantnagar, during *Kharif* 2009 and 2010 in a randomized block design with twelve treatments replicated thrice. The treatments consisted of three doses of tembotrione *viz.,* 100, 110 and 120 g/ha with or without surfactant (1000 ml/ha) , 2-4,D Na salt (80 WP, 800 ml/ha), atrazine, diuron and pendimethalin (1000 ml/ha) and twice hand weeding (at 20 and 40 DAS) while an untreated plot served as a control.

Maize crop variety *'4212'* was sown on 24th June, 2009 and 17th June, 2010 during the first and second years, respectively, in plots of size 3.0m x 5.0m. Herbicides were sprayed with Knapsack sprayer fitted with flat fan nozzle. In 2009, pre-emergence herbicides (atrazine, pendimethalin and diuron) were applied on June 24, 2009 and the post-emergence herbicide tembotrione alone or in combination with surfactant was applied on July 10, 2009 while in 2010, pre-emergence were applied on June 19, 2010 and post emergence on July 7, 2010. The different cultural practices recommended for maize crop were adopted during the crop growth period. Crop was harvested on September 23, 2009 and September 24, 2010, respectively.

Weed sampling was done randomly by placing a 0.5 x 0.5 m quadrate at four different locations in the experimental unit to assess the weed flora at 30 and 45 DAS and the number of weed species were counted and expressed

*Corresponding author: vpratapsingh@rediffmail.com

in number/m^2. Dry weight of total weed species was recorded after drying and expressed in g/m^2. Observations for yield and yield attributing characters were recorded after the harvest of crop.

The succeeding mustard crop was sown in RBD with five treatments, which include four doses of tembotrione *viz*., 100, 110, 120 and 240 g/ha along with surfactant (1000 ml/ha) and untreated plot as a control. Mustard variety *"Kranti"* was sown on October 14, 2009 and October 12, 2010 during *Rabi* season in the different experimental plot with a row to row spacing of 50 cm. Crop was harvested on March 5, in both the years.

The experimental data obtained during the course of investigation were subjected to statistical analysis by analysis of variance (ANOVA) for the randomized block design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level. Standard error of mean was calculated in each case. When the 'F' value from analysis of variance tables was found to be significant, the critical difference (C.D.) was computed to test the significance of the difference between the two treatments.

RESULTS AND DISCUSSION

The experimental plot was uniformly infested with the grassy weeds *Echinochloa colona* (41.0 and 49.4%), *Digitaria sanguinalis* (6.6 and 12.0%), *Bracharia ramose*(4.7 and 3.7%) while the BLWs included *Phyllanthus niruri* (4.3 and 5.94%), *Cleome viscosa* (2.7 and 3.5%) and *Trianthema monogyna*. *Cyperus rotundus* was the only sedge during both the seasons (Tables 3 and 4).

Weed population

All the weed control treatment significantly reduced weed population compared to that in weedy check plots (Tables 1, 2, 3 and 4). Tembotrione (post-emergence) along with surfactant was found to be very effective in reducing the weed density and their growth. Density of both grassy and non-grassy weeds decreased with increase in the doses of the tembotrione from 100 to 120 g/ha at both the stages of observation (30 and 45 days after sowing). Addition of surfactant was found to increase the bio-efficacy of tembotrione in reducing the density of weeds. Among the pre-emergence herbicides, atrazine was found most effective in reducing the weed density over other herbicides.

Among the herbicidal treatments, tembotrione at all the three doses (100, 110 and 120 g/ha) when applied post-emergence with the surfactant at 2-4 leaf stage of weeds registered significantly less population of all the weed species compared to the herbicidal treatments at both the stages of observation. Among the different doses of tembotrione, higher dose (120 g) was found more effective than its lower doses in reducing the weed density at both 30 and 45 DAS. Application of tembotrione along with the surfactant at all the doses was found superior than the application of tembotrione alone or other herbicides applied as pre-emergence or the hand weeding treatment in reducing the weed population during both the years of study.

Echinochloa colona among the grassy and *Cyperus rotundus* among the sedges were the most dominating weeds in maize at both the stages during both the years. Among all the weed species, *Bracharia ramose* and *Cleome*

Table 1. Effect of treatments on grassy weeds (m^2) at 30 days after sowing in maize

Treatment	Dose	Application stage	Grassy					
			E.colona		*D. sanguinalis*		*B. ramosa*	
			2009	2010	2009	2010	2009	2010
Tembotrione+S	100+S	15-20 DAS	4.0(56.0)	3.9(47.3)	2.0(6.7)	1.5(5.3)	0.0(0.0)	0.0(0.0)
Tembotrione+S	110+S	15-20 DAS	3.8(46.0)	3.6(34.7)	1.1(2.7)	1.1(2.7)	0.0(0.0)	0.0(0.0)
Tembotrione+S	120+S	15-20 DAS	3.5(32.0)	3.2(24.7)	0.5(1.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Tembotrione	100	15-20 DAS	4.6(97.3)	4.7(112.0)	2.5(12.0)	2.4(10.7)	1.7(4.7)	1.7(4.3)
Tembotrione	110	15-20 DAS	4.3(80.0)	4.6(98.7)	2.4(10.7)	1.5(5.3)	1.7(4.3)	1.6(4.0)
Tembotrione	120	15-20 DAS	4.2(63.3)	4.0(56.0)	2.3(9.3)	1.5(5.3)	1.4(3.0)	1.4(3.0)
Atrazine	1000	0-3 DAS	3.6(34.7)	4.7(106.7)	1.1(2.7)	0.5(1.3)	0.0(0.0)	0.5(1.3)
Pendimethalin	1000	0-3 DAS	4.2(68.0)	5.0(149.3)	2.0(6.7)	1.8(5.3)	0.0(0.0)	0.5(1.3)
2,4-D Na salt	800	20-25 DAS	5.3(203.3)	4.7(113.3)	3.3(26.7)	3.1(21.3)	2.4(10.7)	2.0(6.7)
Diuron	1000	0-3 DAS	3.9(51.3)	4.1(57.3)	2.4(10.7)	2.4(10.7)	1.1(2.7)	1.1(2.7)
Hand weeding	-	20 & 40 DAS	4.1(62.7)	3.7(41.3)	1.8(5.3)	2.3(9.3)	0.0(0.0)	1.1(2.7)
Weedy check	-	-	5.2(177.3)	5.5(254.7)	3.4(29.3)	3.3(26.7)	2.6(13.3)	1.9(6.7)
LSD (P=0.05)	-	-	0.3	0.3	0.8	1.2	0.5	1.0

Original values are given in parentheses; S - Surfactant

Table 2. Effect of treatments on non-grassy weeds (m^2) at 30 days after sowing in maize

Treatment	Dose	Application stage	Non-grassy weeds							
			P.niruri		*C. viscosa*		*T. monogyna*		*C. rotundus*	
			2009	2010	2009	2010	2009	2010	2009	2010
Tembotrione+S	100+S	15-20 DAS	1.1(2.7)	0.5(1.3)	0.0(0.0)	0.5(1.3)	1.1(2.7)	0.5(1.3)	3.7(41.3)	3.0(20.0)
Tembotrione+S	110+S	15-20 DAS	1.1(2.7)	0.5(1.3)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	3.5(32.0)	2.4(10.7)
Tembotrione+S	120+S	15-20 DAS	0.0(0.0	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	3.3(25.3)	2.0(6.7)
Tembotrione	100	15-20 DAS	1.8(5.3)	1.3(4.0)	1.6(4.0)	1.5(3.7)	1.6(4.0)	1.5(3.7)	4.4(78.7)	3.7(41.3)
Tembotrione	110	15-20 DAS	1.3(4.0)	1.3(4.0)	1.5(3.7)	1.2(2.3)	1.4(3.3)	1.4(3.3)	4.1(60.0)	3.2(24.0)
Tembotrione	120	15-20 DAS	1.1(2.7)	1.1(3.0)	0.9(2.0)	1.1(2.0)	1.4(3.3)	1.2(2.3)	4.0(54.7)	2.9(17.3)
Atrazine	1000	0-3 DAS	1.1(2.7)	0.5(1.3)	1.1(2.7)	0.5(1.3)	0.0(0.0)	0.0(0.0)	4.8(128.0)	4.3(77.3)
Pendimethalin	1000	0-3 DAS	2.0(6.7)	1.8(5.3)	2.0(6.7)	1.8(5.3)	1.8(5.3)	2.0(6.7)	4.8(130.0)	4.3(70.7)
2,4-D Na salt	800	20-25 DAS	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.5(1.3)	0.5(1.3)	3.4(30.7)	2.8(16.0)
Diuron	1000	0-3 DAS	1.1(2.7)	1.1(1.3)	1.1(2.7)	1.1(2.7)	1.8(5.3)	1.3(4.0)	4.0(56.0)	4.0(56.0)
Hand weeding	-	20 & 40 DAS	0.5(1.3)	0.5(1.3)	1.1(2.7)	0.5(1.3)	1.1(2.7)	1.1(2.7)	3.6(36.0)	3.6(34.7)
Weedy check	-		2.3(9.3)	2.0(6.7)	2.3(9.3)	2.0(6.7)	2.3(9.3)	2.0(6.7)	5.0(145.3)	4.4(85.3)
LSD (P=0.05)	-		1.2	NS	0.9	0.9	0.8	1.0	0.3	0.4

Original values are given in parentheses; S - Surfactant

Table 3. Effect of treatments on grassy weeds (m^2) at 45 days after sowing in maize

Treatment	Dose	Application stage	Grassy weeds					
			E.colona		*D. sanguinalis*		*B. ramosa*	
			2009	2010	2009	2010	2009	2010
Tembotrione+S	100+S	15-20 DAS	3.7(39.3)	3.5(32.7)	1.8(5.3)	1.1(2.7)	0.0(0.0)	0.0(0.0)
Tembotrione+S	110+S	15-20 DAS	3.6(36.0)	3.3(27.3)	1.1(2.7)	1.1(2.7)	0.0(0.0)	0.0(0.0)
Tembotrione+S	120+S	15-20 DAS	3.0(18.7)	3.0(18.7)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Tembotrione	100	15-20 DAS	4.1(61.3)	4.3(72.7)	2.4(10.7)	1.8(5.3)	1.7(4.3)	1.7(4.3)
Tembotrione	110	15-20 DAS	3.8(42.7)	4.0(52.0)	2.3(9.3)	1.3(4.0)	1.6(4.0)	1.7(4.3)
Tembotrione	120	15-20 DAS	3.7(40.7)	3.5(34.0)	2.1(8.0)	1.1(3.0)	1.4(3.3)	1.4(3.3)
Atrazine	1000	0-3 DAS	3.6(36.0)	3.5(32.7)	0.0(0.0)	1.1(2.7)	0.0(0.0)	0.0(0.0)
Pendimethalin	1000	0-3 DAS	4.2(69.3)	3.8(45.3)	2.2(9.3)	2.0(6.7)	0.0(0.0)	1.1(2.7)
2,4-D Na Salt	800	20-25 DAS	4.9(132.0)	4.6(101.3)	3.4(29.3)	3.2(25.3)	2.6(13.3)	1.1(2.7)
Diuron	1000	0-3 DAS	3.7((38.0)	4.0(58.7)	2.7(13.3)	2.7(14.7)	1.3(4.0)	1.8(5.3)
Hand weeding	-	20 & 40 DAS	3.8(44.0)	3.4(30.7)	2.0(6.7)	1.8(5.3)	0.0(0.0)	0.5(1.3)
Weedy check	-		5.0(152.0)	4.8(122.7)	3.5(32.0)	3.4(32.0)	2.9(17.3)	2.3(9.3)
LSD (P=0.05)	-		3.7(39.3)	0.3	0.7	1.1	0.6	0.8

Original values are given in parentheses; S - Surfactant

Table 4. Effect of treatments on grassy weeds (m^2) at 45 days after sowing in maize

Treatment	Dose	Application stage	Non –grassy weeds							
			P. niruri		*C. viscosa*		*T. monogyna*		*C. rotundus*	
			2009	2010	2009	2010	2009	2010	2009	2010
Tembotrione+S	100+S	15-20 DAS	1.1(2.7)	1.1(2.7)	0.0(0.0)	0.0(0.0)	0.5(1.3)	0.0(0.0)	3.5(32.7)	2.8(16.0)
Tembotrione+S	110+S	15-20 DAS	0.5(1.3)	1.1(2.7)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	3.2(22.7)	2.3(9.3)
Tembotrione+S	120+S	15-20 DAS	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)	2.8(16.7)	1.8(5.3)
Tembotrione	100	15-20 DAS	1.9(6.0)	1.7(4.6)	1.7(4.6)	1.2(4.0)	1.7(4.6)	1.6(4.3)	3.9(48.7)	3.2(30.7)
Tembotrione	110	15-20 DAS	1.7(4.6)	1.6(4.0)	1.6(4.0)	1.1(3.3)	1.6(4.0)	1.5(3.6)	3.7(41.3)	2.7(14.7)
Tembotrione	120	15-20 DAS	1.5(3.6)	1.5(3.6)	1.4(3.0)	1.1(3.0)	1.5(3.6)	1.1(3.0)	3.6(36.0)	2.4(10.7)
Atrazine	1000	0-3 DAS	1.1(2.7)	1.1(2.7)	1.8(5.3)	1.1(2.7)	0.0(0.0)	0.0(0.0)	4.8(116.0)	3.7(40.0)
Pendimethalin	1000	0-3 DAS	2.3(9.3)	2.0(6.7)	2.3(9.3)	2.0(6.7)	2.0(6.7)	1.8(5.3)	4.7(109.3)	3.7(40.7)
2,4-D Na salt	800	20-25 DAS	1.1(2.0)	1.0(2.3)	1.2(2.3)	0.9(2.0)	0.6(1.0)	0.9(2.0)	2.8(16.0)	2.0(6.7)
Diuron	1000	0-3 DAS	1.6(4.0)	1.1(2.7)	1.8(5.3)	1.8(5.3)	2.0(6.7)	1.1(2.7)	3.7(40.0)	3.2(25.3)
Hand weeding	-	20 & 40 DAS	0.0(0.0)	0.0(0.0)	0.5(1.3)	0.5(1.3)	0.0(0.0)	0.0(0.0)	2.0(14.0)	2.3(9.3)
Weedy check	-		2.8(16.0)	2.7(14.7)	2.4(10.)	2.2(8.7)	2.4(10.7)	2.1(8.0)	4.9(132.0)	4.0(52.7)
LSD (P=0.05)	-		0.8	1.0	0.6	1.1	0.6	0.7	0.9	0.6

Original values are given in parentheses; S - Surfactant *viscosa* were controlled effectively by the application of herbicides and manual weeding over the weedy plot. Application of tembotrione at higher dose 120g/ha + S was significantly superior to its lower doses 100 and 110 g/ha + S in reducing the density of all the weed species.

Weed dry weight

In general, weed dry matter was higher during the first year (2009) than the second year (2010) due to higher weed population. During both the years, the dry matter of weeds at 30 and 45 DAS was significantly reduced in all the weed control treatments over the weedy check (Figure 1 and 2). At 30 days after sowing, in 2009, the lowest weed dry matter was recorded with application of tembotrione at 120 g/ha + surfactant followed by its lower dose (110 g/ha + surfactant) and atrazine (1000 g/ha). At the same stage, during 2010, lowest weed dry matter was recorded in the hand weeding (twice) treatment which was superior to all other treatments. At 45 DAS, in both the years, the lowest weed dry weight was recorded with Tembotrione 120 g/ha + surfactant followed by its lower dose (110 g/ha + surfactant). Addition of surfactant was found to improve the bio-efficacy of Tembotrione in reducing the weed dry matter at all the doses.

Yield performance of maize

Weed control treatments brought about significant increases in no. of kernels per cob, kernel weight per cob and 100 kernel weight as compared to the weedy check (Table 5). In both the years the highest cob yield was recorded with the application of Tembotrione at 120 g/ha along with surfactant which was at par with tembotrione 110 g/ha + surfactant; twice hand weeding and pre emergence application of atrazine. However, no. of kernel rows per cob was unaffected by the different weed control treatments. Among the treatments, highest no. of kernel/cob was obtained with atrazine (422.5) in first year whereas in the second year, it was at par with Tembotrione along with surfactant. All the weed control treatments registered significantly higher kernel weight per cob and test weight over the weedy check.

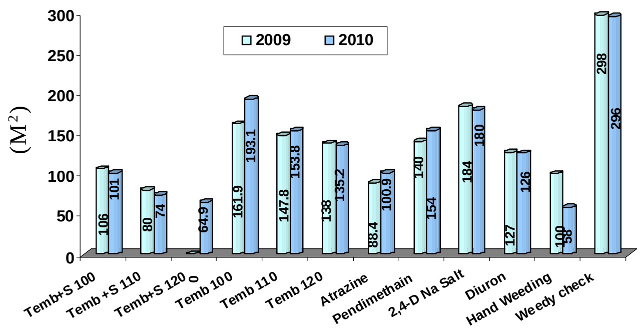

Fig. 1. Total dry weight of weeds (m^2) at 30 days after sowing in maize

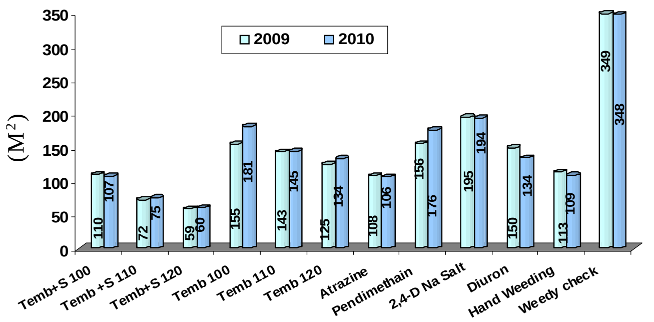

Fig. 2. Total dry weight of weeds (m^2) at 45 days after sowing in maize

Table 5. Effect of different treatments on yield and yield attributes of maize

Treatment	Dose (g/ha)	Application stage	No. of kernel rows per cob		No. of kernels per cob		Kernel weight per cob(g)		100, kernel weight (g)		Grain yield (kg/ha)	
			2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Tembotrione+S	100+S	15-20 DAS	14.0	14.3	408.6	442	107.3	120.0	26.2	26.4	4800	4950
Tembotrione+S	110+S	15-20 DAS	14.5	14.4	417.6	457	112.7	130.0	26.6	26.7	5167	5300
Tembotrione+S	120+S	15-20 DAS	14.5	14.5	435.7	475	116.3	130.3	27.3	27.2	5333	5483
Tembotrione	100	15-20 DAS	13.5	13.7	365.8	390	95.3	102.0	25.6	26.0	4283	4433
Tembotrione	110	15-20 DAS	13.5	13.7	376.0	401	99.7	103.3	26.3	26.2	4492	4583
Tembotrione	120	15-20 DAS	13.9	13.9	400.3	423	105.3	112.3	26.5	26.4	4533	4633
Atrazine	1000	0-3 DAS	14.6	14.1	442.5	433	118.3	116.7	26.8	26.4	5267	5283
Pendimethalin	1000	0-3 DAS	13.6	13.8	363.7	427	93.7	117.3	25.9	25.1	4667	4800
2,4-D Na salt	800	20-25 DAS	13.3	13.7	348.2	418	88.3	100.3	24.5	24.1	4267	4350
Diuron	1000	0-3 DAS	13.9	13.9	385.3	443	102.7	110.0	26.5	25.5	4633	4783
Hand weeding		20 & 40 DAS	14.3	14.6	439.5	462	116.0	123.3	26.4	27.0	5150	5233
Weedy check	-		12.1	12.5	280.6	376	65.3	84.3	22.0	22.3	2817	3017
LSD (P=0.05)	-		NS	NS	27.5	19.6	6.8	12.9	1.6	2.2	244	496

Table 6. Effect of treatments on germination, plant height, branches per plant and yield of succeeding mustard crop (*Rabi* 2009-10)

Treatment	Dose (g/ha) + surfactant	Germination (%)		Plant height (cm)		No. of branches /plant		Grain yield (kg/ha)	
		2009	2010	2009	2010	2009	2010	2009	2010
Tembotrione+S	100+1000	85.7	87.4	187.3	190.2	7.0	7.2	1283	1291
Tembotrione+S	110+1000	87.5	88.6	190.7	191.7	6.3	6.9	1283	1312
Tembotrione+S	120+1000	87.9	88.9	188.0	191.0	6.8	7.0	1325	1354
Tembotrione+S	240+2000	87.1	87.9	188.3	191.3	6.7	7.1	1350	1291
Weedy check	-	86.0	87.0	188.3	190.6	6.3	7.3	1270	1254
LSD (P=0.05)	-	NS	NS	NS	NS	NS	NS	NS	NS

Application of tembotrione 100 g/ha along with surfactant was found at par with application of pendimethalin and diuron but significantly superior over the application of 2,4-D with respect to their grain yield during both the years. Weedy plots recorded 50 and 40 per cent lower grain yield as compared to highest yield producing treatments (tembotrione 120 g/ha along with surfactant) during 2009 and 2010, respectively. The kernel yield was higher in the second year (2010) as compared to first year. The possible reason for the better performance of tembotrione at 120g/ha along with surfactant in terms of grain yield could be attributed to its effect on expression of yield attributes due to better weed suppression through significant reduction in dry weed weight and weed population and consequent reduction in crop-weed competition.

Succeeding crop

In succeeding mustard crop, all the parameters recorded such as germination per cent, plant height, number of branches/plant and grain yield were not affected due to combined application of tembotrione + surfactant in both the years (Table 6). Among the weed management practices, application of tembotrione 120g/ha + surfactant recorded higher germination percentage. Plant height was highest in the treatment tembotrione (110 g/ha) + surfactant over the weedy check during both the years. During 2009, the highest grain yield was recorded with tembotrione at 120g/ha + surfactant whereas in 2010, it was highest at the higher dose i.e 240 g/ha + surfactant.

Based on the field studies conducted for two years, it was concluded that tembotrione 120 g/ha along with surfactant is effective for controlling the grassy and non-grassy weeds as compared to other herbicidal treatments. Addition of surfactant 1000 ml/ha formulation was found to increase the kernel yield significantly as compared to application of tembotrione without it. Application of tembotrione + surfactant in mustard crop significantly reduced the growth and development of weeds and increased the yield as compared to weedy check. Moreover, there was no phytotoxic effect on either crop.

ACKNOWLEDGEMENT

The authors acknowledge Bayer Crop Science, India Pvt. Ltd., Hyderabad (India) for funding the project and sparing the herbicide molecules for the present investigation.

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Indian Journal of Weed Science **44**(1): 6–10, 2012

Management of dodder in lucerne and Egyptian clover

J.S. Mishra*
Directorate of Weed Science Research, Jabalpur, Madhya Pradesh 482 004

Received: 30 July 2011; Revised: 25 October 2011

ABSTRACT

Field dodder (*Cuscuta campestris*), the most damaging annual obligate stem parasite is a serious problem in forage legumes lucerne (*Medicago sativa* L.) and Egyptian clover (*Trifolium alexandrinum* L.). Studies were conducted to investigate the interference of *C. campestris* densities in lucerne and the efficacy of herbicides for its control in lucerne and Egyptian clover. Even at *Cuscuta* density of 0.25 plants/m^2 (1 plant/4m^2) caused detrimental effect on lucerne seed yield (85.5-95.3% loss). A high dose of pendimethalin (1000 g/ha) applied pre-emergence reduced *Cuscuta* emergence but was phytotoxic to lucerne as compared to lower doses and application at 14 days after sowing (DAS). Application of imazethapyr 100 g/ha and pendimethalin 750 g/ha at 14 DAS significantly improved green fodder yield of lucerne but failed to control *Cuscuta* infestation at reproductive stage resulting in poor seed yield. Method of seeding did not influence the population and green fodder yield of Egyptian clover and *Cuscuta* emergence. Post-emergence (at 14 DAS) application of pendimethalin 500-750 g/ha effectively controlled *Cuscuta campestris* in Egyptian clover and produced the maximum green fodder and seed yields.

Key words: Berseem, *Cuscuta*, Herbicides, Interference, Lucerne, Pendimethalin

Lucerne (alfalfa) (*Medicago sativa* L.) and Egyptian clover (berseem) (*Trifolium alexandrinum* L.) are the major forage crops grown worldwide. In India, these crops are extensively grown in irrigated areas during winter season. Field dodder (*Cuscuta campestris* Yuncker) is a serious problem in these forage legumes and lucerne was reported to be highly susceptible to *Cuscuta* than the Egyptian clover (Farah and Al-Abdulsalam 2004). Seeds of *Cuscuta* are ideally suited to be transported as a contaminant of alfalfa and clover seeds (Dawson *et al*. 1994). During the seed production of these crops, *Cuscuta* seeds are harvested with the crop seed and being similar in size and density to the forage legume seed, it is extremely difficult to separate from the crop seed and consequently, *Cuscuta* is often seeded with forage legumes (Dawson *et al*. 1994). Infestation of *C. campestris* caused more than 50% reduction in forage and seed yields of alfalfa (Cudney *et al*. 1992). Movsesyan and Azaryan (1974) reported that *C. campestris* can be poisonous to animals if it exceeds 5% of the total roughage.

Manual removal and frequent inter-row cultivation before the parasite attaches the host plant are the usual control measures. However, these methods are laborious and often not effective. As dodder is able to compete with lucerne and is not readily controlled by herbicide, knowledge of density dependent effects of dodder interference in lucerne for the successful implementation of the economic threshold concept is needed to develop an integrated weed management programme. Dinitroaniline herbicides (trifluralin, pendimethalin and prodiamine) provide pre-emergence dodder control without injury to alfalfa (Orloff *et al*. 1989). However, Barevadia *et al*. (1998) reported that application of pendimethalin at 0.50 kg/ha as pre-emergence and at 4 days after sowing (DAS), and fluchloralin at 0.50 kg/ha as pre-plant incorporation and at 4 DAS showed severe phytotoxicity to lucerne seedlings. Therefore, efficacy of pendimethalin with different rates and timing of application and newer herbicides, known to have activity against *Cuscuta* and safe to alfalfa and clover needs to be evaluated. The objectives of the present study were to investigate (i) the interference of *C. campestris* densities and (ii) the efficacy of herbicides for its control in lucerne and Egyptian clover.

MATERIALS AND METHODS

Four field experiments were conducted during winter seasons of 2005-06 and 2006-07 at the Directorate of Weed Science Research, Jabalpur (23^0 90' N, 79^0 58' E, 412 m above mean sea level). In all the four experiments, crops were grown with a recommended package of practices other than weed control. *Cuscuta* seeds were treated with concentrated sulfuric acid for 30 min before broadcasting them in the field to break seed dormancy and to facilitate germination. Fifty *Cuscuta* seeds/m^2 were uniformly broadcasted near the soil surface (2-3 cm depth) in each plot (except in *Cuscuta* free plots) before sowing of lucerne and Egyptian clover. Lucerne (*cv.* Anand 2)

***Corresponding author:** jsmishra31@gmail.com
Present address: *Directorate of Sorghum Research, Rajendranagar, Hyderabad, Andhra Pradesh 500 030*

was sown in rows 20 cm apart in first week of November during both the years with a seed rate of 15 kg/ha. The seed was treated with *Rhizobium melilotii* culture which helps in nitrogen fixation after the establishment of the seedlings. The soil was clay loam (Typic chromusterts), low in available nitrogen (242 kg/ha), medium in available phosphorus (37 kg/ha), and high in available potassium (315 kg/ha), with organic carbon 0.54% and pH 7.1. Pendimethalin was applied with a knapsack sprayer fitted with flat fan nozzle at a spray volume of 500 l/ha. Number of *Cuscuta campestris* and clover emerged/m^2 were recorded at 30 DAS. All the weeds except *Cuscuta* were removed from the plots manually as and when required. Total 3 cuttings were taken for green fodder yields. The first cutting was done at 60 DAS and subsequent 2 cuttings were done at 30 days intervals when the crop attained the height of around 45 cm from the ground. The cuttings were done at about 5-7 cm height for better quick growth. The total fodder yield includes the weight of *Cuscuta* vines as it was difficult to remove it from the host plants. The crops were left for seed production after the 3rd cutting and given light irrigations until flowering and seed setting. These were harvested in the last week of May.

Interference of *Cuscuta campestris* in lucerne

Treatments consisting of varying densities of *Cuscuta* (0, 0.25, 0.5, 1, 2, 4, and 8 plants/m^2) were replicated thrice in a randomized block design. The *Cuscuta* densities of 0.25 and 0.50/m^2 were maintained by keeping 1 and 2 plants/4 m^2 area, respectively. The plot size was 4 m^2 leaving 1m wide discards between plots. *Cuscuta* densities as per the treatments were maintained at 20 days after sowing by removing the excess plants.

Bio-efficacy of pendimethalin against *Cuscuta campestris* in lucerne in relation to dose and time of application

This experiment was conducted to evaluate the efficacy of pendimethalin as influenced by its dose and time of application. Treatments consisted of three doses of pendimethalin (0.50, 0.75 and 1.0 kg/ha) and 3 timing of application (1, 7 and 14 days after sowing) were replicated thrice in a factorial randomized block design. *Cuscuta* infested and *Cuscuta* free checks were also kept for comparison. The experiment was laid out in micro plots (4 m^2).

Bio-efficacy of herbicides against *Cuscuta campestris* in lucerne

Different herbicides (pendimethalin, fluchloralin, imazethapyr, butachlor and pretilachlor) along with 1 hand weeding at 30 days after sowing, *Cuscuta* infested and *Cuscuta* free checks were evaluated for their relative efficacy against *Cuscuta campestris* in lucerne. Treatments were replicated thrice in a randomized block design.

Bio-efficacy of pendimethalin against *Cuscuta campestris* in Egyptian clover in relation to method of sowing, dose and time of application

An experiment was conducted to evaluate the efficacy of pendimethalin as influenced by method of sowing, dose and time of application. Treatments consisted of two methods of sowing (dry and wet seeding), three doses of pendimethalin (0.50, 0.75 and 1.0 kg/ha) and 3 timing of application (1, 7 and 14 days after sowing) were replicated thrice in a split-plot design. *Cuscuta* infested and *Cuscuta* free checks were also kept for comparison. Egyptian clover (*cv*. Vardan) was sown by broadcasting in the first week of November during both the years with a seed rate of 30 kg/ha. In dry bed method, seed was broadcasted, mixed and covered with half to one cm fine soil. Sprinkler irrigation was given after sowing for proper germination. In case of wet sowing, plots were flooded with 5-6 cm deep water and puddled before broadcast sowing.

RESULTS AND DISCUSSION

Interference of *Cuscuta campestris* in lucerne

It was observed that increasing densities of *Cuscuta campestris* did not influence the initial (at 30 DAS) plant population of lucerne. Total green fodder yield declined significantly with increasing *Cuscuta* densities (Table 1). *Cuscuta* density of 2 plants/m^2 during 2005-06 and a single plant/m^2 during 2006-07 caused significant reduction (15.87 and 15.10%, respectively) in green fodder yield of lucerne as compared to *Cuscuta* free treatment. Seed yield of lucerne declined drastically (95.3 and 85.45%, respectively during 2005-06 and 2006-07) even at *Cuscuta* density of 0.25 plants/m^2 (1 plant/4 m^2). Increasing density of *Cuscuta* up to 1 plant/m^2 increased its seed production capacity. However, further increase in *Cuscuta* densities resulted in significant decline in its seed production capacity. This might be due to the fact that higher *Cuscuta* densities resulted in to restricted growth of host plant leading to reduced supply of resources and poor growth of the parasite.

Bio-efficacy of pendimethalin against *Cuscuta campestris* in lucerne in relation to dose and time of application

Increasing dose of pendimethalin from 500 to 1000 g/ha though significantly reduced the *Cuscuta* emergence but also caused phytotoxicity to lucerne crop and reduced its population significantly (Table 2). Total fodder yield did not vary significantly during 2005-06, however, during 2006-07, application of pendimethalin at 1000g/ha

Table 1. Interference of *Cuscuta* in lucerne

Treatment (*Cuscuta* density/m^2)	Number of lucerne emerged/m^2 at 30 DAS		Green fodder yield* (t/ha) (total of 3 cuttings)		Seed yield of lucerne (kg/ha)		Seed yield of *Cuscuta* (kg/ha)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
0	161	172	22.49	23.17	246.67	352.20	0	0
0.25	141	168	20.14	21.85	11.64	51.23	349	396
0.50	167	170	21.85	21.66	11.81	46.15	424	425
1	138	153	20.75	19.67	9.61	26.30	483	464
2	128	169	18.92	18.32	4.82	21.85	391	407
4	157	178	17.83	16.14	2.96	12.04	361	368
8	150	159	16.67	15.63	3.05	10.68	193	208
LSD (P=0.05)	NS	NS	2.99	2.16	19.8	15.32	68	57

DAS-Days after sowing, *Including weight of *Cuscuta* vines.

Table 2. Efficacy of pendimethalin against *Cuscuta campestris* in lucerne

Treatment	Number of lucerne emerged/m^2 at 30 DAS		Number of *Cuscuta* emerged/m^2 at 30 DAS *		Green fodder yield (t/ha) (total of 3 cuttings)		Seed yield (kg/ha)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Dose of pendimethalin (g/ha)								
500	122	158	0.85 (0.22)	2.93 (8.08)	25.35	26.47	461	23.33
750	119	142	0.78 (0.11)	2.88 (7.79)	24.40	26.81	352	49.57
1000	76	111	0.74 (0.05)	1.88 (3.03)	24.16	22.09	359	158.33
LSD (P=0.05)	12	15	0.09	0.30	NS	1.07	35	17.5
Time of application of pendimethalin (DAS)								
1 (pre-emergence)	83	124	0.85 (0.22)	2.42 (5.36)	22.88	22.86	351	15.56
7	110	135	0.79 (0.12)	2.98 (8.38)	24.82	24.31	406	48.78
14	124	152	0.72 (0.02)	2.29 (4.74)	26.13	28.20	415	166.89
LSD (P=0.05)	12	15	0.09	0.30	2.61	1.08	35	15.8
Cuscuta-infested	142	165	(2.5)	(5.03)	13.05	22.53	0	5.67
Cuscuta-free	144	163	(0)	(0)	31.78	30.09	512	850

*Square root transformed ($\sqrt{x+0.5}$); figures in parentheses are original values, DAS-Days after sowing.

caused significant reduction compared to its lower doses (750 and 500 g/ha). Significantly maximum seed yield (461 kg/ha) was obtained at lower level of pendimethalin (500 g/ha) probably due to lower level of *Cuscuta* infestation during 2005-06. However, during 2006-07 application of pendimethalin at 1000 g/ha produced the maximum seed yield of lucerne due to better control on *Cuscuta* emergence. Application of pendimethalin at 14 DAS was safe for lucerne emergence as compared to its application as pre-emergence at 7 DAS and also effective in reducing *Cuscuta* emergence. The maximum fodder and seed yields of lucerne were also recorded with pendimethalin applied at 14 DAS.

Bio-efficacy of herbicides against *Cuscuta campestris* in lucerne

Application of herbicides significantly reduced the *Cuscuta campestris* emergence in lucerne as compared to the *Cuscuta*-infested control treatment (Table 3). Among different herbicides, pendimethalin 750 g/ha as pre-emergence, pendimethalin 750 g/ha at 14 DAS and imazethapyr 100 g/ha at 14 DAS were the most effective and significantly better than fluchloralin 1000 g/ha as pre-plant incorporation, pretilachlor 750 g/ha and butachlor 1000 g/ha as pre-emergence in reducing *Cuscuta* emergence during both the years. Liu *et al*. (1990) reported that pendimethalin inhibited the cell division and formation of spindle microtubules in the cells of germinated *Cuscuta* seedlings. Imazethapyr 100 g/ha at 14 DAS was significantly better than its pre-emergence application in reducing *C. campestris* emergence. All the above herbicides, though they significantly reduced the initial *Cuscuta* population could not check the growth of remaining *Cuscuta* plants, which ultimately infested the lucerne plants severely, especially after 3rd cutting when left for seed production, and reduced the seed yield considerably. All the herbicides except imazethapyr as pre-emergence caused slight reduction in lucerne plant population at 30 DAS as com-

Table 3. Efficacy of herbicides against *Cuscuta* in lucerne

Treatment	Number of *Cuscuta* emerged/m^2 at 30 DAS *		Number of lucerne emerged/m^2 at 30 DAS		Green fodder yield (t/ha) (total of 3 cuttings)		Seed yield of lucerne (kg/ha)		Seed yield of *Cuscuta* (kg/ha)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Pendimethalin 750 g/ha (PE)	1.12 (0.75)	1.33 (1.22)	128	137	9.26	10.74	23.21	7.38	462	521
Pendimethalin 750 g/ha (14 DAS)	1.18 (0.89)	1.80 (2.74)	159	161	13.87	13.99	25.67	9.58	436	592
Fluchloralin 1000 g/ha (PPI)	2.06 (3.74)	2.39 (5.21)	163	170	12.34	12.62	22.00	10.53	382	363
Imazethapyr 100 g/ha (PE)	2.65 (6.52)	3.22 (9.87)	189	196	10.21	11.69	16.89	7.04	263	168
Imazethapyr 100 g (14 DAS)	1.15 (0.82)	1.78 (2.67)	172	179	13.90	14.26	18.12	8.42	302	296
Butachlor 1000 g/ha (PE)	2.14 (4.08)	2.84 (7.57)	175	169	10.63	11.30	15.36	7.97	289	224
Pretilachlor 750 g/ha (PE)	2.23 (4.47)	2.54 (5.95)	159	162	10.33	11.29	10.50	5.26	265	200
1 hand weeding at 30 DAS	2.66 (6.58)	3.39** (11.0)	185	197	10.50	11.08	12.78	9.22	310	312
Cuscuta free	0.71 (0.00)	0.71 (0.00)	182	197	14.86	15.10	192.5	209.6	-	-
Cuscuta infested	2.58 (6.16)	3.35 (10.72)	186	195	9.63	10.75	10.62	5.19	406	420
LSD (P=0.05)	0.36	0.48	46	51	1.71	1.62	15.55	17.38	93	101

PE-pre-emergence; PPI-pre-plant soil incorporation; DAS-days after sowing.
*Square root transformed ($\sqrt{x+0.5}$); figures in parentheses are original values, **Population before hand weeding.

Table 4. Efficacy of pendimethalin against *Cuscuta campestris* in Egyptian clover

Treatment	Number of Egyptian clover emerged/m^2 at 30 DAS *		Number of *Cuscuta* emerged/m^2 at 30 DAS *		Green fodder yield (t/ha) I cutting		II cutting		III cutting		Total		Seed yield (kg/ha)	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Method of sowing														
Dry seeding	169	176	1.01 (0.52)	1.26 (1.09)	5.73	10.08	13.16	20.81	25.44	17.30	43.47	47.95	638	854
Puddle broadcast	165	172	0.95 (0.40)	1.24 (1.04)	5.71	9.93	15.82	25.13	22.10	16.21	42.79	51.19	433	837
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	93	NS
Dose of pendimethalin (g/ha)														
500	169	178	1.04 (0.58)	1.38 (1.40)	6.05	10.12	15.55	22.91	22.93	16.76	45.76	49.23	477	831
750	168	173	1.00 (0.50)	1.23 (1.01)	5.91	11.23	13.92	24.72	22.06	19.63	41.84	55.64	619	854
1000	165	171	0.90 (0.31)	1.14 (0.80)	5.20	8.67	14.08	21.29	22.22	13.87	41.71	43.83	511	850
LSD (P=0.05)	NS	NS	0.07	0.15	0.70	1.35	1.47	2.29	NS	1.34	3.87	3.39	39	NS
Time of application of pendimethalin (DAS)														
1 (pre-emergence)	138	116	0.84 (0.21)	1.30 (1.19)	4.46	11.78	13.84	21.57	22.29	16.94	42.08	45.66	526	809
7	20	45	0.78 (0.11)	1.20 (0.94)	1.13	9.04	8.16	23.61	18.17	15.31	27.37	47.78	370	847
14	343	362	1.32 (1.24)	1.26 (1.09)	11.61	9.19	21.51	23.75	26.74	18.01	59.85	55.27	710	880
LSD (P=0.05)	25	28	0.09	NS	0.75	1.43	2.20	1.92	1.53	2.03	3.33	4.4	50	NS
Cuscuta- infested	347	378	(3.81)	(1.96)	11.82	14.53	22.63	25.06	23.91	18.59	58.35	58.18	516	734
Cuscuta-free	330	385	(0)	(0)	11.35	15.61	23.06	27.38	27.86	24.13	62.27	67.12	812	908

*Square root transformed ($\sqrt{x+0.5}$); figures in parentheses are original values, DAS-Days after sowing.

pared to untreated plots, but pendimethalin 750 g/ha as pre-emergence significantly reduced the lucerne plant population leading to lowest fodder yield. Barevadia *et al.* (1998) also reported that application of pendimethalin at 0.50 kg/ha as pre-emergence and at 4 DAS, and fluchloralin at 0.50 kg/ha as pre-plant incorporation and at 4 DAS showed severe phytotoxicity to lucerne seedlings. Post-emergence application of imazethapyr and pendimethalin yielded 14.26 and 13.99 t/ha green fodder and was at par with *Cuscuta*-free control (15.10 t/ha). However, post-emergence application of these herbicides checked the *Cuscuta* spread for a certain period but thereafter, it re-generated from the isolated haustoria within the host stem and soon infested the crop causing severe damage. None of the herbicides and hand weeding at 30 DAS proved effective in checking *Cuscuta* growth, especially during reproductive stage of the lucerne. It was observed that after 3rd cutting for fodder when the lucerne crop was left for seed production, its vegetative growth was reduced and *Cuscuta* grew very vigorously making a mat over lucerne and resulted in very poor seed yields.

Bio-efficacy of pendimethalin against *Cuscuta campestris* in Egyptian clover in relation to method of sowing, dose and time of application

Method of seeding had no significant influence on population and green fodder yield of Egyptian clover as well as on *Cuscuta* emergence (Table 4). Seed yield of clover during 2005-06 was significantly higher in dry seeding as compared to puddle broadcast seeding. Increasing doses of pendimethalin from 500 to 1000 g/ha did not influence the clover plant population, but irrespective of the pendimethalin doses, there was around 50% reduction in clover population as compared to untreated control because of the phytotoxic effect of pendimethalin when applied as pre-emergence or at 7 DAS. *Cuscuta* emergence decreased significantly with increase in pendimethalin doses. The highest fodder yield was obtained with 500g/ha during 2005-06 and 750 g/ha during 2006-07. Pre-emergence application of pendimethalin at 750 g/ha produced the maximum seed yield of clover during 2005-06, however, during 2006-07, the differences among herbicide doses were not significant. Application of pendimethalin at 7 DAS caused severe phytotoxicity on clover followed by its pre-emergence application. Post-emergence application at 14 DAS was safe for the clover crop and produced the maximum green fodder yields during both the years. Application of pendimethalin at 14 DAS produced the maximum seed yield of clover, but the differences were significant during 2005-06 only.

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Indian Journal of Weed Science **44**(1): 11–17, 2012

Management of hardy weeds in maize under mid-hill conditions of Himachal Pradesh

Suresh Kumar*, S.S. Rana, Navell Chander and N.N. Angiras

Department of Agronomy, Forages and Grassland Management, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh 176 062

Received: 4 February 2012; Revised: 23 March 2012

ABSTRACT

Twelve treatments involving tank-mix combinations of atrazine and pendimethalin as pre-emergence followed by (*fb*) post emergence application of 2,4-D and metsulfuron methyl along with hand weeding twice (20 and 40 DAS) and untreated check were tested in maize during 2009 and 2010 at Palampur. *Echinochloa colona, Panicum dichotomiflorum, Cyperus iria, Commelina benghalensis, Ageratum conyzoides, Digitaria sanguinalis* and *Polygonum alatum* were the dominant weeds. Pendimethalin 1.50 kg/ha, atrazine *fb* atrazine 0.75 kg/ha, atrazine 0.75/1.0 + pendimethalin 0.75/0.50 *fb* metsulfuron methyl 4 g/ha effectively controlled *Echinochloa colona*. Atrazine *fb* atrazine brought about significant reduction in the count of *Panicum dichotomiflorum* up to 60 DAS. Pendimethalin *fb* atrazine, atrazine 1.0 + pendimethalin 0.50 *fb* 2, 4-D 0.75 kg/ha and hand weeding twice effectively reduced the population of *Commelina* up to 60 DAS. Pendimethalin/atrazine *fb* atrazine and atrazine + pendimethalin *fb* 2,4-D/ metsulfuron-methyl controlled *Ageratum conyzoides* up to 60 DAS. Pendimethalin/atrazine *fb* atrazine, atrazine + pendimethalin *fb* metsulfuron-methyl/2, 4-D and pendimethalin significantly reduced total weed dry weight. Atrazine 1.0 + pendimethalin 0.50 kg/ha (post) and atrazine 0.75 + pendimethalin 0.75 kg/ha *fb* 2, 4-D gave significantly higher grain yield and net returns. Weeds reduced maize grain yield by 50.3%.

Key words: Atrazine, Herbicide combinations, Maize, Pendimethalin, Weeds

Maize (*Zea mays* L.) is an important cereal crop and plays a pivotal role in agricultural economy of Himachal Pradesh. Among the factors responsible for low yields, severe infestation by weeds due to wider row spacing coupled with frequent rains in rainy season inflict huge yield losses upto 68.9% (Walia *et al.* 2007). In order to obtain economical yield of maize, weeds must be kept under check. For controlling weeds in this crop, pre-emergence or early post-emergence application of atrazine depending upon the soil type has been recommended. Application of pendimethalin also has been recommended under maize + legume intercropping situations. These herbicides do not control hardy weed species like *Commelina benghalensis, Ageratum conyzoides* and *Brachiaria ramosa* as they appear late in the season. The infestation of these weeds is increasing day by day in the maize-growing areas of the state especially where the farmers are using atrazine year after year. So in order to widen the weed control spectrum, it is imperative to use combination of herbicides having different mode of action (Walia *et al.* 2007, Rana *et al.* 1998, Kumar *et al.* 2011). Therefore, tank-mix combinations of atrazine and pendimethalin alone as pre-emergence followed by post-emergence application of 2,4-D and metsulfuron-methyl were tried in the present investigation.

***Corresponding author:** skg_63@yahoo.com

MATERIALS AND METHODS

A field experiment was conducted during *kharif* seasons of 2009 and 2010 at Palampur in silty clay loam soil having pH 5.6 and medium in available N (289.4 kg/ ha), P (15.4 kg/ha) and K (272 kg/ha). Twelve treatments *viz*., pre-emergence atrazine and pendimethalin each at 1.50 kg/ha, atrazine and pendimethalin each followed by atrazine 0.75 kg/ha, atrazine and pendimethalin each at half rate in combination at sowing alone and followed by post-emergence 2,4-D at 0.75 kg/ha and metsulfuron-methyl at 4 g/ha, atrazine 2/3rd and pendimethalin 1/3rd in combination at sowing alone and followed by post-emergence 2, 4-D at 0.75 kg/ha and metsulfuron-methyl at 4 g/ha, hand weeding twice (20 and 40 DAS) and unweeded check were tested in randomized block design with three replications. Maize hybrid 'KH-101' was sown during first week of June keeping row to row spacing of 60 cm and plant to plant spacing of 20 cm (approximately 20 kg/ha seed rate). The crop was harvested in the first week of October. The crop was fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha through urea, single super phosphate and muriate of potash, respectively. The required quantity of half N and whole P_2O_5 and 40 kg K_2O was drilled at sowing. The remaining half N was band placed in two equal splits at knee high and tasseling stages. Hand weeding and hoeing as per treatment was done at 20 and

40 days after sowing. Herbicides as per treatment were applied with backpack power sprayer using 600 litre water/ ha. Pre-emergence application of herbicides (pendimethalin and atrazine) was made within 48 hours of sowing. Post-emergence application of 2,4-D and metsulfuron-methyl was made on the emergence of broadleaf weeds. Weed count and dry weight (60 DAS and at harvest) were recorded at two spots using a quadrate of 50 x 50 cm. Yields were harvested from net plot. Impact assessment was carried out as per Walia (2003). Economics of the treatments was computed based upon prevalent prices.

RESULTS AND DISCUSSION

Effect on weeds

Weed flora was composed of *Commelina benghalensis* (25.6 and 12.3% at 60 DAS and at harvest, respectively), *Ageratum conyzoides* (45.1 and 56.1%), *Echinochloa colona* (L.) Link (17.6% and 8.7%), *Panicum dichotomiflorum* (8.4 and 7.7%), *Cyperus iria* (2.8 and 7.2%), *Digitaria sanguinalis* (0.0 and 8.2%) and *Polygonum alatum* (0.5 and 8.0%). *Aeschynomene indica* also showed its sporadic occurrence especially in the treated plots.

Treatments under evaluation brought about significant variation in the count and dry weight of *Echinochloa colona* at 60 DAS. All treatments except pendimethalin 1.50 kg/ha (pre), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post) and atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) in 2009 were superior to weedy check in suppressing the growth of *Echinochloa colona* during both the years. However, pendimethalin 1.50 kg/ha and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha in 2009 and atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post) and atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) in 2010 could bring about significant reduction in its count. Saini and Angiras (1998) reported significant superiority of atrazine or pendimethalin as well as atrazine followed by atrazine against *Echinochloa* sp (*E. colona* and *E. crusgalli*) in maize.

There was significant variation in the count and dry weight of *Panicum dichotomiflorum* during 2010. Only atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post) could bring about significantly reduction in the count of *Panicum* at 60 DAS. However, all treatments were significantly superior to weedy check in reducing its count and dry weight at harvest. Superiority of herbicide combinations in controlling *Panicum* has been reported by Saini and Angiras (1998).

Pendimethalin 0.75 kg/ha (pre) *fb* atrazine 0.75 kg/ ha (post), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post) and hand weeding twice (20 and 40 DAS) remaining at par with atrazine 1.5 kg/ha (pre), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) and atrazine 1.0 kg/ ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) in lowering dry weight of *Commelina benghalensis* were superior to rest of the treatments up to 60 DAS during 2009. All treatments were superior to weedy check in reducing count of *Commelina benghalensis* up to 60 DAS but atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha *fb* 2,4-D and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre) *fb* metsulfuron-methyl could not suppress its growth over unweeded check during 2010. Atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) remained at par with atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post) pendimethalin 1.5 kg/ha (pre), atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre), pendimethalin 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) and hand weeding twice (20 and 40 DAS) gave significantly lower dry weight of *Commelina benghalensis* over other treatments up to 60 DAS during 2010. Atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post) being at par with atrazine 1.5 kg/ha (pre), pendimethalin 1.5 kg/ha (pre), pendimethalin 1.50 kg/ha *fb* atrazine 0.75 kg/ha (post) atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) and hand weeding (20 and 40 DAS) gave lower count of *Commelina* up to 60 DAS in 2010. Similar results have also been shown by Saini and Angiras (1998).

Application of pendimethalin 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post), atrazine 1.50 kg/ha *fb* atrazine 0.75 kg/ha, atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ ha (pre) *fb* 2,4-D 0.75 kg/ha (Post), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ ha (post), hand weeding twice (20 and 40 DAS) and atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb*. 2,4-D 0.75 kg/ha (post) significantly suppressed the growth of *Ageratum conyzoides* at one or the other stage. The effectiveness of atrazine or pendimethalin (pre-emergence) followed by atrazine (post) against *Ageratum conyzoides* has been well documented (Saini and Angiras 1998). Under the remaining treatments, the count and dry weight of *Ageratum conyzoides* were either higher or not significantly different from the untreated check. This could be attributed

Table 1. Effect of treatments on count (no./m^2) and dry weight (g/m^2) of *Echinochloa* and *Panicum* in maize

Treatment	Dose (kg/ha)	Time	*Echinochloa*								*Panicum*							
			Count				Dry weight				Count				Dry weight			
			60 DAS		At harvest		60 DAS		At harvest		60 DAS		At harvest		60 DAS		At harvest	
			2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Atrazine	1.50	Pre	2.3 (5.3)	3.4 (10.7)	2.5 (6.7)	2.3 (5.3)	1.2 (0.5)	1.6 (1.5)	1.4 (1.15)	1.3 (0.7)	1.7 (2.7)	2.5 (5.3)	3.1 (10.67)	1.0 (0.0)	1.0 (0.0)	1.2 (0.5)	2.2 (5.15)	1.0 (0.0)
Pendimethalin	1.50	Pre	1.0 (0.0)	2.7 (8.0)	1.9 (4.0)	1.4 (0.3)	1.9 (3.1)	1.3 (0.7)	1.2 (0.46)	1.1 (0.1)	1.7 (4.0)	3.8 (13.3)	1.0 (0.00)	1.4 (1.3)	1.0 (0.0)	1.5 (1.4)	1.0 (0.00)	1.1 (0.2)
Atrazine *fb* atrazine	1.50 *fb* 0.75	Pre *fb* post	1.7 (2.7)	1.0 (0.0)	1.4 (1.3)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.1 (0.15)	1.0 (0.0)	1.3 (1.3)	1.0 (0.0)	2.7 (8.00)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.6 (1.84)	1.0 (0.0)
Pendimethalin *fb* atrazine	1.50 *fb* 0.75	Pre *fb* post	3.8 (18.0)	2.1 (4.0)	1.7 (2.7)	2.1 (4.0)	1.1 (0.1)	1.1 (0.3)	1.1 (0.28)	1.2 (0.5)	2.1 (6.00)	2.9 (9.3)	2.7 (8.00)	1.8 (2.7)	1.0 (0.0)	1.5 (1.6)	1.5 (1.48)	1.1 (0.3)
Atrazine + pendimethalin	0.75 + 0.75	Pre	2.7 (12.0)	5.0 (24.0)	1.7 (2.7)	2.5 (5.3)	1.0 (0.0)	1.5 (1.4)	1.2 (0.41)	1.3 (0.7)	2.8 (10.0)	4.3 (17.3)	2.9 (8.00)	1.4 (1.3)	1.1 (0.1)	2.1 (3.7)	1.5 (1.22)	1.1 (0.2)
Atrazine + pendimethalin *fb* 2,4-D	0.75 + 0.75 *fb* 0.75	Pre *fb* post	2.1 (6.0)	3.1 (10.7)	1.7 (2.7)	1.8 (2.7)	1.5 (1.5)	1.6 (1.9)	1.1 (0.24)	1.1 (0.3)	2.3 (8.0)	2.9 (9.3)	1.0 (0.00)	1.0 (0.0)	1.0 (0.0)	1.5 (1.5)	1.0 (0.00)	1.0 (0.0)
Atrazine + pendimethalin *fb* metsulfuron-methyl	0.75 + 0.75 *fb* 0.004	Pre *fb* post	1.2 (0.7)	2.1 (4.0)	2.0 (5.3)	2.3 (5.3)	1.7 (2.3)	1.2 (0.4)	1.4 (1.12)	1.2 (0.6)	2.3 (8.0)	5.0 (24.0)	2.9 (8.00)	2.1 (4.0)	1.0 (0.0)	3.1 (8.7)	1.5 (1.28)	1.2 (0.4)
Atrazine + pendimethalin	1.0 + 0.50	Pre	2.1 (4.7)	2.3 (5.3)	1.4 (1.3)	1.8 (2.7)	1.4 (0.9)	1.2 (0.5)	1.1 (0.16)	1.1 (0.3)	2.0 (5.33)	2.9 (8.0)	1.0 (0.00)	1.4 (1.3)	1.0 (0.0)	1.3 (0.8)	1.0 (0.00)	1.1 (0.1)
Atrazine + pendimethalin *fb* 2,4-D	1.0 + 0.50 *fb* 0.75	Pre *fb* post	2.7 (8.0)	3.0 (8.0)	3.4 (10.7)	1.8 (2.7)	2.1 (4.1)	1.3 (0.6)	1.6 (1.50)	1.1 (0.3)	3.5 (14.7)	2.9 (8.0)	3.7 (13.33)	1.4 (1.3)	1.0 (0.0)	1.3 (0.7)	1.9 (2.77)	1.1 (0.1)
Atrazine + pendimethalin *fb* metsulfuron-methyl	1.0 + 0.50 *fb* 0.004	Pre *fb* post	2.6 (7.3)	1.8 (2.7)	3.6 (12.0)	1.4 (1.3)	2.5 (5.2)	1.1 (0.2)	2.0 (3.49)	1.1 (0.1)	2.5 (9.3)	2.5 (6.7)	2.7 (8.00)	1.0 (0.0)	1.0 (0.0)	1.2 (0.6)	1.7 (1.99)	1.0 (0.0)
Hand weeding	-	20 and 40 DAS	2.8 (8.7)	2.7 (8.0)	2.9 (9.3)	1.7 (2.7)	1.0 (0.0)	1.4 (0.9)	2.0 (3.67)	1.1 (0.4)	1.0 (0.0)	2.3 (5.3)	2.7 (8.00)	1.0 (0.0)	1.0 (0.0)	1.2 (0.4)	1.6 (1.75)	1.0 (0.0)
Untreated check	-		3.6 (13.3)	3.6 (12.0)	2.8 (13.3)	3.2 (9.3)	2.9 (9.9)	2.9 (7.8)	2.1 (5.61)	1.5 (1.2)	1.3 (1.3)	3.1 (10.7)	3.1 (10.67)	3.2 (9.3)	1.1 (0.2)	1.5 (1.4)	2.3 (5.21)	1.4 (0.9)
LSD (P=0.05)			2.0	1.8	NS	NS	1.1	0.5	NS	NS	NS	1.9	NS	1.0	NS	0.7	NS	0.2

Values given in parentheses are original means

Table 2. Effect of treatments on count (no./m^2) and dry weight (g/m^2) of *Commelina* and *Ageratum* in maize

Treatment	Dose (kg/ha)	Time	*Commelina*								*Ageratum*							
			Count				Dry weight				Count				Dry weight			
			60 DAS		At harvest		60 DAS		At harvest		60 DAS		At harvest		60 DAS		At harvest	
			2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Atrazine	1.50	Pre	2.7 (8.0)	2.7 (6.7)	4.6 (20.00)	4.1 (16.0)	1.2 (0.5)	1.6 (1.8)	2.9 (7.83)	1.9 (2.7)	3.4 (22.7)	7.8 (60.0)	16.0 (256.0)	7.3 (52.0)	1.9 (2.7)	4.0 (15.1)	8.1 (65.2)	3.6 (12.2)
Pendimethalin	1.50	Pre	1.5 (2.0)	1.9 (4.0)	1.9 (4.00)	5.1 (25.3)	1.9 (2.9)	1.2 (0.4)	1.3 (0.95)	2.8 (7.0)	3.0 (12.0)	1.7 (2.7)	12.2 (148.0)	2.2 (6.7)	1.6 (1.8)	1.1 (0.1)	2.2 (4.6)	1.3 (0.9)
Atrazine *fb* atrazine	1.50 *fb* 0.75	Pre *fb* post	1.9 (4.0)	1.0 (0.0)	3.2 (9.33)	1.0 (0.0)	1.8 (2.7)	1.4 (1.3)	1.5 (1.37)	1.0 (0.0)	2.2 (11.3)	1.0 (0.0)	3.8 (17.3)	4.1 (16.0)	1.0 (0.0)	1.0 (0.0)	6.3 (39.3)	1.6 (1.6)
Pendimethalin *fb* atrazine	1.50 *fb* 0.75	Pre *fb* post	3.0 (10.0)	2.5 (6.7)	1.0 (0.00)	3.4 (10.7)	1.0 (0.0)	1.3 (0.7)	1.0 (0.00)	1.5 (1.2)	2.3 (7.3)	1.7 (2.7)	4.1 (21.3)	2.5 (6.7)	1.0 (0.0)	1.1 (0.2)	2.4 (5.6)	1.3 (0.8)
Atrazine + pendimethalin	0.75 + 0.75	Pre	2.6 (7.3)	2.7 (8.0)	2.0 (5.33)	2.5 (6.7)	1.6 (1.9)	1.2 (0.6)	1.6 (2.15)	1.3 (0.9)	3.0 (12.0)	4.9 (22.7)	11.7 (193.3)	5.0 (24.0)	2.0 (3.7)	1.9 (2.6)	5.6 (41.5)	2.0 (3.0)
Atrazine + pendimethalin *fb* 2,4-D	0.75 + 0.75 *fb* 0.75	Pre *fb* post	1.8 (2.7)	1.7 (2.7)	5.0 (24.00)	3.2 (9.3)	1.7 (2.95)	2.3 (4.6)	3.2 (9.36)	1.6 (1.6)	4.0 (20.0)	4.3 (17.3)	14.9 (221.3)	7.6 (57.3)	1.7 (1.9)	1.8 (2.1)	6.3 (39.1)	3.5 (11.7)
Atrazine + pendimethalin *fb* metsulfuron-methyl	0.75 + 0.75 *fb* 0.004	Pre *fb* post	2.2 (5.3)	2.9 (9.3)	4.3 (17.33)	4.0 (14.7)	1.4 (1.1)	2.0 (4.0)	2.4 (4.90)	1.9 (2.5)	2.7 (12.7)	4.1 (16.0)	16.4 (266.7)	2.1 (4.0)	2.1 (5.5)	1.5 (1.2)	7.1 (49.9)	1.2 (0.4)
Atrazine + pendimethalin	1.0 + 0.50	Pre	1.6 (3.3)	3.4 (10.7)	2.2 (6.67)	2.1 (4.0)	1.6 (1.9)	1.0 (0.0)	1.7 (2.93)	1.2 (0.4)	3.2 (14.0)	4.7 (49.3)	16.0 (254.7)	5.7 (32.0)	1.9 (4.2)	2.4 (8.3)	6.7 (44.4)	2.8 (6.7)
Atrazine + pendimethalin *fb* 2,4-D	1.0 + 0.50 *fb* 0.75	Pre *fb* post	2.5 (7.3)	1.7 (2.7)	1.0 (0.00)	1.9 (4.0)	1.0 (0.0)	1.2 (0.5)	1.0 (0.00)	2.5 (5.8)	4.3 (24.0)	1.0 (0.0)	12.2 (148.0)	1.7 (2.7)	1.7 (1.8)	1.0 (0.0)	5.7 (32.2)	1.1 (0.2)
Atrazine + pendimethalin *fb* metsulfuron-methyl	1.0 + 0.50 *fb* 0.004	Pre *fb* post	3.3 (13.3)	2.7 (6.7)	3.2 (12.00)	2.7 (8.0)	1.2 (0.6)	1.1 (0.2)	2.2 (3.84)	1.4 (1.0)	5.1 (33.3)	2.9 (9.3)	12.4 (152.0)	8.1 (65.3)	1.0 (0.0)	1.3 (0.9)	5.9 (34.0	3.4 (10.9)
Hand weeding	-	20 & 40 DAS	2.5 (9.3)	2.1 (4.0)	3.5 (14.67)	2.3 (5.3)	1.0 (0.0)	1.3 (0.6)	2.4 (5.88)	1.3 (0.7)	6.3 (38.7)	10.0 (100.0)	11.0 (170.7)	7.4 (53.3)	1.0 (0.0)	3.9 (14.1)	5.9 (45.9)	3.3 (10.3)
Untreated check	-		3.1 (10.0)	5.2 (26.7)	3.1 (10.67)	4.7 (21.3)	2.7 (7.6)	2.2 (4.2)	1.9 (2.88)	1.2 (0.5)	3.3 (15.3)	1.0 (0.0)	8.6 (101.3)	4.6 (45.3)	2.1 (3.5)	1.0 (0.0)	4.5 (25.9)	2.8 (12.9)
LSD (P=0.05)			NS	1.8	1.4	1.3	0.6	0.5	1.3	0.6	3.6	3.4	5.1	3.4	1.1	1.2	3.3	1.6

Values given in the parentheses are the original means

Table 3. Effect of treatments on weed dry weight weed control efficiency and plant height of maize

Treatment	Dose (kg/ha)	Time	Weed dry weight (g/m^2)				WCE (%)	Plant height	
			2009		2010				
			60 DAS	At harvest	60 DAS	At harvest		2009	2010
Atrazine	1.50	Pre	3.6 (12.6)	9.7 (93.3)	4.4 (18.3)	3.7 (12.5)	-5.1	276	271
Pendimethalin	1.50	Pre	2.7 (8.1)	6.9 (46.9)	2.1 (3.5)	3.2 (9.4)	60.5	293	287
Atrazine *fb* atrazine	1.50 *fb* 0.75	Pre *fb* post	2.6 (5.8)	2.8 (8.9)	1.0 (0.0)	2.6 (5.8)	80.3	278	285
Pendimethalin *fb* atrazine	1.50 *fb* 0.75	Pre *fb* post	1.9 (2.9)	3.1 (11.1)	2.3 (4.4)	2.0 (2.9)	75.2	286	277
Atrazine + pendimethalin	0.75 + 0.75	Pre	3.6 (12.8)	6.9 (54.2)	4.1 (15.7)	2.6 (5.6)	3.1	279	275
Atrazine + pendimethalin *fb* 2,4-D	0.75 + 0.75 *fb* 0.75	Pre *fb* post	3.4 (10.8)	7.2 (50.6)	3.3 (10.5)	3.9 (14.3)	27.6	280	279
Atrazine + pendimethalin *fb* metsulfuron-methyl	0.75 + 0.75 *fb* 0.004	Pre *fb* post	2.7 (6.5)	7.8 (60.0)	1.8 (2.4)	2.3 (4.4)	69.7	284	178
Atrazine + pendimethalin	1.0 + 0.50	Pre	3.6 (12.8)	7.0 (48.1)	3.8 (14.5)	3.0 (8.1)	7.1	293	286
Atrazine + pendimethalin *fb* 2,4-D	1.0 + 0.50 *fb* 0.75	Pre *fb* post	2.6 (6.1)	6.8 (45.3)	2.1 (3.6)	3.0 (8.2)	67.0	297	288
Atrazine + pendimethalin *fb* metsulfuron-methyl	1.0 + 0.50 *fb* 0.004	Pre *fb* post	2.6 (6.0)	7.0 (48.9)	2.1 (3.5)	3.7 (12.7)	67.7	274	273
Hand weeding	-	20 & 40*	1.0 (0.0)	7.1 (67.9)	4.3 (17.7)	3.6 (12.0)	39.8	287	281
Untreated check	-		3.9 (14.8)	7.0 (60.8)	3.8 (14.6)	4.0 (18.2)	0.0	188	186
LSD (P=0.05)			1.7	NS	1.2	1.2	-	36	39

Values given in parentheses are original means; *Days after sowing to the fact that *A. conyzoides* appeared at the later stage and by that time all other weed species covered the ground fully and let a very few plants of this weed to come up in the weedy check, whereas in treated plots it escaped application of herbicides and its population was increased. *Ageratum* usually appears in large numbers in later stages and its distribution appeares to be contiguous rather than uniform as there is large variation in the population of this weed. Weed control treatments could not bring about significant variation in the count and dry weight of *Digitaria sanguinalis*, *Cyperus* sp., *Polygonum alatum* and *Aeschynomene indica* at any stage during both the years.

Weed control treatments brought about significant variation in the total weed dry weight at 60 DAS during both the years, and at harvest during 2010. At 60 DAS during 2009, hand weeding twice and pendimethalin *fb* atrazine could bring about significant reduction in total weed dry weight over untreated check. The other treatments could not curtail the growth of the survivors or the late comers rather they assumed alarming growth in the absence of competition. However, in 2010, pendimethalin 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post), atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post) atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre), atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post) and atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) were all effective in reducing total weed dry weight as compared to untreated check upto harvest. Atrazine *fb* atrazine resulted in highest weed control efficiency of 80.3%. This was followed by pendimethalin *fb* atrazine, atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha *fb* metsulfuron-methyl, atrazine 1.0 kg/ha + pendimetnalin 0.50 kg/ha *fb* metsulfuron-methyl and atrazine 1.0 kg/ha + pendimethalin 0.50 kg/ha *fb* 2,4-D. Mundra *et al.* (2003), Patel *et al.* (2006) and Walia *et al.* (2007) also reported significant reduction in count and dry weight of weeds with tank-mix application of herbicides in maize.

Effect on crop

All weed control treatments were significantly superior to untreated check in influencing plant height during 2009. However, under atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) and atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) plant height did not differ significantly from that under untreated check in 2010. Controlling weeds is important in obtaining desired plant stand as evident from higher plant population under all treatments over the untreated check. However, atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) had lower effective plant population than all the other treatments.

All treatments were significantly superior to untreated check in increasing grain and straw yield of maize in 2009. However, possibly owing to toxic effect of metsulfuron-methyl, atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) did not differ significantly from weedy check in influencing the yield of maize in 2010. Atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post) during both the years and atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* metsulfuron-methyl 4 g/ha (post) and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre) *fb*. metsulfuron-methyl 4 g/ha (post) in 2009, all being at par to handweeding and atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post) resulted in significantly higher grain as well as straw yield of maize over rest of the treatments. Grain and straw yield of maize was negatively associated with weed biomass ($r = -0.584$ and -0.336, respectively) and count ($r = -0.447$ and -0.509), though, the degree of association was low. Weeds in untreated check reduced maize grain yield by 50.3% over the best treatment atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post).

Impact assessment and economics

Treatment efficiency index (TEI), which indicates weed killing potential and phytotoxicity on the crop (Walia 2003), was highest under atrazine *fb* atrazine. This was followed by pendimethalin *fb* atrazine and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha *fb* 2,4-D. The treatments under study followed the similar trend for crop resistance index (CRI) as TEI. Atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha *fb* metsulfuron-methyl and atrazine 1.0 kg/ha + pendimethalin 0.50 kg/ha had lower weed persistence index (WPI) as compared to other treatments. However, owing to phytotoxicity of metsulfuron-methyl especially during the second year of study, these treatments were next only to atrazine *fb* atrazine, pendimethalin *fb* atrazine and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha *fb* 2,4-D for TEI and CRI. Atrazine/pendimethalin *fb* atrazine, atrazine + pendimethalin *fb* 2,4-D or metsulfuron-methyl, pendimethalin and hand weeding twice were superior to atrazine + pendimethalin (pre) alone for weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI). This suggested that surviving weeds or those appearing in late flushes need to be taken care with some post-emergence herbicide application or manually. Dry matter accumulation under atrazine 1.50 kg/ha treated plots was higher than

Table 4. Effect of different treatments on yield attributes and yield of maize

Treatment	Dose (kg/ha)	Time	Plant population /ha		Cob length (cm)		Cob girth (cm)		No. of rows /cob		Grain yield (t/ha)		Stover yield (t/ha)	
			2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Atrazine	1.50	Pre	60,101	58,331	15.0	14.27	14.6	13.6	14.3	13.60	4.69	4.34	16.2	16.0
Pendimethalin	1.50	Pre	65,604	60,275	15.1	14.53	14.5	13.8	14.5	14.33	4.81	4.87	16.4	16.5
Atrazine *fb* atrazine	1.50 *fb* 0.75	Pre *fb* post	64,895	62,220	15.2	15.47	14.6	14.0	14.9	14.33	5.87	5.47	17.2	17.2
Pendimethalin *fb* atrazine	1.50 *fb* 0.75	Pre *fb* post	65,694	64,720	15.1	15.87	14.3	14.0	15.1	13.20	5.19	5.19	17.1	16.9
Atrazine + pendimethalin	0.75 + 0.75	*Pre*	63,488	63,053	14.9	14.80	14.9	13.9	14.8	14.13	5.04	4.75	16.5	16.5
Atrazine + pendimethalin *fb* 2,4-D	0.75 + 0.75 *fb* 0.75	Pre fb post	68,101	64,164	16.1	15.47	14.6	13.2	14.1	12.90	5.31	5.16	17.3	17.1
Atrazine + pendimethalin *fb* metsulfuron-methyl	0.75 + 0.75 *fb* 0.004	Pre *fb* post	64,895	62,498	16.3	14.33	15.6	14.5	14.9	14.60	6.52	3.50	17.8	13.5
Atrazine + pendimethalin	1.0 + 0.50	Pre	63,779	61,386	15.0	15.60	15.3	14.1	14.7	13.97	4.61	4.37	16.2	16.0
Atrazine + pendimethalin *fb* 2,4-D	1.0 + 0.50 *fb* 0.75	Pre *fb* post	67,985	65,220	16.7	16.13	14.0	14.2	16.7	15.07	6.17	5.63	17.1	16.8
Atrazine + pendimethalin *fb* metsulfuron-methyl	1.0 + 0.50 *fb* 0.004	Pre *fb* post	60,843	48,331	14.8	14.60	14.1	13.6	14.4	13.73	6.12	2.93	17.1	12.1
Hand weeding	-	20 and 40 DAS	63,985	61,664	14.4	14.27	14.8	13.9	14.2	13.80	5.90	5.46	16.8	16.4
Untreated check	-		40,843	34,443	12.0	11.80	12.4	12.3	12.6	11.3	3.19	2.68	13.5	12.1
LSD (P=0.05)			10,830	9,482	2.3	2.8	1.5	1.3	1.1	1.2	0.82	0.55	0.9	0.8

Table 5. Impact assessment indices and economics of weed control treatments in maize

Treatment	Dose (kg/ha)	Time	TEI	WPI	CRI	WMI	AMI	IWMI	CWC	GR	GRWC	NRWC	MBCR
Atrazine	1.50	Pre	0.51	1.68	1.25	-30.2	-31.2	-30.7	1350	54640	15860	14510	10.75
Pendimethalin	1.50	Pre	1.64	1.23	3.43	2.7	1.7	2.2	2780	57318	18538	15758	5.67
Atrazine *fb*. atrazine	1.50 *fb* 0.75	Pre *fb* post	4.73	0.38	7.37	2.4	1.4	1.9	2265	64079	25299	23034	10.17
Pendimethalin *fb*. atrazine	1.50 *fb* 0.75	Pre *fb* post	3.10	0.33	5.68	2.4	1.4	1.9	3695	60553	21773	18078	4.89
Atrazine + pendimethalin	0.75 + 0.75	Pre	0.69	1.04	1.40	54.5	53.5	54.0	2065	57791	19011	16946	8.21
Atrazine + pendimethalin *fb*. 2,4-D	0.75 + 0.75 *fb* 0.75	Pre *fb* post	1.08	1.01	1.97	6.5	5.5	6.0	2808	61103	22323	19515	6.95
Atrazine + pendimethalin *fb*. metsulfuron-methyl	0.75 + 0.75 *fb* 0.004	Pre *fb* post	2.33	0.27	4.34	2.4	1.4	1.9	2945	57272	18492	15547	5.28
Atrazine + pendimethalin	1.0 + 0.50	Pre	0.57	0.72	1.41	21.4	20.4	20.9	1827	54478	15698	13871	7.59
Atrazine + pendimethalin *fb*. 2,4-D	1.0 + 0.50 *fb* 0.75	Pre *fb* post	3.07	0.45	4.40	3.0	2.0	2.5	2570	66290	27510	24940	9.70
Atrazine + pendimethalin fb. metsulfuron-methyl	1.0 + 0.50 *fb* 0.004	Pre *fb* post	1.68	0.28	3.76	2.3	1.3	1.8	2707	52471	13691	10984	4.06
Hand weeding	-	20 & 40 DAS	1.55	1.12	2.35	4.9	3.9	4.4	12000	60388	21608	9608	0.80
Untreated check	-		0.00	1.00	1.00	-	-	-	-	38780	-	-	-
LSD (P=0.05)													

Grain ₹=6750 per tonne, Straw= ₹1000/tonne; TEI, treatment efficiency index; WPI, weed persistence index; CRI, crop resistance index; WMI, weed management index; AMI, agronomic management index; IMWI, integrated weed management index; CWC, cost of weed control (₹/ha); GR, gross returns (₹/ha); GRWC, gross returns due to weed control (₹/ha); NRWC, net returns due to weed control (₹/ha); MBCR, Marginal benefit: cost ratio; Pendimethalin, ₹490/kg ; Atrazine, 290/kg ; ₹2,4-D, 250/kg, Metsulfuron methyl, ₹140/8 gram under untreated check, and therefore, unusual values of WMI, AMI and IWMI were noticed under this treatment.

Control of weeds using herbicides was a cheaper proposition than with manual methods. Cost of weed control using herbicides was only 11.3-30.8% of the total cost under manual weeding. Atrazine 1.50 kg/ha was the cheapest treatment, whereas pendimethalin 1.50 kg/ha *fb* atrazine 0.75 kg/ha, was the costliest. Only atrazine 1.0 kg/ha + pendimethalin 0.50 kg/ha *fb* 2, 4-D, atrazine 1.50 kg/ha *fb* atrazine 0.75 kg/ha (post) and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha *fb* 2,4-D gave higher gross returns due to weed control over traditional practice. However, all herbicidal treatments were superior to hand weeding twice in terms of net returns due to weed control and MBCR. Atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post) resulted in the highest net returns due to weed control. This was followed by atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post) and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre) *fb* 2,4-D 0.75 g/ha (post). Highest MBCR was fetched under atrazine 1.5 kg/ha (pre), and was closely followed by atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post) and atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post) Higher MBCR with herbicides has also been reported by Kumar *et al.* (2011).

It was concluded that atrazine 1.0 kg/ha + pendimethalin 0.5 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post), followed by atrazine 1.5 kg/ha (pre) *fb* atrazine 0.75 kg/ha (post), atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre) *fb* 2,4-D 0.75 kg/ha (post), pendimethalin 1.5 kg/ha (pre) *fb*. atrazine 0.75 kg/ha (post) and atrazine 0.75 kg/ha + pendimethalin 0.75 kg/ha (pre) *fb*. metsulfuron-methyl 4 g/ha (post) could be the better alternatives to hand weeding in managing different flushes of weeds in maize.

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Indian Journal of Weed Science **44**(1): 18–20, 2012

Weed management practices on growth and yield of winter season brinjal under Chhattisgarh plain conditions

Kunti, Gaurav Sharma* and A.P. Singh[1]

Department of Horticulture, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh 492 012

Received: 7 May 2011; Revised: 20 November 2011

ABSTRACT

The present investigation was conducted to evaluate the effect of weed management practices on weeds as well as crop growth and yield parameters of brinjal along with the economics of weed management during winter season of 2009-10 at the Department of Horticulture, Indira Gandhi Krishi Vishwavidyalaya, Raipur. It was observed that the weed *Parthenium hysterophorus* dominated the experimental field. All the weed management treatments significantly reduced the dry matter of weeds and increased fruit yield of the crop significantly over unweeded check. Among the treatments, pendimethalin (Extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (Extra) (0.64 kg/ha) at 45 DAT as post-emergence resulted in better performance followed by pendimethalin (1.0 kg/ha) pre-transplanting + one hand weeding at 45 DAT with respect to growth and yield parameters due to effective weed management in brinjal. Maximum benefit: cost ratio was also obtained with pendimethalin (extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (Extra) (0.64 kg/ha) at 45 DAT.

Key words: Benefit : cost ratio, Economics, Hand weeding, Herbicides, *Solanum melongena*, Yield

Brinjal (*Solanum melongena* L.) is considered to be one of the most important crops among the vegetables. In India, it is cultivated in about 5.66 lakhs hectares with a production of 9.596 million tonnes and productivity of 16.9 t/ha (Anon 2008). Brinjal contributes 9 per cent of the total vegetable production of the country occupying a major share in the Indian diet. Weed menace is considered to be one of the major constraints for low productivity of brinjal. Weeds compete with crop for nutrients, soil moisture, sun light and reduce the crop yield. Yield reduction due to weed competition in brinjal is in the range of 49 to 90 per cent (Reddy *et al.* 2000). The use of herbicides along with cultural practices has been reported to suppress the fast growth of weeds in brinjal. However, reports on the efficacy of these herbicides in brinjal crop under Chhattisgarh plains are scanty and require thorough study. Hence, the present investigation was conducted to test the efficacy of various herbicides alone or in combination for obtaining higher brinjal yield under Chhattisgarh plain conditions.

MATERIALS AND METHODS

The present experiment was conducted at Indira Gandhi Krishi Vishwavidyalaya, Raipur which is situated in the central part of Chhattisgarh at 21°16' N latitude, 81°36' E longitude and at an altitude of 289.56 m from mean sea level. The soil of experimental field was clay - loam in texture with average fertility locally know as dorsa. Brinjal variety ‘Mukta Keshi’ was grown as test crop. The crop was fertilized with 100 kg/ha nitrogen in the form of urea, 80 kg/ha phosphorus in the form of single super phosphate and 60 kg/ha potassium in the form of muriate of potash. Total quantity of P_2O_5 and K_2O was applied as basal, while N was applied in four splits i.e. basal, 30, 60 & 90 days after transplanting (DAT). The experiment was laid-out in a randomized block design with three replications having 11 treatments comprising of hand weeding, mulching, pre-transplanting treatments with alachlor (2.0 kg/ha), pendimethalin (1.0 kg/ha), pendimethalin (extra) (0.64 kg/ha), post-transplanting treatment with glyphosate (1.5 kg/ha) and unweeded check. Spraying was done by hand operated knap-sack sprayer with flat-fan nozzle using water as carrier 500 liter/ha. The required quantity of herbicide was dissolved in measured quantity of water and sprayed uniformly over the plot. The blanket spray of alachlor, pendimethalin and pendimethalin (Extra) and directed spray of glyphosate was done as per treatment. Observations on various vegetative and flowering parameters *viz.*, plant height, number of branches per plant, leaf area, leaf area index (at 120 DAT), number and weight of fruits per plant, fruit yield as well as weed observations such as weed density, dry matter of weeds and weed control efficiency were recorded at harvest. The economics of these weed management practices were also worked out.

***Corresponding author:** sharmagaurav1@rediffmail.com

[1]*Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh 492 012*

RESULTS AND DISCUSSION

In the experimental field broad leaved weeds were found predominantly throughout the period of study. It was observed that *Parthenium hysterophorus* dominated the field followed by *Cynodon dactylon, Alternenthera triandra, Cyperus iria, Sonchus arvensis, Chenopodium album, Physalis minima* and *Euphorbia hirta*. Pendimethalin (Extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (extra) (0.64 kg/ha) at 45 DAT resulted in better performance with respect to growth parameters. Significantly taller plants (85.36 cm), maximum number of total branches per plant (31.53), leaf area per plant (9352 cm^2) and maximum leaf area index per plant (3.46 cm^2) were recorded with pendimethalin (extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (extra) (0.64 kg/ha) at 45 DAT (Table 1). With respect to yield parameters, significantly highest number of fruits per plant (5.26), weight of fruits per plant (85.00g) and fruit yield (25.18t/ha) were also recorded with pendimethalin (extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (extra) (0.64 kg/ha) at 45 DAT followed by pendimethalin (1.0 kg/ha) pre-transplanting + One hand weeding at 45 DAT. The higher yield may be attributed to lower dry matter accumulation by weeds and decrease in their population that helped in increasing the yield attributes which ultimately led to higher yield (Mekki *et al.* 2010).

Minimum weed density (4.10/m^2) was observed with application of pendimethalin (Extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (Extra) (0.64 kg/ha) at 45 DAT (Table 2). The variability in weed density in different treatments can be attributed to the fact that some herbicides are more effective for weed control than others (Khan *et al.* 2008). Meena (2004) also found similar results in brinjal crops. The minimum dry matter weight (3.00g/m^2) under application of pendimethalin (Extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (Extra) (0.64 kg/ha) at 45 DAT might be due to longer persistence of this herbicide up to harvest. This may also be attributed to better control of weeds thereby lower weed population and suppression of weed growth which might have resulted in lower accumulation of dry matter of weeds (Biradar *et al.* 1999). Similarly, application of herbicides which recorded slightly higher density of weeds and their dry weight may be due to lower herbicidal activity of these chemicals, which could not control newly emerged weeds up to longer period (Patel *et al.* 2006). Maximum weed control efficiency (79.67%) was also recorded under pendimethalin (extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (Extra) (0.64 kg/ha) at 45 DAT. The weed control efficiency is inversely related to dry matter production of weeds. This may be due to lower accumulation of dry matter of weeds at the later stage of crop growth, under all the herbicide treat-

Table 1. Effect of different weed management practices on growth, yield attributes and yield in brinjal

Treatment	Plant height (cm)	Number of branches /plant	Leaf area /plant(cm^2)	Leaf area index (120 DAT)	Number of fruits /plant	Weight of fruits /plant(g)	Fruit yield (t/ha)
Unweeded check	70.8	18.4	4385	1.6	1.7	42.3	12.2
Two hand weeding at 30 and 60 DAT	78.9	24.8	7500	2.8	3.5	65.0	19.3
Mulch (straw) at 0 up to 60 DAT	75.8	22.7	4984	1.8	2.9	44.3	15.9
Alachlor (2.0 kg/ha) pre-transplanting	76.2	24.2	5640	2.1	3.2	56.7	18.1
Alachlor (2.0 kg/ha) pre-transplanting +one hand weeding at 45 DAT	82.1	29.8	8797	3.2	5.1	71.7	23.3
Pendimethalin (1.0 kg/ha) pre-transplanting	78.3	24.5	6534	2.4	3.4	60.7	18.6
Pendimethalin (1.0 kg/ha) pre-transplanting + one hand weeding at 45 DAT	84.9	31.2	9034	3.3	5.2	74.3	24.3
Glyphosate (1.5 kg/ha) post-transplanting at 30 and 60 DAT	80.3	25.1	7851	2.9	3.5	71.0	21.1
Glyphosate (1.5 kg/ha) post-transplanting at 30 and 60 DAT + one hand weeding at 15 DAT	81.9	29.2	8600	3.2	4.2	74.3	23.1
Pendimethalin (extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT	80.9	28.5	8407	3.1	4.2	76.7	22.3
Pendimethalin (extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (extra) (0.64 kg/ha) at 45 DAT	85.4	31.5	9352	3.5	5.3	85.0	25.2
LSD (P=0.05)	7.5	3.7	1360	0.5	1.67	11.9	3.2

Table 2. Effect of different weed management practices on weeds and economics of weed management in brinjal

Treatment	Weed density (no/m^2)	Dry matter of weeds (g/m^2)	Weed control efficiency (%)	Gross returns (x10^3 ₹/ha)	Net returns (x10^3 ₹/ha)	Benefit : cost ratio
Unweeded check	21.05	14.76	_	97.60	56.64	1.38
Two hand weeding at 30 and 60 DAT	8.06	6.13	58.46	154.24	106.98	2.26
Mulch (straw) at 0 up to 60 DAT	12.74	9.43	36.11	127.36	85.77	2.06
Alachlor (2.0 kg/ha) pre-transplanting	10.67	7.43	49.66	144.72	103.01	2.47
Alachlor (2.0 kg/ha) pre-transplanting + one hand weeding at 45 DAT	4.90	3.50	76.28	186.56	14275	3.25
Pendimethalin (1.0 kg/ha) pre-transplanting	10.57	6.33	57.11	149.12	107.57	2.58
Pendimethalin (1.0 kg/ha) pre-transplanting + one hand weeding at 45 DAT	4.75	3.40	76.96	194.48	150.83	3.45
Glyphosate (1.5 kg/ha) post-transplanting at 30 and 60 DAT	6.89	6.00	59.34	169.20	127.19	3.02
Glyphosate (1.5 kg/ha) post-transplanting at 30 and 60 DAT + one hand weeding at 15 DAT	5.93	4.00	72.89	184.64	140.53	3.18
Pendimethalin (Extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT	6.29	4.86	67.07	178.24	134.68	3.09
Pendimethalin (Extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (Extra) (0.64 kg/ha) at 45 DAT	4.10	3.00	79.67	201.44	157.38	3.57
LSD (P=0.05)	-	2.87	-	-	-	-

ments. Similar findings were also reported by Singh *et al.* (1997) and Mekki *et al.* (2010). The maximum gross return (Rs. 2,01,440/ha), net return (Rs. 1,57,386/ha) as well as benefit: cost ratio (3.57) was obtained under pendimethalin (extra) (0.64 kg/ha) pre-transplanting + one hand weeding at 40 DAT + pendimethalin (extra) (0.64 kg/ha) at 45 DAT.

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Indian Journal of Weed Science **44**(1): 21–25, 2012

Weed dynamics and production efficiency of rice-based cropping system

Monika Soni*, V.B. Upadhyay and Poonam Singh
Department of Agronomy Jawaharlal Nehru Krishi Vishwavidhyalay, Jabalpur, Madhya Pradesh 482 004

Received: 23 July 2011; Revised: 11 February 2012

ABSTRACT

Field experiments were conducted during 2007-08 and 2008-09 to study weed dynamics and production efficiency under diversified and intensified rice based cropping systems in Kymore Plateau and Satpura Hills Zone of Madhya Pradesh. Among the all 12 rice based cropping systems under *Kharif*, in rice *Echinochloa crusgalli* was the most dominating weed contributing 32.8% of total weed intensity at most critical period (25 DAT) while *Monochoria vaginalis* at harvest stage (18.8%). During *Rabi*, relative density of weeds varied between different crops. In early (30.2 to 43.3%) and at harvest stage (10.1 to 46.8%) *Medicago denticulata* was found to be more serious weed almost in all *Rabi* crops grown under different cropping systems but in onion and garlic *Portulaca oleracea* having higher intensity at harvest stage (45.2%). The *Portulaca* spp. predominantly infested to all summer crops at early (41.5 to 54.6%) and harvest stage (37.2 to 44.1%). In rice varieties the weed intensity and biomass ranged from 229.0 to 254.2/m^2 and 1.0 to 1.15 t/ha under different crop systems respectively. During *Rabi*, weed intensity was higher in vegetable pea (207.3/m^2) and weed biomass was higher berseem (0.71 t/ha). During summer season, the weed intensity was maximum (156.4/m^2) in okra which resulted into the highest weed biomass production (0.67 t/ha). Both rice and wheat crops grown under rice–wheat system require large quantity of irrigation water which is favourable to build up a typical weed infestation problem. All diversified and intensified cropping systems significantly led to record higher production efficiency (83.13kg/ha/day to 57.05kg/ha/day) beneficial to minimize the serious challenges posed by the weeds as compared to both existing cropping systems *viz.*, rice-wheat (45.63kg/ha/day) and rice-chickpea (39.49kg/ha/day).

Key words: Diversification and intensification, Production efficiency, Rice-based cropping systems,Weed dynamics

Rice-wheat and rice-chickpea cropping systems are predominant in Kymore Plateau and Satpura Hills agroclimatic zone of Madhya Pradesh. Both rice and wheat crops require large quantity of irrigation water which favours build up of weed infestation in such areas. Therefore, it is imperative to make a systemic research effort for achieving twin objectives of higher production efficiency with efficient water use and weed control through suitable crop diversification. Present investigation was aimed to evaluate the relative performance of twelve rice-based cropping systems of Kymore plateau and Satpura hills agro-climatic zone under assured irrigated production system. These cropping systems were compared for their production efficiency and weed dynamics.

MATERIALS AND METHODS

Field experiment was conducted on diversification and intensification of cropping system over existing rice-wheat and rice-chickpea cropping systems during the year 2007-08 and 2008-09 in Jabalpur (M.P.). Jabalpur district is the central part of Madhya Pradesh and it lies between $22^0$49' to $24^0$8' N latitude and $78^0$21' to $80^0$58' E longitudes with an average altitude of 411.78 metres above the mean sea level. The soil of the experimental field was sandy clay loam in texture, slightly alkaline in reaction (pH 7.70) with normal EC (0.48 dS/m) and low OC contents (0.68%), medium in available N (266 kg/ha), low in available P (9. 2 kg/ha) and medium in available K (300 kg/ha) contents. The treatments consisted with 12 cropping systems *viz.*, T_1-rice (*Kranti*)-wheat (*GW 273*), T_2-rice (Kranti)- chickpea (*JG 322*), T_3-Hy. rice (*Pro Agro 6444*)-onion (*Pusa Red*)-greengram (*Pusa Vishal*), grain+residue management, T_4-rice (*Pusa Basmati 1*)-berseem fodder seed (*JB 5*), T_5-Hy. rice (*JRH 5*)-potato (*Kufri Sinduri*)-maize (JM 12) cob+fodder, T_6-Hy. rice (JRH 5)-gobhi sarson (*Terri Uttam*)-maize (*JM 12*) cob+fodder, T_7-Hy. rice (*JRH 5*)-vegetable pea (*Arkel*)-sunflower (*PSH 12*), T_8 -Hy. rice (*JRH 5*)-potato (*Kufri Sinduri*)-groundnut (*Jyoti*), T_9-Hy. rice (*JRH 5*)-gobhi sarson (*Terri Uttam)*-groundnut+maize 4:2, T_{10}-Hy. Rice (*JRH 5*)-gobhi sarson (*Terri Uttam*)-okra (*Parbhani Kranti*), T_{11}-Hy. rice (*JRH*

***Corresponding author:** monika.soni8@gmail.com

5)-garlic (*G-41*)-maize+cowpea 4:2 rows and T_{12} -Hy. rice (*Pro Agro 6444*)-marigold (*African Giant*)-maize (*JM 12*) cob+fodder. These treatments were tested in a randomized block design with 4 replications. In *Kharif* season all varieties of rice were transplanted. Recommended package of practices for all the crops in system were followed. Weeds were controlled in rice with the use of rice rotary weeder at 20 and 40 DAT. In wheat weeds were controlled with the use of hand weeding at 30 DAS. In irrigated chickpea, green pea, gobhi sarson and marigold weeds were controlled with the use of hand weeding at 30 DAS. Weed control in onion and garlic was made with the use of hand weeding at 20 and 40 DAT. Berseem weeds were controlled with one hand weeding before allowing the crop for seed production. In potato, weeds were controlled with hand weeding followed by earthing at 20 DAS and with hand weeding only at 50 DAS. In sunflower, green gram and okra weeds were controlled with the use of hand hoe at 20 DAS fallowed by a hand weeding at 40 DAS. In maize and groundnut first hand weeding was done at 20 DAS immediately fallowed by earthing and again one hand weeding was done at 30 DAS.

Various observations were recorded on pattern of weed infestation in various crops under different crop systems at 25 days after transplanting (DAT) days after sowing (DAS) and at harvest. After this, weed dynamics of all cropping systems were worked out. Production efficiency of all cropping systems was also worked out with the help of following formula:

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Rice equivalent yield (kg/ha) of a particular crop sequences}}{\text{Total duration of all crop components of the same crop sequence (days)}}$$

RESULTS AND DISCUSSION

Relative weed density in *Kharif* season

In rice, the dominating weeds were *Echinochloa crusgalli (32.8%)*, *Cyperus irria* (22.2%), *Fimbristylis barbata* (13.9%), *Sahima nervosum* (7.0%), *Monochoria vaginalis* (6.3%), *Commelina communis* (5.1%) and *Eclipta alba* (3.2%) with other weeds (9.5%) at 25 DAT. At maturity stage, the relative density of all weeds was changed. The severity of *E. Crusgalli* (7.8%), *C. Irria*/*C. difformis* (10.2%) and other weeds (6.2%) were reduced to great extent. But relative density of *Fimbristylis barbata* (16.3%), *Monochoria vaginalis* (18.8%), *Sahima nervosum* (18.4%), *Eclipta alba* (4.0%) increased at final stage over their relative density at 25 DAT. Typically *Caesulia axillaris* (8.1%) had shown its presence at maturity which was almost nil at early stage (Tible 1).

Relative weed density in *Rabi* season

During *Rabi* season, relative density of weeds varied between different crops. *Medicago denticulata* was found to be more serious weed in almost all *Rabi* crops grown under different crop-sequences. Its relative density was 39.4, 41.7, 30.2, 34.5, 46.9 26.8, and 43.3% in wheat, berseem, onion and garlic, chickpea and vegetable pea, gobhi sarson, potato and marigold, respectively at 25 DAS, which changed as 42.1, 24.4, 10.1, 30.2, 42.4, 9.4 and 46.8%, respectively at maturity stage. It means infestation of this weed declined due to cultivation of berseem, onion and garlic and potato crops. Frequent cuttings for fodder in berseem and earthing as well as cultural practices associated with potato, onion and garlic resulted in decline in its infestation. The late emerged plants of this weed generally made corpet like shape on cropped plots under wheat, gobhi sarson and marigold and thus resulted to its higher weed relative density. *Chenopodium album* and *Melilotus alba* were common weeds in almost all *Rabi* crops. But severity of *Chenopodium album* was much serious in marigold (23.3%), gobhi sarson (19.1%), chick pea and vegetable pea (16.9%), wheat (16.4%), potato (12.7%), onion and garlic (12.6%) and berseem (6.8%), in early stage which decline at maturity 13.5, 10.8, 6.4, 10.4, 6.2, 5.2, and 3.4% respectively. While *Melilotus* spp. severely dominated to wheat (14.3), chickpea and vegetable pea (30.4%) at maturity stage (Table 1). Some of *Rabi* weeds shown their presence with their most associated crops like *Phalaris minor* (4.1%) and *Vicia sativa* (8.4%) in wheat, *Anagallis arvensis* in onion and garlic (3.1%), gobhi sarson (9.1%), potato (8.4%) and marigold (5.4%); *Rumex dentatus* in potato (12.4%), berseem (20.2%) and marigold (6.4%); and *Chichorium intybus* (8.1%) in berseem at maturity. Typically *Portulaca oleracea* infested potato only during *Rabi* in early (36.4%) and at maturity stages (40.4%).

Relative weed density in summer season

In greengram, *Portulaca oleracea*, *Cyperus* spp., *Echinochloa crusgalli* and other minor weeds contributed to 44.15, 25.49, 10.00 and 10.00% of total weeds, respectively at 25 DAS, while the relative intensity of these weeds deviated as 44.1, 18.2, 18.2 and 19.5%, respectively at maturity. In maize, *Portulaca oleracea*, *Cyperus* spp., *Trianthima monogyna* and others weeds had relative density of 41.43, 16.42, 13.99, 28.16%, respectively, while relative density of these weeds were 53.17, 15.21, 16.88 and 14.74%, respectively in sunflower at 25 DAS. The relative intensity of these weeds was 51.67, 17.56, 11.29 and 19.48%, respectively in groundnut and okra at this stage. The relative density of all these weeds was changed

Table 1. Relative density of weeds at 25 DAS and maturity of various crops

Crop	Predominant weeds	Relative density (%) At 25 DAS	Relative density (%) At maturity
Rice	*Echinochloa crusgalli*	32.8	7.8
	Cyperus iria / C. difformis	22.2	10.2
	Fimbristylis barbata	13.9	16.3
	Sahima nervosum	7.0	18.4
	Monochoria vaginalis	6.3	18.8
	Commelina communis	5.1	10.2
	Eclipta alba	3.2	4.0
	Caesulia axillaris	-	8.1
	Others	9.5	6.2
	Total	100.0	100.0
Wheat	*Medicago denticulata*	39.4	42.1
	Chenopodium album	16.4	10.4
	Melilotus alba	12.8	14.3
	Phalaris minor	6.2	4.1
	Vicia sativa	6.6	8.4
	Others	18.6	20.7
	Total	100.0	100.0
Berseem	*Medicago denticulata*	41.7	24.4
	Trifolium flagiferum	14.3	20.3
	Rumex dentatus	9.6	20.2
	Chenopodium album	6.8	3.4
	Chichorium intybus	6.5	8.1
	Othres	21.1	23.6
	Total	100.0	100.0
Onion & Garlic	*Medicago denticulata*	30.2	10.1
	Portulaca oleracea	28.2	45.2
	Chenopodium album	12.6	5.2
	Anagallis arvensis	10.4	3.1
	Others	18.6	36.4
	Total	100.0	100.0
Chickpea & vegetable pea	*Medicago denticulata*	34.5	30.2
	Melilotus alba	18.4	30.4
	Chenopodium album	16.9	6.4
	Anagallis arvensis	9.8	5.8
	Others	20.4	27.2
	Total	100.0	100.0
Gobhi sarson	*Medicago denticulata*	46.9	42.4
	Chenopodium album	19.1	10.8
	Melilotus alba	14.9	9.4
	Anagallis arvensis	8.3	9.1
	Others	10.8	28.3
	Total	100.0	100.0
Potato	*Portulaca oleracea*	36.4	40.4
	Medicago denticulata	26.8	9.4
	Chenopodium album	12.7	6.2
	Anagallis arvensis	10.6	8.4
	Rumex dentatus	6.8	12.4
	Others	6.7	23.2
	Total	100.0	100.0
Marigold	*Medicago denticulata*	43.3	46.8
	Chenopodium album	23.3	13.5
	Rumex dentatus	8.8	6.1
	Anagallis arvensis	8.4	5.4
	Others	16.2	28.2
	Total	100.0	100.0
Greengram	*Portulaca oleracea*	54.6	44.1
	Cyperus spp.	25.5	18.2
	Echinochloa crusgalli	10.1	18.2
	Others	10.1	19.5
	Total	100.0	100.0
Maize	*Portulaca oleracea*	41.5	37.2
	Cyperus spp.	16.5	10.6
	Trianthima monogyna	13.8	28.4
	Others	28.2	23.8
	Total	100.0	100.0
Sunflower	*Portulaca olercea*	53.2	41.4
	Trianthima monogyna	16.7	20.2
	Cyperus spp.	15.3	9.4
	Others	14.8	29.0
	Total	100.0	100.0
Groundnut & okra	*Portulaca oleracea*	51.6	40.1
	Cyperus spp.	17.6	16.8
	Trianthima monogyna	11.3	20.2
	Others	19.5	22.9
	Total	100.0	100.0

as 37.2, 10.6, 28.4 and 23.8% in maize, 41.4, 20.2, 9.4 and 29.2% in sunflower and 40.1, 16.8, 20.2 and 22.9% in groundnut and okra, respectively at their maturity stages. Similar findings were reported by Singer *et al*. 2000 and Singh *et al*. 2005.

Weed intensity and weed biomass

During *Kharif* season, total weed population ranged from 229.0/m^2 in Hy. rice-marigold - maize cob+fodder (T_{12}) to 254.2 /m^2 in Hy. rice-potato-groundnut (T_8). The weed population did not vary much due to the effect of different rice varieties. The weed biomass also varied from 1.00 t/ha in Hy. rice- gobhi sarson - groundnut+maize 4:2 (T_9) to 1.15 t/ha in rice - marigold - maize cob+fodder (T_{12}). The weed biomass was also almost identical in all the varieties (Table 2).

During *Rabi* season, the weed intensity was minimum (93.9 to 103.0/m^2) in potato crop grown under two different cropping systems, hence the lowest weed biomass (0.13 to 0.14 t/ha) was recorded in both potato fields. Both onion and garlic faced almost similar kind of weed-infestation, which were higher as compared to potato, hence, these resulted into higher weed biomass (0.25 to 0.26 t/ha) and 105.3 and 106.0 weeds/m^2 weed intensity. In gobhi sarson weed population ranged from 167.9 to 184.0/m^2 with weed dry weight of 0.37 to 0.41 t/ha. The weed density were 165.0, 189.1, 183.4, 207.3 and 183.0 weeds/m^2 in wheat chickpea, berseeem, vegetable pea and marigold, respectively, but weed biomass were 0.42, 0.51, .071, 0.61 and 0.50 t/ha in respective crops.

During summer season, okra allowed maximum infestation of weeds (156.4/m^2) with the highest weed biomass (0.65 t/ha). Sunflower and green gram had weed intensity of 134.9 and 132.0/m^2 and produced weed biomass of 0.53 and 0.46 t/ha, respectively. Weed intensity ranged from 120.4 to 122.1/m^2 in maize with dry matter weight of 0.50 to 0.55 t/ha. Groundnut had the weed intensity of 126.4/m^2 with minimum weed biomass of 0.37 t/ha. When cowpea and groundnut intercropped with maize, maize had weed intensity of 116.9 and 107.0/m^2, respectively and produced weed biomass of 0.42 and 0.42 t/ha, respectively. The inter cropping of groundnut and cowpea with further maize reduced the weed infestation over sole maize.

Production efficiency

Among different cropping systems tested, Hy. rice *JRH 5*-garlic-maize + cowpea (fodder) markedly registered the highest production efficiency (83.1 kg/ha/day). The next best cropping system was Hy. rice *JRH 5* - potato- groundnut (69.7 kg/ha/day) closely followed by Hy. rice *JRH 5* - potato - maize (65.8 kg/ha/day). Remaining

Table 2. Weed intensity, weed biomass and production efficiency at maturity stage under different cropping systems (mean of two years)

Cropping system		Weed intensity (no/m^2)			Weed biomass (t/ha)			Production efficiency (kg/ha/year)
		Kharif	*Rabi*	Summer	*Kharif*	*Rabi*	Summer	
T_1	Rice (*Kranti*) - wheat (*GW 273*)	248.9	165.0	-	1.10	0.42	-	45.6
T_2	Rice (*Kranti*) -chickpea (*JG 322*)	236.9	189.1	-	1.06	0.51	-	39.5
T_3	Rice (*Pro Agro 6444*) - onion (*Pusa red*) – greengram (*Pusa Vishal*) G+R	241.0	105.3	132.0	1.13	0.25	0.46	55.2
T_4	Rice (*Pusa Basmati*) - berseem (*JB 5*) fodder + seed	249.4	183.4	-	1.01	0.71	-	57.0
T_5	Rice (*JRH 5*) - potato (*Kufri Sinduri*) -maize (*JM 12*) cob + fodder	241.1	93.9	122.1	1.14	0.13	0.55	65.8
T_6	Rice (*JRH 5*)- gobhi garson (*Terri Uttam*) – maize (*JM 12*)	230.9	191.7	120.4	1.13	0.39	0.50	45.8
T_7	Rice (*JRH 5*) – vegetable pea (*Arkel*) -sunflower (*PSH 12*)	248.1	207.3	134.9	1.07	0.61	0.53	48.3
T_8	Rice (*JRH 5*) - potato (*Kufri Sinduri*) -groundnut (*Jyoti*)	254.2	103.0	126.4	1.05	0.14	0.37	69.7
T_9	Rice (*JRH 5*) - gobhi sarson (*Terri Uttam*) – Groundnut (*Jyoti*) + Maize (*JM 12*) 4:2 row	253.9	184.0	107.0	1.00	0.41	0.42	51.3
T_{10}	Rice (*JRH 5*) - gobhi sarson (*Terri Uttam*) – okra (*Parbhani Kranti*)	245.9	167.9	156.4	1.12	0.37	0.65	51.6
T_{11}	Rice (*JRH 5*) - garlic (*G-41*) - maize (*JM 12*) + cowpea (Local) 4:2 row	241.8	106.0	116.9	1.01	0.26	0.42	83.1
T_{12}	Rice (*Pro Agro 6444*) - marigold (*African Giant*) - maize (*JM 12*) cob + fodder	229.0	183.0	120.5	1.15	0.50	0.48	54.0
	LSD (P=0.05)	0.484	0.398	0.394	0.18	0.03	0.03	0.60

diversified intensive cropping systems recorded production efficiency ranging from 45.8 to 57.05 kg/ha/day, which were higher than existing cropping systems *viz.*, rice - wheat (45.6 kg/ha/day) and rice - chickpea (39.5 kg/ha/day). Beseem being a high yielding crop during *Rabi* season resulted into handsome production efficiency of 57.1 kg/ha/day under rice '*Pusa Basmati 1*' - berseem fodder + seed system, although rice '*Pusa Basmati 1*' was low yielder during *Kharif* season (Table 2). Similar high values of production efficiencies with the inclusion of high yielding crops under existing cropping systems have been also reported by several other workers from different agro-climatic conditions. (Sharma and Kewat 1999, Yadav *et al.* 2000, Chouhan *et al.* 2001, Kharub *et al.* 2003.

Hence, it can be concluded that relative weed density and weed-flora differed from crop to crop from early stage to maturity of crops. Thus, infestation of severe weeds *viz., Phalaris minor* in wheat, *Chichorium intybus* and *Rumex* spp. and *Medicago denticulata* in berseem could be minimized by intensified and diversified them with other crops with higher production efficiency.

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Indian Journal of Weed Science 44(1): 26–29, 2012

Weeds and crop productivity of maize + blackgram intercropping system in Chhattisgarh plains

Sanjay K. Dwivedi*, G.K. Shrivastava, A.P. Singh and R. Lakpale

Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh 492 006

Received: 31 March 2011; Revised: 15 February 2012

ABSTRACT

Field experiments were conducted to study the effect on weeds and crop yield under maize + blackgram intercropping system at Raipur during 2004 and 2005. Treatments consisted of five planting geometry *viz*., sole maize, sole blackgram, maize +blackgram (1:1), maize + blackgram (2:1) and maize + blackgram (2:2) and four weed management practices *viz*., weedy check, hand weeding (HW) at 30 DAS, alachlor 2.0 kg/ha as pre-emergence and alachlor 1.5 kg/ha as pre-emergence + HW at 40 DAS. Grain yield, productivity rating index (PRI), production efficiency (PE) and weed-control efficiency (WCE) were the highest under maize + blackgram (2:1) for maize. However, weed smothering efficiency of maize was highest under maize + blackgram (1:1). At harvest of blackgram (75 DAS) and maize (105 DAS), the dry weight of weeds were the lowest with alachlor 1.5 kg/ha + HW at 40 DAS. This treatment produced maximum grain yield, PRI and PE of maize and blackgram.

Key words: Intercropping, Maize+blackgram, Weed management

Weed management in intercropping system needs concentrated scientific efforts to provide weed-free environment to both the crop components. The development of wide-spectrum herbicides in the past has opened up excellent opportunities for chemical weed control in component crops of differential nature growing in association with each other. Alachlor, a broad-spectrum herbicide, could be safely used in different intercropping system for controlling dicot and monocot weeds. It would help a great deal to boost the growth and development and finally the productivity of maize and blackgram. Physical manipulations of the intercrop environment for weed control very closely resemble those used for sole crops. Several researchers have suggested that more competitive crop cover and high plant density available in intercropping caused severe competition with weeds and reduce weed growth. Intercropping has potential as a means of weed control because it offers the possibility of a mixture of crops capturing a great share of available resources than in monocropping. The wider row spacing in maize can be used to grow short duration legumes which not only will act as smother crop, but will give additional yield. Weed control approach involving intercropping, herbicides and non- chemical method in maize and maize based intercropping system is very important to provide effective and acceptable weed control for realizing high production (Shah *et al.* 2011). Besides, intercropping also reduces weeding cost and realizes higher total productivity of the system and monetary returns (Pandey and Prakash 2002). But this system alone is not sufficient to ensure adequate weed control because of varied canopy coverage by the intercrops. Planting geometry, which modifies the crop canopy structure and micro-climate, in combination with weed management practices, may influence the weed infestation to a great extent. Hence, an integrated approach is needed to control weeds through manual and chemical weeding in an intercropping system.

MATERIALS AND METHODS

Field experiments were conducted at the Instructional cum Research Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) during *Kharif* season of 2004 and 2005. The treatments consisted of five planting geometry, *viz*., sole maize (45 cm), sole blackgram (30 cm), maize (45 cm) + blackgram (1:1), maize (30 cm) + blackgram (2:1) and maize (30 cm) + blackgram (2:2) and four weed management practices, *viz*., weedy check, HW at 30 DAS, alachlor 2.0 kg/ha as pre-emergence and alachlor 1.5 kg/ha as pre-emergence + HW at 40 DAS laid out in split plot design with three replication. The soil was clayey (Vertisols) with pH 7.2, EC 0.12 ds/m, and available N, P and K of 216, 12.1 and 366 kg/ha, respectively. Application of fertilizer in sole maize was 100:60:40 kg N: P_2O_5:K_2O/ha, whereas in case of sole blackgram, was 20:40:20 kg N: P_2O_5:K_2O/ha. The composite maize '*Navjot*' and blackgram '*TAU-2*' was sown with the gross plot size of 37.8 m^2. Herbicides were applied as per the treatments. Weedy plots remained

*Corresponding author: sanjay_dwivedi2000@yahoo.com

infested with native population of weeds till harvest. The test herbicide alachlor, is an aniline herbicide used to control annual grasses and broad leaved weeds in maize, blackgram and other crops. It is a selective systemic herbicide, absorbed by germinating shoots and by roots. The productivity rating index (PRI) pertaining to maize crop was worked out to judge the performance of the treatments. The yield of the crop under a particular treatment (t/ha) divided by standard yield of the crop (t/ha) with multiplication of hundred. production efficiency (PE) was calculated by dividing grain yield (kg/ha) with duration of the crop (Tomar and Tiwari 1990).

RESULTS AND DISCUSSION

Effect on weeds

Alternanthera triandra, Cyperus rotundus, Cynodon dactylon, and *Cynotis axillaries* were predominant weeds (Table 1). At 75 DAS, planting geometry showed significant effect on dry matter production of all species of weed. It was observed that sole maize resulted in the highest weed dry matter production which was significantly higher than rest of the treatments. Sole blackgram recorded the lowest dry matter production of *Alternanthera triandra* and *Brachiaria ramosa*, whereas maize + blackgram (1:1) registered the lowest dry matter production of *Cynotis axillaries, Cynodon dactylon,* and *Cyperus rotundus*. The weed suppression was about the same as that obtained with two HW. Kurchania *et al.* (1995) and Dubey (1998) also reported similar findings. As regards to weed management practices, the lowest weed dry matter production was recorded with alachlor 1.5 kg/ha + HW at 40 DAS, which was significantly superior to rest of the treatments. The highest dry matter production was observed under weedy check. At harvest of maize, *Alternanthera triandra, Cynotis axillaries, Cynodon dactylon, Brachiaria ramosa* and *Cyperus rotundus* were found dominant, and the dry matter production of these weed species was significantly influenced due to planting geometry (Table 2). Highest weed dry matter production was observed under sole maize, which was significantly higher than other treatments. Alachlor 1.5 kg/ha + HW at 40 DAS registered the lowest amount of dry matter production of all species of weeds. It showed that the integrated approach was more beneficial in controlling weeds than the HW or chemical approach alone (Chandel *et al.* 1995, Vairavan *et al.* 1997). Several workers also found that the intercropping maize and legumes considerably reduced the weed density compared with the monocropping maize by decrease in available light for weeds compared to mono crops. Evidence of better weed control was reasonably clear where intercropping provides a more

Table 1. Species-wise dry matter of weeds (g/m^2) at harvest of blackgram as influenced by planting geometry and weed management in maize + blackgram intercropping system

Treatment	*Alternanthera triandra*		*Cynotis axillaris*		*Cynodon dactylon*		*Brachiaria ramosa*		*Cyperus rotundus*		Others	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Planting geometry												
Maize sole	4.82	4.04	1.92	1.99	1.92	1.99	2.64	3.11	4.17	3.91	3.48	3.56
	(26.05*)	(19.25)	(3.71)	(4.00)	(3.87)	(4.13)	(8.68)	(9.97)	(20.34)	(16.91)	(13.07)	(13.67)
Blackgram soles	3.41	3.28	1.93	1.94	1.90	1.89	2.19	2.17	3.28	3.03	2.73	2.71
	(14.64)	(13.98)	(3.72)	(3.79)	(3.69)	(3.57)	(5.34)	(5.34)	(12.49)	(10.51)	(8.14)	(7.83)
Maize + blackgram (1:1)	4.24	4.01	1.58	1.55	1.70	1.71	2.33	2.36	2.82	2.86	2.89	2.94
	(21.18)	(19.40)	(2.25)	(2.19)	(2.94)	(2.81)	(6.13)	(6.13)	(9.60)	(9.68)	(9.05)	(9.23)
Maize + blackgram (2:1)	4.43	4.51	1.87	1.78	1.79	1.78	2.48	2.57	3.83	3.59	3.21	3.33
	(22.80)	(23.80)	(3.43)	(3.04)	(3.26)	(3.15)	(7.12)	(7.29)	(16.80)	(14.33)	(11.28)	(11.74)
Maize + blackgram (2:2)	3.83	3.67	1.69	1.66	1.71	1.73	2.43	2.48	3.43	3.35	3.04	3.12
	(18.45)	(17.04)	(2.71)	(2.65)	(2.87)	(2.90)	(6.71)	(6.91)	(13.75)	(12.76)	(10.02)	(10.23)
LSD (P=0.05)	0.260	0.250	0.085	0.079	0.090	0.090	0.137	0.142	0.204	0.197	0.170	0.177
Weed management												
Weedy check	7.28	7.09	2.75	2.72	3.05	2.97	4.30	4.19	5.81	5.48	4.83	4.77
	(52.86)	(50.01)	(7.14)	(7.00)	(8.88)	(8.40)	(18.09)	(17.16)	(33.70)	(29.75)	(22.99)	(22.49)
Hand weeding at 30 DAS	3.29	2.95	1.54	1.49	1.37	1.41	1.89	2.31	3.79	3.40	2.10	2.24
	(10.61)	(8.47)	(1.88)	(1.75)	(1.39)	(1.52)	(3.07)	(5.05)	(14.29)	(11.27)	(3.92)	(4.55)
Alachlor 2.0 kg/ha	3.83	3.62	1.89	1.92	1.63	1.70	2.35	2.27	3.05	2.93	3.31	3.35
	(14.46)	(12.94)	(3.13)	(3.23)	(2.17)	(2.40)	(5.20)	(4.76)	(8.94)	(8.19)	(10.54)	(10.83)
Alachlor 1.5 kg/ha + HW	2.19	1.94	1.00	1.02	1.16	1.19	1.12	1.38	1.37	1.57	2.04	2.16
at 40 DAS	(4.57)	(3.35)	(0.51)	(0.55)	(0.86)	(0.93)	(0.82)	(1.53)	(1.45)	(2.13)	(3.80)	(4.28)
LSD (P=0.05)	0.188	0.178	0.070	0.071	0.073	0.073	0.109	0.109	0.156	0.146	0.132	0.133

*Original values are given in parentheses

Table 2. Species-wise dry matter of weeds (g/m^2) at harvest of maize (105 DAS) as influenced by planting geometry and weed management in maize + blackgram intercropping system

Treatment	*Alternanthera triandra*		*Cynotis axillaris*		*Cynodon dactylon*		*Brachiaria ramosa*		*Cyperus rotundus*		Others	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Planting geometry												
Maize sole	6.11	5.90	2.50	2.55	2.35	2.54	4.64	4.78	4.38	4.64	4.27	4.32
	(39.71)	(37.14)	(6.29)	(6.62)	(5.92)	(6.82)	(22.75)	(23.25)	(23.17)	23.57	(18.63)	(19.07)
Blackgram sole	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	0.00	(0.00)	(0.00)
Maize + blackgram (1:1)	4.90	4.77	2.09	2.08	2.12	2.20	3.59	3.61	3.57	3.75	3.55	3.71
	(26.35)	(25.16)	(4.25)	(4.19)	(4.60)	(4.95)	(13.99)	(13.79)	(16.34)	16.90	(12.61)	(13.77)
Maize + blackgram (2:1)	5.27	5.25	2.36	2.41	2.26	2.47	4.18	4.37	4.00	4.26	4.10	4.20
	(30.42)	(30.78)	(5.51)	(5.93)	(5.45)	(6.39)	(18.64)	(20.33)	(20.06)	20.19	(17.38)	(18.10)
Maize + blackgram (2:2)	4.89	4.94	2.24	2.28	2.17	2.30	3.90	3.93	3.82	3.79	3.98	4.04
	(27.16)	(27.83)	(4.94)	(5.15)	(4.91)	(5.50)	(16.35)	(16.27)	(18.55)	16.28	(16.29)	(16.79)
LSD (P=0.05)	0.308	0.300	0.110	0.120	0.130	0.140	0.212	0.226	0.245	0.264	0.226	0.236
Weed management												
Weedy check	6.59	6.60	2.74	2.83	3.12	3.20	4.59	4.44	5.61	5.13	4.44	4.52
	(51.88)	(51.93)	(8.11)	(8.75)	(10.71)	(11.39)	(24.52)	(22.87)	(37.19)	(30.90)	(22.89)	(23.84)
Hand weeding at 30 DAS	4.11	4.04	1.74	1.83	1.49	1.75	3.33	3.66	3.99	4.18	2.83	3.02
	(19.77)	(18.91)	(2.81)	(3.16)	(1.90)	(2.83)	(12.39)	(15.28)	(18.22)	(20.25)	(8.69)	(10.00)
Alachlor 2.0 kg/ha	4.06	4.00	2.14	2.11	1.64	1.78	3.88	3.79	2.40	2.53	3.46	3.37
	(18.91)	(18.30)	(4.60)	(4.46)	(2.43)	(2.97)	(17.25)	(16.53)	(6.11)	(6.91)	(13.50)	(12.64)
Alachlor 1.5 kg/ha + HW	2.74	2.62	1.29	1.25	1.42	1.45	1.82	2.02	1.18	1.88	2.54	2.68
at 40 DAS	(8.34)	(7.59)	(1.27)	(1.14)	(1.66)	(1.73)	(3.22)	(4.23)	(0.98)	(3.49)	(6.84)	(7.69)
LSD (P=0.05)	0.201	0.199	0.082	0.084	0.081	0.860	0.157	0.155	0.159	0.150	0.146	0.148

*Original values are given in parentheses

competitive effect against weeds either in time or space than monocropping (Srikrishnah *et al.* 2008). Makindea *et al.* (2009) also found that the leafy greens can be intercropped with maize to control weeds and increase productivity.

Weed control efficiency

Weed control efficiency at 75 DAS for blackgram was the highest under alachlor 1.5 kg/ha + HW at 40 DAS (91 - 92%) which was followed by HW at 30 DAS (75 - 76%) and alachlor 2.0 kg/ha (69%) (Table 3). Weed control efficiency at harvest of maize was significantly influenced by weed management, where all the weed management treatments resulted in increase of weed control efficiency over the weedy check. The highest weed control efficiency was observed under alachlor 1.5 kg/ha + HW at 40 DAS (83%) which was followed by alachlor 2.0 kg/ha (59%) and HW at 30 DAS (59-53%). Weed control efficiency of maize was appreciably influenced by planting geometry at harvest of maize (Table 3). The highest weed control efficiency was obtained under maize + blackgram (1:1) which was higher than maize + blackgram (2:2) and maize + blackgram (2:1). This confirmed the findings of Pandey and Prakash (2002).

Grain yield and production efficiency

Grain yield, Productivity rating index (PRI) and Production efficiency (PE) of maize were the highest with maize + blackgram (2:1), followed by maize + blackgram (1:1). However, it was the lowest with maize + blackgram (2:2). All the weed management practices recorded significantly higher values of grain yield, PRI and PE over weedy check. Application of alachlor 1.5 kg/ha + HW at 40 DAS recorded significantly higher values over other weed management practices (Table 3). In case of blackgram, the seed yield, PRI and PE were significantly highest under sole crop and the lowest under maize + blackgram (2:1). All weed management practices recorded significantly higher grain yield, PRI and PE over weedy check. Application of alachlor 1.5 kg/ha + HW at 40 DAS recorded significantly higher values over rest of the weed management practices during first year where it was at par with HW at 30 DAS and alachlor 2.0 kg/ha. Several workers also advocated that the legume and non legume intercropping, yield of non legume increased in intercropping as compared with monocropping (Brintha and Seran, 2008). Mashingaidze (2004) found that by intercropping land was effectively utilized and yield was improved. Intercropping occupies greater land use and thereby provides higher net returns (Seran and Brintha 2009).

It was concluded that planting geometry of maize + blackgram (2:1) was found to be best in terms of maize yield and sole in terms of blackgram yield. Application of alachlor 1.5 kg/ha + HW at 40 DAS resulted in the highest weed control efficiency, grain yield, PRI and PE of maize and blackgram.

Table 3. Grain yield, productivity rating index (PRI) and production efficiency (PE) of maize and blackgram as influenced by planting geometry and weed management in maize + blackgram intercropping system

Treatment	Maize						Blackgram						Maize		Blackgram	
	Grain yield (kg/ha)		PRI		PE		Grain yield (kg/ha)		PRI		PE		Weed Control efficiency			
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Planting Geometry																
Maize sole	2935	2142	146.8	107.1	28.8	20.8	-	-	-	-	-	-	-	-	-	-
Blackgram sole	-	-	-	-	-	-	633	665	211.2	221.9	8.0	8.5	-	-	-	
Maize + blackgram (1:1)	3080	2235	154.01	111.8	30.2	21.7	382	453	127.5	151.1	4.8	5.8	32.9	32.4	-	-
Maize + blackgram (2:1)	3143	2311	157.2	115.6	30.8	22.4	190	329	63.4	109.8	2.4	4.2	16.3	12.7	-	-
Maize + blackgram (2:2)	2356	1738	117.8	86.9	23.1	16.9	293	411	97.8	137.2	3.7	5.3	24.3	24.6	-	-
LSD (P=0.05)	163	152	8.15	7.6	1.60	1.5	31.50	43.40	14.7	21.9	0.56	0.84	-	-	-	-
Weed management																
Weedy check	2117	1538	105.9	76.9	20.76	14.9	265	253	88.3	84.50	3.43	3.28				
Hand weeding at 30 DAS	3096	2224	154.8	111.2	30.35	21.6	407	488	135.8	162.7	5.15	6.23	58.93	52.94	75.52	75.82
Alachlor 2.0 kg/ha	2931	2056	146.6	102.8	28.74	19.9	400	516	133.3	172.0	5.11	6.67	59.56	58.70	69.06	68.59
Alachlor 1.5 kg/ha + HW at 40 DAS	3370	2608	168.5	130.4	33.0	25.3	427	602	142.4	200.8	5.3	7.6	85.6	82.7	91.6	90.5
LSD (P=0.05)	70	130	3.49	6.55	0.68	1.27	18.3	28.6	12.69	15.42	0.48	0.59	-	-	-	-

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Indian Journal of Weed Science **44**(1): 30–33, 2012

Bioefficacy of pre- and post-emergence herbicides in direct-seeded rice in Central Punjab

U.S. Walia, S.S. Walia, Amandeep Singh Sidhu* and Shelly Nayyar
Department of Agronomy, Punjab Agricultural Univerisity Ludhiana, Punjab 141 004

Received: 28 February 2012; Revised: 24 March 2012

ABSTRACT

Field experiments were conducted during *Kharif* season of 2007 and 2008 at Punjab Agricultural University, Ludhiana to evolve suitable combination of pre and post-emergence herbicides for effective weed management in direct-seeded rice under unpuddled conditions. Results indicated that during 2007, integration of post-emergence application (30 Days after sowing) of bispyribac (25 and 30 g/ha) or azimsulfuron (20 g/ha) with pre-emergence application of pendimethalin 0.75 kg/ha, pretilachlor 0.5 kg/ha and thiobencarb 1.25 kg/ha provided effective control of weeds and produced significantly higher grain yields than unweeded (control) treatment. During 2008 also, integration of pre-emergence application of pendimethalin 0.75 kg/ha or oxadiargyl 0.90 g/ha with post-emergence application of bispyribac 25 kg/ha, azimsulfuron 20 g/ha and 2,4-D 0.5 kg/ha resulted in significant reduction in dry matter of weeds and increased grain yield as compared to alone application of pendimethalin 0.75 kg/ha. Pre-emergence application of flufenacet 80 g/ha and early post-emergence application of penoxsulam 30 and 35/g ha were found ineffective for controlling weeds.

Key words: Direct-seeded rice, Dry matter accumulation, Herbicides, Seed yield, Weed control

Rice (*Oryza sativa* L.) is the most important staple food for more than half of the world's population, including regions of high population density and rapid growth. India has the largest area among rice growing countries and stands second in production. Rice is being cultivated by three principal methods *viz.*, transplanting, dry seeding and wet seeding. Transplanting is the traditional system of rice cultivation and it is in vogue in many rice growing areas. Expansion in the irrigated area, introduction of early maturing rice cultivars, availability of selective herbicides for weed management together with increasing transplanting cost and declining profitability of transplanted rice production system have encouraged rice farmers to shift from transplanting to direct seeding (Subbaiah *et al.* 1999). In order to check the declining water table, a new technique of direct-seeding is now fast replacing traditional transplanted rice in areas with good drainage and irrigation facilities (Balasubramanian and Hill 2000). Globally, actual rice yield losses due to pests have been estimated at 40%, of which weeds have the highest loss potential (32%). The worldwide estimated loss in rice yield from weeds is around 10% of the total production (Oerke and Dehne 2004). However, for cultivation of direct-seeded rice, weeds are a major hurdle as nearly all *Kharif* season weeds depending upon seed bank in the field infest this crop. Direct seeding of rice is possible, provided there is a good crop establishment as well as adequate weed control methods are available to keep the crop free from weeds (Rao *et al.* 2007, Rao and Nagamani 2007) , however in absence of proper weed control, rice yields are reduced by 35-100 per cent in DSR (Kumar *et al.* 2008). Weeds pose major problem in rice production due to the prevalence of congenial atmosphere during *Kharif* season and uncontrolled weeds compete with dry-seeded rice and reduce yield upto 30.2% (Singh *et al.* 2005). The risk of crop yield loss due to competition from weeds by all seeding methods is higher than for transplanted rice because of the absence of the size differential between the crop and the weeds and the suppressive effect of standing water on weed growth at crop establishment. The conversion from transplanted to direct seeded rice results in more aggressive weed flora and increases reliance on herbicides for weed control. The adoption of direct seeded rice has resulted in a change in the relative abundance of weed species in rice crops. In particular *Echinochloa* spp., *Ischaemum rugosum*, *Cyperus difformis* and *Fimbristylis miliacea* are widely adapted to conditions of DSR. Chemical weed control (pre-emergence and post-emergence application) provides best weed control and grain yield. So, present investigations were undertaken to find out appropriate combination of pre and post-emergence herbicides to keep direct-seeded rice free from weeds.

***Corresponding author:** amansidhu_80@rediffmail.com

MATERIALS AND METHODS

Field experiments were conducted during *Kharif* 2007 and 2008 at Punjab Agricultural University, Ludhiana (30^0 56' N latitude with 75^0 52' E longitude, 247 m mean sea level) to find out appropriate combination of herbicides in direct seeded rice. Direct seeding of rice was done in unpuddled (dry) conditions during both the years. The experiment field was loamy sand in texture with 76.7% sand, 9.2% silt and 14.0% clay. It was low in available nitrogen (255 and 263 kg/ha), medium in available P (11.8 and 12.7 kg/ha) and K (138.5 and 146.5 kg/ha) during 2007 and 2008, respectively. During 2007 pre-emergence application of pendimethalin 750 g/ha, pretilachlor 400 g/ha, thiobencarb 1250 g/ha and oxadiargyl 60 g/ha were followed by post-emergence (25 DAS) application of bispyribac 25 and 30 g/ha and azimsulfuron 20 g/ha. Alone pre-emergence application of pretilachlor 500 g/ha, flufenacet 80 g/ha as well as post–emergence application of bispyribac 25, 30 and 35 g/ha and pinoxsulam 30 and 35 g/ha were also kept. Unweeded control was also kept as check.

During 2008, pendimethalin at 750 g/ha and penoxsulam 30 g/ha were applied as pre-emergence. Integration of pre-emergence pendimethalin 750 g/ha with post-emergence application of azimsulfuron 20 g/ha, 2, 4-D 500g/ha, metsulfuron 15 g/ha, etoxysulfuron 20g/ha and bensulfuron 60 g/ha as well as pre-emergence application of oxadiargyl 90 g/ha followed by post-emergence application of bispyribac 25 g/ha, azimsulfuron 20 g/ha, ethoxysulfuron 20 g/ha were applied. Tank mix application of bispyribac + azimsulfuron (25 + 20 g/ha), bispyribac + etoxysulfuron (25 g + 20 g/ha), Bispyribac + 2,4-D (25 g + 500 g/ha) were also included along with post-emergence application of bispyribac 25 g/ha and unweeded control. All the post-emergence herbicides were applied 30 days after sowing with knapsack sprayer using 250 litre water/ha. Direct-seeding of rice variety PR 115 was done manually with hand drill keeping row to row spacing of 20 cm on 10th June, 2007 and 7th June, 2008 using seed rate of 50 kg/ha. Data on weed dry matter was recorded at 60 DAS with quadrate measuring 50×50 cm and expressed as t/ha. Data on plant height, effective tillers, panicle length and grain yield was recorded at the time of crop harvest. Data was subjected to analysis as detailed by Cheema and Singh (1991) in statistical package CPCS-1.

RESULTS AND DISCUSSION

The major weed flora of the experiment field consisted of sedges (*Cyperus rotundus*, *Cyperus iria* and *Cyperus compressus*), grasses (*Digitaria sanguinalis*, *Echinochloa* spp, *Eleusine aegyptiacum*, *Leptochloa chinesis* and *Eragrostis* spp.) and broadleaves (*Ammania baccifera* and *Caesulia axillaris*). In 2007, all the herbicidal treatments reduced the dry matter of weeds significantly as compared to the unweeded control except for post-emergence application of penoxsulam 30 and 35 g/ha. Lowest weed dry matter (80 kg/ha) was recorded with the pre-emergence application of pendimethalin 0.75 kg/ha followed by post-emergence application of bispyribac 30 g/ha, which was significantly more than unweeded control but statistically at par with pre-emergence application of pretilachlor or thiobencarb or oxadiargyl followed by post emergence application of bispyribac and alone post emergence application of bispyribac (Table 1). Alone application of pre-emergence herbicides i.e. pretilachlor/ flufenacet or post emergence herbicide i.e. penoxsulam did not provided effective control of weeds as compared to combination of pre and post-emergence herbicides. Porwal (1999) also reported similar findings that post-emergence application of pretilachlor with Safener at 0.375 kg/ha gave 13.4 percent higher yield over its pre-emergence application. Among the post-emergence herbicides, bispyribac 25 and 30 g/ha proved better than azimsulfuron 20 g/ha, when these were integrated with pre-emergence application of pendimethalin 0.75 kg/ha or thiobencarb 1.25 kg/ha. Above data concludes that it is difficult to get effective weed control in DSR with a single herbicide. A combination of pre and post emergence herbicides is required to effectively control weeds. Highest weed control efficiency (86.2 and 77.6%) was recorded with pre-emergence application of pendimethalin 0.75 kg/ha followed by post emergence application of bispyribac 30 g/ha during both years.

All the growth parameters i.e. plant height, effective tillers and panicle length during 2007 were significantly higher under herbicidal combinations as compared to the alone application of these herbicides except bispyribac (Table 1). Application of thiobencarb followed by post-emergence application of bispyribac at 30 g/ha recorded highest grain yield of 5.7 t/ha which was 375 per cent higher than that of unweeded control. It was closely followed by the treatments where post-emergence application of bispyribac 30 g/ha was made following the pre-emergence application of pendimethalin or pretilachlor, which recorded 5.4 and 5.2 t/ha grain yield, respectively. The performance of oxydiargyl 60 g/ha followed by bispyribac 25 and 30 g/ha and bispyribac alone at higher dose 35 g/ha was found better as compared to pretilachlor at 0.50 kg/ha, flufenacet 80 g/ha (applied 2-3 days after sowing) and penoxsulam 30 g/ha.

During second year, pre-emergence application of pendimethalin 0.75 kg/ha followed by bispyribac 25 g/ha

Table 1. Effect of different combination of pre- and post-emergence herbicides on weed dry matter, yield and yield attributes of direct-seeded rice (2007)

Treatment	Dose g/ha	Dry matter of weeds (60 DAS) (kg/ha)	Plant height (cm)	Effective tillers/m^2	Panicle length (cm)	Seed yield (t/ha)	Weed control efficiency (%)
Pretilachlor, pre-emergence	400	300 (1010)	62.0	312.5	24.0	3.8	47.3
Pendimethalin *fb* bispyribac	750, 25	80 (130)	65.4	387.3	25.3	4.9	86.2
Pendimethalin *fb* bispyribac	750, 30	110 (20)	65.5	400.5	25.2	5.4	81.6
Pendimethalin *fb* azimsulfuron	750, 20	310 (930)	63.9	369.2	23.6	4.7	47.6
Pretilachlor *fb* bispyribac	500, 25	180 (220)	65.9	398.2	25.3	5.2	69.6
Pretilachlor *fb* bispyribac	500, 30	150 (160)	63.0	402.3	23.6	5.2	73.9
Pretilachlor *fb* azimsulfuron	500, 20	240 (550)	65.0	365.7	24.0	4.7	58.2
Thiobencarb *fb* bispyribac	1250, 25	140 (160)	66.2	395.4	24.5	5.1	72.9
Thiobencarb *fb* bispyribac	1250, 30	120 (140)	68.3	415.4	24.2	5.7	79.9
Thiobencarb *fb* azimsulfuron	1250, 20	230 (590)	64.5	359.5	24.3	4.6	60.1
Oxadiargyl *fb* bispyribac	60, 25	140 (150)	68.5	375.0	25.3	4.8	75.4
Oxadiargyl *fb* bispyribac	60, 30	130 (90)	68.3	384.5	24.0	4.9	77.1
Oxadiargyl *fb* azimsulfuron	60, 20	420 (1910)	62.1	310.2	24.0	3.8	27.8
Bispyribac, post-emergence	25	160 (150)	67.3	342.5	25.0	4.3	72.5
Bispyribac, post-emergence	30	160 (150)	65.9	372.5	24.8	4.8	72.9
Bispyribac, post-emergence	35	170 (230)	66.4	393.4	24.7	5.0	70.8
Penoxsulam, post-emergence	30	490 (2570)	59.7	147.5	22.9	1.6	16.0
Penoxsulam, post-emergence	35	470 (2670)	62.9	213.2	22.9	2.4	19.2
Flufenacet, pre-emergence	80	320 (1300)	60.1	233.8	23.1	2.5	45.5
Control (unweeded)		580 (3560)	55.7	121.2	20.5	1.2	
LSD (P=0.05)		120	5.6	11.5	2.5	0.8	

*Figures in parentheses are original values

Table 2. Influence of different combinations of pre- and post-emergence herbicides on dry matter of weeds, yield and yield attributes of rice (2008)

Treatment	Dose g/ha	Dry matter of weeds (kg/ha)	Plant height (cm)	Effective tillers/m^2	Panicle length (cm)	Seed yield (t/ha)	Weed control efficiency (%)
Pendimethalin, pre-em	750	300 (780)	66.3	284.5	22.5	3.5	76.0
Pendimethalin *fb* bispyribac	750, 25	280 (850)	65.0	405.0	23.2	5.3	77.6
Pendimethalin *fb* azimsulfuron	750, 20	460 (2240)	67.6	384.0	22.7	4.9	63.2
Pendimethalin *fb* 2,4-D	750, 500	470 (2140)	66.0	353.2	23.3	4.6	62.4
Pendimethalin *fb* metsulfuron	750, 15	340 (1380)	66.5	291.3	23.7	3.6	72.8
Pendimethalin *fb* ethoxysufuron	750, 20	350 (1600)	65.2	345.5	23.4	4.5	72.0
Pendimethalin *fb* bensulfuron methyl	750, 6s0	340 (1380)	65.5	352.3	23.0	4.1	72.8
Bispyribac + azimsulfuron	25 + 20	670 (4030)	54.6	243.2	21.5	2.8	46.4
Bispyribac + ethoxysulfuron	25 + 20	300 (780)	62.7	269.4	21.6	3.1	76.0
Bispyribac + 2,4-D	25 + 500	310 (900)	60.5	21.02	21.5	2.4	75.2
Bispyribac	25	320 (950)	60.0	276.3	22.8	3.2	74.4
Oxadiargyl *fb* aispyribac	90, 25	540 (3130)	65.0	378.2	23.6	5.1	56.8
Oxadiargyl *fb* azimsulfuron	90, 20	300 (610)	64.7	381.2	22.3	4.9	76.0
Oxadiargyl *fb* ethoxysulfuron	90, 20	710(4760)	57.3	358.2	23.0	4.2	43.2
Penoxulam	30	660 (3760)	62.1	284.6	21.7	3.3	47.2
Control (unweeded)	-	1250 (3530)	65.2	182.3	21.0	2.1	
LSD (P=0.05)	-	330	7.0	31.4	1.8	1.1	

*Figures in parentheses are original values proved highly effective in controlling the weed infestation as dry matter of weeds was the lowest in this treatment (Table 2). This was closely followed by pendimethalin 0.75 kg/ha followed by metsulfuron 15 g/ha, pendimethalin 0.75 kg/ha followed by bensulfuron 60 g/ha and pendimethalin 0.75 kg/ha followed by ethoxysulfuron 20 g/ha. Bispyribac alone and pendimethalin alone did not provide effective control of weeds. Also post-emergence tank mix application of bispyribac (25 g/ha) + 2,4-D (500 g/ha) and bispyribac (25 g/ha) + azimsulfuron (20 g/ha) did not provide effective control of weeds as grain yield obtained in these treatments was at par with unweeded control. Singh *et al* (2005) also reported similar findings.

The maximum grain yield (5.3 t/ha) was obtained with pre-emergence application of pendimethalin 0.75 kg/ha followed by bispyribac 25 g/ha which was closely followed by oxadiargyl (90 g/ha) followed by bispyribac (25 g/ha), oxadiargyl (90 g/ha) followed by azimulfurom (20 g/ha) and pendimethalin 0.75 kg/ha followed by azimsulfuron 20 g/ha. There was 152.4, 142.9, 133.3 and 133.3 per cent increase in grain yield over unweeded control with these treatments, respectively. Plant height, panicle length and number of effective tillers/m^2 were also higher in these treatments.

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Indian Journal of Weed Science **44**(1): 34–37, 2012

Concurrent growing of green manure with wet-seeded rice for cost-effective weed management

S. Anitha*, Jose Mathew[1] and C.T. Abraham[2]

Agricultural Research Station, Kerala Agricultural University, Mannuthy, Kerala 680 651

Received: 14 July 2010; Revised: 5 November 2011

ABSTRACT

Field experiments were conducted during 2004-06 at Agricultural Research Station, Mannuthy, Thrissur, Kerala to find out the effect of concurrent growing of dhaincha (*Sesbania aculeata*) and its methods of incorporation on weed management in wet seeded rice. Sowing of rice and dhaincha was done in alternate rows using the rice-cum-green manure seeder. Treatments consisted of incorporation of dhaincha at 20 and 30 days after sowing (DAS) by using cono weeder, spraying 2, 4-D 1.0 kg/ha, and metsulfuron-methyl 5 .0 g/ha. Two levels of N (100 and 75% of recommended dose of 90 kg N/ha) were superimposed. Rice alone with 5 t/ha FYM and recommended dose of 90-45-45 kg N-P-K/ha was taken as control. Concurrent growing of dhaincha and its incorporation at 30 DAS resulted in a weed suppression of 70% with an yield enhancement to the tune of 0.840 t/ha and increased profitability of ₹ 12520/ha). Application of 2,4–D resulted in maximum reduction of weeds without any adverse effect on rice. Nitrogen at different levels had no significant influence of weed incidence.

Key words: 2,4-D, Cono weeding, Metsulfuron-methyl, Rice, *Sesbania aculeata*, Weed management

Rice cultivation in Kerala has become less profitable in recent years due to increasing production cost. High labour cost, particularly for labour intensive operations like crop establishment and weeding, significantly contributes to increase production cost. Wet seeding of rice in lowlands is a cost effective and labour-saving crop establishment method followed by the farmers. However, excessive weed growth is a major constraint in wet-seeded rice. Intercropping green manure crops in dry-seeded rice and its subsequent incorporation is very effective in supplying the required quantity of organic manures to rice with additional benefit of weed suppression (Mathew *et al.* 1996). In wet seeded rice, the system involves raising dhaincha as a green manure crop concurrently with wet-seeded rice using rice-cum-green manure seeder and subsequent incorporation of dhaincha (*Sesbania aculeata*) using a cono weeder. The possibility of intense rainfall immediately after sowing may adversely affect the establishment of rice and dhaincha in lines, thus posing problems in the incorporation of dhaincha by using cono-weeder. Thus, it is essential to identify alternate methods of incorporation of dhaincha without any adverse effects on rice plants. The present study was undertaken to find out optimum stage and effective method of incorporation of dhaincha on weed control and productivity of wet-seeded rice.

*Corresponding author: anitha.sarala@gmail.com
Present address : [1]*Cashew Research Station, KAU, Madakkathara, Kerala 680 651*
[2]*College of Horticulture, Kerala Agricultural University, Vellanikkara, Kerala 680 654*

MATERIALS AND METHODS

Field experiments were conducted at the Agricultural Research Station, Mannuthy, Thrissur, Kerala during the rainy (*Kharif*) season of 2004-05 and 2005-06. The experimental site was sandy loam in texture with pH 5.6, low in available N (247.7 kg/ha), medium in available P_2O_5 (66.1 kg/ha) and high in available K_2O (616 kg/ha). The experiments were laid out in factorial randomized block design with one control replicated thrice. '*Aiswarya*' was used as the test variety. Sowing of rice and dhaincha was done simultaneously into puddled soil using the rice-cum-green manure seeder. Rice seeds (60 kg/ha), with radicle just emerging and unsprouted dhaincha seeds (20 kg/ha) were used for sowing with the seeder. Treatments consisted of incorporation of dhaincha at two stages *i.e.* 20 and 30 days after sowing (DAS) by using one of the three methods *viz.*, using cono weeder, by spraying 2,4-D 1.0 kg/ha, and metsulfuron-methyl 5.0 g/ha. Two levels of N (100 and 75% of recommended dose of 90 kg N/ha) were superimposed. Wet-sown rice without dhaincha receiving 5 t FYM/ha and recommended dose of nutrients (90 - 45 - 45 kg N- P- K/ha) was taken as control. FYM was applied to control plots alone and incorporated by digging before sowing. Nitrogen fertilizer 100 and 75% of the recommended dose were applied according to the treatment schedule ($^1/_3$rd basal, 45 DAS, and 60 DAS). Fertilizers P and K were applied uniformly to all the treatments. Irrigation was given as and when required. One weeding was given at 50 DAS to all the treatments. Observations on weed incidence and weed dry matter was recorded from 1m^2 area by placing a quadrate of 50 x 50 cm randomly at four places in each plot before weeding at 50 DAS. Growth and yield attributes were measured from 10 randomly selected hills. Labour charges, cost of inputs, and the additional cost of incorporating dhaincha were worked out to compute the gross expenditure.

RESULTS AND DISCUSSION

Weed flora and growth

Weed flora were *Echinochloa colona*, *Isachne miliacea, Panicum repens* and *Ischaemum rugosum* among grasses; *Monochoria vaginalis*, *Ludwigia parviflora*, *Marsilea quadrifoliata, Nymphaea nouchali* and *Spenoclea zeylanica* among broad-leaved weeds; and *Cyperus rotundus*, *Schoenoplectus* sp. and *Fimbristylis miliacea* among sedges.

Concurrent growing of dhaincha along with wet-seeded rice significantly reduced the weed count and dry weight of grasses, broad-leaved weeds and sedges, and dry matter production compared with rice grown alone (Table 1). Beneficial effects of concurrent growing of dhaincha in reducing the weed population and weed biomass were reported by Sankar *et al.* (2003). The decline in total weed count due to concurrent growing of dhaincha was 72%, while that in weed dry matter production was 57% compared to rice grown alone (Table 2). The reduction in weed population and dry matter may be attributed to shading effect exerted by the canopy of dhaincha. The co-cropping system reduced the weeding cost by 59% due to saving in labour requirement by 38 man-days/ha. This indicated that dhaincha grown at the expense of weeds by using the growth resources which weeds would have otherwise utilized,. Reduced weed population in treatments involving co-cropping of dhaincha created a competition free environment for growth resources for rice, and might have resulted in increased nutrient uptake and yield of rice compared with pure crop of rice. Stage of incorporation of dhaincha had no significant influence on weed incidence.

Methods of incorporation

In this investigation, dhaincha was incorporated at 20 and 30 DAS by using cono-weeder, or spraying 2,4-D 1.0 kg/ha, or spraying metsulfuron-methyl 5.0 g/ha. Results revealed that grassy weeds were significantly less in cono-weeded treatments. Accordingly, incorporation of dhaincha by cono-weeder resulted in reduction of total weed count by 65% and weed dry matter by 55% compared to control. Rajendran *et al.* (2002) reported that weeds were controlled by adoption of concurrent growing of dhaincha and rice using rice cum green manure seeder and the subsequent incorporation of dhaincha by using cono weeder. Broad-leaved weeds and sedges were significantly higher in cono-weeded plots compared to other methods of incorporation but less than control. Incorpo-

Table 1. Effect of stages and methods of incorporation of concurrently grown dhaincha and N levels on weed count (no./m^2) at 50 DAS

Treatment	Grass weeds		Broad-leaved weeds		Sedges		Total	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Stage of incorporation								
20 DAS	4.33	8.61	7.28	12.72	15.33	23.11	26.94	44.44
30 DAS	3.11	6.50	8.17	11.67	16.44	22.39	27.72	40.67
LSD (P=0.05)	1.45	NS	NS	NS	NS	NS	NS	NS
Method of incorporation								
Conoweeding	2.33	4.25	11.25	17.33	22.67	28.42	36.25	50.00
2,4-D spray	4.25	11.50	5.33	11.33	9.50	13.42	19.08	36.00
Metsulfuron-methyl spray	4.58	6.92	6.58	7.92	15.50	26.42	26.67	41.67
LSD (P=0.05)	1.77	3.23	3.73	5.80	5.61	7.94	8.76	10.42
N levels								
100% N	3.83	7.33	7.17	11.94	16.06	21.67	27.06	41.44
75% N	3.61	7.78	8.28	12.44	15.72	23.83	27.61	43.67
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Rice alone	25.00*	23.33*	18.00*	38.33*	80.67*	72.33*	123.67*	127.67

* Rice alone vs. treatments significant

Table 2. Effect of stages and methods of incorporation of concurrently grown dhaincha and N levels on dry weight of weeds (g/m²) at 50 DAS

Treatment	Grass weeds		Broad-leaved weeds		Sedges		Total	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Stage of incorporation								
20 DAS	6.15	10.33	6.07	8.52	7.67	10.90	19.89	29.75
30 DAS	5.32	9.37	7.09	9.05	7.73	12.01	20.13	30.43
LSD (P=0.05)	0.70	NS	0.77	NS	NS	NS	NS	NS
Method of incorporation								
Conoweeding	4.24	8.67	7.37	10.94	8.68	11.92	20.29	31.53
2,4-D spray	6.47	10.62	5.89	8.65	6.33	9.68	18.69	28.94
Metsulfuron-methyl spray	6.50	10.27	6.48	6.78	8.08	12.76	21.56	29.81
LSD (P=0.05)	0.86	1.55	0.95	1.23	1.78	2.82	2.06	NS
N levels								
100% N	5.71	9.36	6.33	8.75	6.99	11.07	19.03	29.18
75% N	5.76	10.34	6.83	8.83	8.40	11.84	21.00	31.01
LSD (P=0.05)	NS	NS	NS	NS	1.46	NS	1.68	NS
Rice alone	9.94*	19.24*	19.00*	17.97*	21.70*	27.76*	50.63*	64.97*

* Rice alone vs. treatments significant

ration of dhaincha by spraying 2,4-D resulted in 78% reduction in total weed count and 59 % in weed dry matter production. Application of 2,4-D for incorporation of dhaincha controlled broad-leaved weeds and sedges substantially because 2,4-D is a selective herbicide recommended against broad-leaved weeds and sedges in rice. Gupta *et al*. (2006) reported that co-culture of *Sesbania* in rice and its subsequent knock down by 2,4-D ester reduced the weed population by nearly half without any adverse effect on rice yield. Reduction in total weed population and weed dry matter by metsulfuron-methyl spray was 72 and 56% respectively. Metsulfuron-methyl is also a selective herbicide for broad-leaved weeds and sedges in rice, and resulted in reduced count and dry matter of total weeds. In plots, where infestation of weeds like *Marsilea quadrifolia* and *Ludwigia parviflora* was serious, application of metsulfuron-methyl was more effective.

N levels

Nitrogen application at 100 and 75% of the recommended dose had no significant influence on the count and dry matter of weeds at 50 DAS. Weed incidence was comparatively more in rice alone plots which received 100% of the recommended N dose along with FYM. Presence of weed seeds in FYM might here increased weed incidence in FYM applied treatments.

Yield and economics

Incorporation of concurrently grown dhaincha at 30 DAS was found beneficial as this resulted in an enhancement in yield and profitability with weed suppression compared to incorporation of dhaincha at 20 DAS (Table 3). Methods of incorporation of dhaincha by all the three methods were found to be equally effective in terms of productivity. Hence in places where it is difficult to use cono weeder for incorporation of dhaincha, it can be effectively incorporated by spraying 2,4-D or metsulfuron-methyl without affecting the yield. Rice+dhaincha receiving 100% of the recommended N recorded significantly higher grain yield (5.17 t/ha), compared to the lower dose of N (75%). Rice yield in dhaincha intercropped plots which received either 100% or 75% of recommended N fertilizer also was significantly higher than the control plots, which received 5 t FYM /ha and full dose of N. Growing dhaincha along with rice and its subsequent incorporation reduced the use of N fertilizers by about 25% without affecting grain yield.

Concurrent growing of dhaincha and its incorporation at 30 DAS resulted in weed suppression of 70% with yield enhancement to the tune of 0.84 t/ha and profitability of ₹ 12520/ha. Application 2,4-D resulted in maximum reduction of weeds without any adverse effect on rice. Concurrent growing of dhaincha and its incorporation using 2,4-D is a low-cost weed management alternative for wet-seeded rice.

Effectiveness of herbicides for incorporating dhaincha without any adverse effect revealed the possibility of direct broadcasting of dhaincha with rice seeds rather than line sowing by using rice-cum-green manure seeder and incorporating dhaincha by cono weeder.

Table 3. Effect of stages and methods of incorporation of concurrently grown dhaincha and nitrogen levels on the yield and economics of wet-sown rice (pooled data)

Treatment	Grain yield (t/ha)	Cost of treatments ($x10^3$ ₹/ha)	Gross returns ($x10^3$ ₹/ha)	Net returns ($x10^3$ ₹/ha)	B: C ratio
Stage of incorporation					
20 DAS	4.91	4.42	41.09	25.24	2.59
30 DAS	5.18	4.39	43.33	27.47	2.73
LSD (P=0.05)	0.202	-	1.615	1.615	0.10
Method of incorporation					
Conoweeding	5.12	4.75	42.75	26.53	2.64
2,4-D spray	5.03	4.15	42.13	26.55	2.70
Metsulfuron-methyl spray	4.99	4.33	41.75	25.98	2.65
LSD (P=0.05)	NS	-	NS	NS	NS
N levels					
100% N	5.12	4.41	43.17	27.19	2.70
75% N	4.93	4.40	41.25	25.52	2.62
LSD (P=0.05)	0.202	-	1.615	1.615	0.10
Rice alone	4.50*	9.60	37.83*	16.14*	1.74*

* Rice alone vs. treatments significant, Cost of operation – conoweeding - ₹ 1300/ha; 2,4-D application - ₹ 660/ha; Metsulfuron-methyl application - ₹ 850/ha, Price of Produce – Rice - ₹ 8/kg; Straw - ₹ 0.5/kg

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Indian Journal of Weed Science 44(1): 38–42, 2012

Management strategies for rehabilitation of *Lantana* infested forest pastures in Shivalik foothills of Jammu & Kashmir

B.C. Sharma*, Anil Kumar and S.K. Gupta[1]

Division of Agronomy, SKUAST-J, Main Campus Chatha, Jammu, Jammu & Kashmir 180 009

Received: 16 November; Revised: 12 February 2012

ABSTRACT

A study on rejuvenation of wild sage (*Lantana camara L.*) infested forest pastures in Shivalik foot-hills of Jammu & Kashmir was conducted from April 2006 to December 2008. The study included manual cuttings of *Lantana* bushes*;* manual cuttings followed by application of 1% glyphosate on its regenerated growth of 30 cm in height; and manual grubbings. These were followed by either no plantation of grasses, planting either of hybrid napier and *Setaria* cuttings. Results of the study revealed that the fresh bio-mass of *Lantana* bushes recorded a sizeable reduction ranging from 66 to 99% under different treatments over its initial average fresh bio-mass value of 28 kg/25 m^2. Likewise, a significant reduction in the number of *Lantana* bushes per unit area to the extent of 67-99% over its initial average value of 6 bushes/25 m^2 was also recorded with grubbing and the herbicide applied treatments. Application of glyphosate 30 cm regenerated growth of *Lantana* bushes and grubbing treatments followed by planting either of hybrid napier and *Setaria* were found equally effective in rehabilitation of *Lantana* infested forest pastures as both of these grasses provided good soil cover and recorded higher forage yields under these treatments *i.e.* hybrid napier 1.81 to 2.07 t/ha and *Setaria* 0.98 to1.02 t/ha.These two treatments were also found significantly superior to the repeated *Lantana* cutting treatments and decreased fresh *Lantana* bio-mass by 94.20 to 99.03% over its initial bio-mass value. However, between these two most effective treatments *i.e.* the management of *Lantana* bushes with the application of glyphosate followed by planting of either hybrid napier and *Setaria* grasses were found economically superior, with a net saving of rupees 6,640/ha, over the grubbings of *Lantana* followed by planting either of these grasses .

Key words: Economics, Forest pastures rehabilitation, Grubbing, Glyphosate, *Lantana camara,* Manual cutting, Perennial grasses

The expansion of human population has enforced man to exhaustively exploit the natural resources including forest pastures and grasslands. Over-exploitation of such valuable resources is rendering large area as wasteland year after year which is an alarming signal for the sustenance of these resources. These resources cater the fodder need of more than 90 per cent of the livestock population in India (Anonymous 1995). Among the various pests which affect the productivity of a land, weeds wage a hidden war for plant essentials and interfere with the growth of plants and obstruct the activities of animals and human beings. Perennial weeds because of their immense capacity of reproduction, higher rate of dispersal and adaptation to adverse conditions have infested the land that are not under cultivation. Hilly regions which have more such land due to typical physiographic conditions are more infested by these weeds. The areas which used to support large livestock population have got invaded by uneconomic vegetation i.e. weeds. The perennial weeds infesting these lands resulted into shrinkage of the area for animal grazing and grass production (Angiras 1999).

Jammu & Kashmir, a North-Western hill state of India occupies 2, 22,236 sq km with an altitude range of 307 to 4,700 meter above mean sea level. The physiographic features of Jammu & Kashmir State can be compared to a threefold plateau on the basis of altitudinal variations for Shivaliks, middle Himalaya and the Greater Himalaya ranging from 307 to 615, 921 to 1,228 and 4,300 to 4,700 meters above mean sea level, respectively. The state is agrarian in character and about 75% of its population is engaged in various agriculture and live-stock related pursuits. However, the distribution of cultivable waste land and forest cover in the three regions vary. Out of a total sub-tropical area of about 585 thousand hectares in J&K around 268 thousand hectares is uncultivated (Anonymous 2008) and which probably has been under the threat by the invasion of aggressive native as well as exotic weed

***Corresponding author:** drbhagwati@gmail.com

Present address: [1]*Division of Agroforestry, SKUAST-J, Main Campus Chatha, Jammu, Jammu & Kashmir 180 009*

species, particularly exotic *Lantana camara* which is making inroads in forest pastures and grasslands. Out of total weed invaded area of sub tropical belt of Jammu region, probably a sizeable portion is heavily infested with exotic weed species and amongst them *Lantana* has been found to take hold of most of the area under natural forests as under canopy weeds. The alarming situation arising out of such invasions particularly by the *Lantana camara*, an obnoxious weed which is a wild shrub and does not grow on lands which are under frequent tillage but establish itself on non-cultivated areas has almost dwindled the ecology of the forest ecosystems turning the lush green productive and economically viable forest pastures into unproductive degraded lands which needed a scientific intervention. Thus, keeping this in view, a study on the management of *Lantana* invaded forest pastures of Shivalik foot-hills was carried out from April, 2006 to December, 2008 with the objectives of finding out the most effective and economical technique for rejuvenation of these land pockets rendering their ability to at least provide some forage for local consumption and meanwhile not having much competition with native vegetation like those of the endemic types which face extinction due to biotic environmental stress.

MATERIALS AND METHODS

The study site falls in forest area near village Janglote 8 km away from district headquarter Kathua of Jammu & Kashmir state. The experimental study to restore the forage productivity of forest pastures was conducted from April, 2006 to December, 2008. The soil of the experimental site was sandy loam in texture (sand=49.02%, silt =22.08% and Clay =28.0%), acidic in reaction (pH=6.4) and high in organic carbon (0.90%), medium in available nitrogen (416 kg /ha), phosphorus (15.8 kg/ha) and potassium (152.5 kg/ha). The experiment consisted of nine treatments *viz.*, T_1= 3- *Lantana* cuttings during the year each at 4 months interval to allow the natural native flora to come up, T_2 = 3- *Lantana* cuttings during the year each at 4 months interval and planting of hybrid napier (*NB-21*) cuttings, T_3= 3- *Lantana* cuttings during the year each at 4 months interval and planting of *Setaria sphacelata* cuttings, T_4 = 3- *Lantana* grubbings during the year each at 4 months interval to allow the natural native flora to come up, T_5 = 3- *Lantana* grubbings during the year each at 4 months interval and planting of hybrid napier (*NB-21*) cuttings, T_6 = 3- *Lantana* grubbings during the year each at 4 months interval and planting of *Setaria sphacelata* cuttings, T_7 =Cutting of *Lantana* bushes followed by application of glyphosate 1.0% just before rainy season on about 30 cm regenerated growth of *Lntana* to allow the natural native flora to come up, T_8 = Cutting of *Lantana* bushes followed by application of glyphosate 1.0% just before rainy season on about 30 cm regenerated growth of *Lantana* and planting of hybrid napier (*NB-21*) cuttings, T_9 = Cutting of *Lantana* bushes followed by application of glyphosate 1.0% just before rainy season on about 30 cm regenerated growth of *Lantana* and planting of *Setaria sphacelata* cuttings was laid out in a randomized block design in three repeats. For grubbing treatments, *Lantana* bushes were first cut near the ground level and then grubbing of its roots was done. In case of herbicidal treatments, the *Lantana* bushes were first cut just near the ground surface in the month of April, allowed its regrowth to occur up to about 30 cm in height and then herbicide (glyphosate 0.1%) was applied . About 15-20 cm deep holes were made with the help of screw auger at a spacing of 60 x 40 cm and stem cuttings of perennial grasses *viz.*, hybrid napier (*NB-21*) and *Setaria sphacelata* were planted during the rainy season in the treatment plots where grass cover was to be provided to the soil to suppress the further reoccurrence of the *Lantana* bushes. A uniform dose of 40 kg of N/ha was applied to all the treatments as top dressing. Re-planting of grass cuttings was done in the gaps occurred due to mortality of grass cuttings in February. The grasses were allowed to grow and establish till rainy season of 2008 and thereafter they were harvested and recorded. Treatment wise study of fresh above ground biomass of the introduced grasses was carried out to evaluate their establishment and effectiveness in checking the reoccurrence of the *Lantana* bushes about two years after imposition of the treatments. The weight of above ground biomass of *Lantana* bushes per unit area was assessed by weighing total above ground biomass obtained after cutting from a unit area both at the start as well as completion of the study. Fodder estimation per unit area was also done to work out the fodder output of each grass under each treatment. The economics of all the treatments was worked out on the basis of total man days involved for their respective operations as well as costs of the inputs as given in Table 2. The identification of the effective technique for rejuvenation of *Lantana* invaded forest pastures was done on the basis of higher fodder output and grass cover to the soil with relatively less expenditure incurred for the management of this weed. Identification of grasses was done keeping in view their aggressiveness in establishment under the prevailing conditions by suppressing this weed.

RESULTS AND DISCUSSION

Effect on forage yield

The results of the study (Table 1) revealed that both the introduced grasses *i.e.* napier and *Setaria* as well as native regenerated flora differed significantly in their forage yield and hybrid napier recorded highest forage yield ranging from 1.21 to 2.07 t/ha under different treatments and this was followed by *Setaria* (0.62 to 1.02 t/ha) and natural native flora (1.68 to 2.10 t/ha). It was observed that all the treatments performed better in respect of their forage yields except natural flora under herbicidal treatment. The significant differences in production of different grasses were due to the differences in their respective potential of forage production. Moreover, the probable reasons for higher forage yield of napier and *Setaria* under grubbing and herbicidal treatments might be due to less competitive congenial conditions created under these treatments for the growth and establishment of these introduced grasses. Less forage production from natural native flora can be attributed to its slow growth and establishment as compared to hybrid napier and *Setaria* coupled with non- selective nature of the herbicide used which might have eliminated most of the native flora initially. Sood and Sharma (1993) also reported that the production of different forages was largely governed by their respective production potentials.

Effect on *Lantana* plants

Significant differences in fresh biomass production of *Lantana* bushes were recorded under various strategies adopted for management of this weed at the completion of the study. Treatment T_8 *i.e.* cutting of *Lantana* bushes followed by application of glyphosate 1% on about 30 cm regenerated growth of the weed and planting of hybrid napier thereafter was found to be significantly superior to all the other treatments and lead to almost complete eradication of *Lantana* plants as it recorded quite less biomass (1.12 kg/25 m^2) . Treatment T_1 *i.e.* only cutting of *Lantana* bushes to facilitate the natural native flora to come up and establishment, recorded the highest biomass of *Lantana* (3.22 kg/25 m^2). Highest per cent fresh bio-mass reduction was recorded with herbicide applied treatments ranging from 98.17 to 99.03% followed by grubbing (97.80 to 98.17%) and cutting (66.0 to 75.83%) treatments, irrespective of whether the grasses are introduced or regenerated species of native grasses. A significant reduction to the tune ranging from 67-99% over the initial average values of number of *Lantana* bushes per unit area was also recorded in the treatments where *Lantana* was controlled either by grubbing or by the application of herbicides**.** Better control of *Lantana* under herbicidal treatments can be attributed to the potential efficacy of the applied herbicide in suppressing this weed. Significant superiority of the herbicidal treatments followed by napier planting over *Setaria* and natural native flora, however, shall be ascribed to the fact that napier grass was found to be more aggressive in growth which lead to its early establishment under the Shivalik foot-hill situations. Similar observations with regard to establishment of different grasses were also made by Thakuria and Singh (1990).

Economics

The economic analysis of various treatments as innovative interventions (Table 2) indicated that the herbicidal control was found economically superior than manual grubbing as well as cutting of the wild sage, irrespective of the agrostological interventions in these treatments . However, the application of glyphosate 1.0% on

Table 1. Fresh *Lantana* biomass, per cent biomass reduction, number of *Lantana* bushes, forage yield and cost of management under different *Lantana* management techniques.

Treatment	Fresh biomass kg/25 m^2	% biomass reduction	Number of *Lantana* bushes/25 m^2	Forage yield (t/ha)	Management cost (₹/ha)
T_1= Three *Lantana* cuttings	3.20 (9.50)	66.0	2.971 (8)	0.21	10,500
T_2= T_1 + Hybrid napier planting	2.77 (6.75)	75.8	2.426 (5)	1.25	18,300
T_3= T_1 + *Setaria* planting	2.80 (7.00)	75.0	2.633 (6)	0.62	18,300
T_4= Three grubbing	1.58 (3.50)	94.2	1.715 (2)	0.23	15,010
T_5= T_4 + Hybrid napier planting	1.22 (0.50)	98.2	1.414 (1)	1.81	22,850
T_6= T_4 + *Setaria* planting	1.27 (0.60)	97.8	1.000 (0)	0.98	22,850
T_7= *Lantana* cutting+1% glyphosate on 30 cm regrowth	1.23 (0.50)	98.2	1.414(1)	0.17	7,460
T_8= T_7 + Hybrid Napier planting	1.12 (0.25)	99.0	1.414 (1)	0.21	16,210
T_9 = T_7 + *Setaria* planting	1.31 (0.47)	98.6	1.244 (0.67)	0.10	16,210
LSD (P=0.05)	0.51	9.7	0.61	0.003	-

Data are subject to square root transformation $\sqrt{x+1}$ and original values are given in parenthesis

Initial population of *Lantana* bushes = 6 bushes/25 m^2; Fresh biomass of *Lantana* before imposition of treatments = 28 kg/25 m^2.

Table 2. Details of expenditure incurred on different operations/inputs under various treatments

Treatment	Operations/inputs	Quantity/ha	Unit	Rate (₹/unit)	Cost of operations/ inputs (₹/ha)	Total Expenditure (₹/ha)
T_1	a) Manual cutting of *Lantana* bushes					
	-- I cutting	60	Mandays	70	4,200	
	-- II cutting	50	Mandays	70	3,500	
	-- III cutting	38	Mandays	70	2,660	10,500
	b) Fertilizer urea	40	kg	6.00	240	
T_2	a) Manual cutting of *Lantana* bushes					
	-- I cutting	60	Mandays	70	4,200	
	-- II cutting	45	Man days	70	3,150	
	-- III cutting	28	Mandays	70	1,960	
	b) Planting material cuttings	55,500	Hyb. Napier	0.06	3,330	18,300
	c) Carriage of planting	--	--	--	--	
	d) Planting of hybrid napier cuttings	70	Mandays	70	4,900	
	e) Fertilizer urea	40	kg	6.00	240	
T_3	Similar to T_2 treatment except for planting of *Setaria* instead of hybrid napier					18,300
T_4	a) Grubbing of *Lantana* bushes					
	-- I cutting	110	Mandays	70	7,700	
	-- II cutting	79	Mandays	70	4,830	
	-- III cutting	32	Mandays	70	2,240	15,010
	b) Fertilizer urea	40	kg	6.00	240	
T_5	a) Grubbing of *Lantana* bushes					
	-- I grubbing	110	Mandays	70	7,700	
	-- II grubbing	63	Mandays	70	4,410	
	-- III grubbing	25	Mandays	70	1,750	
	b) Planting material cutting				3,330	22,850
	c) Carriage of planting material	-	-	-	520	
	d) Planting of hybrid napier cuttings	70	Mandays	70	4,900	
	e) Fertilizer Urea	40	kg	6.00	240	
T_6	Similar to T_5 except for planting of *Setaria* instead of hybrid napier					22,850
T_7	a) Manual cutting of *Lantana* bushes	60	Mandays	70	2,600	
	b) Herbicide glyphosate 1.0%	5.2	Litres	500	2,600	
	c) Herbicide application	6	Mandays	70	420	9,560
	d) Fertilizer urea	40	kg	6.00	240	
T_8	a) Manual cutting of *Lantana* bushes	60	Mandays	70	4,200	
	b) Herbicide glyphosate 1.0%	5.2	Litres	500	2,600	
	c) Herbicide application	6	Mandays	70	420	
	d) Planting material cutting	55,500	Napier	0.06	3,330	16,210
	e) Carriage of planting material	--	--	--	520	
	f) Planting of hybrid napier cuttings	70	Mandays	70	4,900	
	g) Fertilizer urea	40	kg	6.00	240	
T_9	Similar to T_8 except for planting of *Setaria* instead of hybrid napier					16,210

Various expenditures incurred during the study were calculated on the prevailing market rates of different inputs

about 30 cm regenerated growth of *Lantana* followed by the planting of either hybrid napier and *Setaria* cuttings were found to be economically better with a net saving of about ₹ 6,640 over all the others similar treatment combinations of grubbings of *Lantana* bushes, respectively. The results are in conformity with the findings of Kumar and Sood (1998). They have also reported relatively differential response of such like treatments with respect to their economics.

The introduction of improved grass species like napier and *Setaria* after herbicidal (glyphosate 1.0%) control of *Lantana* had a pronounced effect on the elimination of this hardy obnoxious weed. The present study thus envisages that the *Lantana* infested forest pasture land pockets can be successfully and economically rejuvenated and converted into highly productive pastures through cutting of *Lantana* followed by application of 1% glyphosate at about its 30 cm regenerated growth and planting either of napier and *Setaria* cuttings.

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Indian Journal of Weed Science **44**(1): 43–45, 2012

Impact of varying densities of jungle rice on rice productivity

M.B.B. Prasad Babu*

Directorate of Weed Science Research, Jabalpur, Madhya Pradesh 482 004

Received: 21 December 2011; Revised: 18 March 2012

ABSTRACT

In order to assess the impact of varying densities of *jungle rice* (*Echinochloa colona*) on rice, a field experiment was conducted at Directorate of Weed Science Research, Jabalpur farm in *Kharif* 2005 and 2006. With increasing population density of *E. colona* from 50 to 400 plants/m^2, there was a significant reduction in LAI, biomass production as well as grain yield of rice due to competition from weed plants for growth factors like light, nutrients and space *etc.* The reduction in dry matter was to the tune of 32% with a *E. colona* density of 400 plants/m^2 as compared to pure rice crop. Though the chlorophyll content of rice decreased with increasing density of *E. colona* but it maintained a higher chlorophyll content than *E. colona*. The increasing densities of *E. colona* significantly decreased various yield attributes of rice with the effect being more drastic on effective tillers/m^2. The reduction in grain yield varied from 48 to 86% as the density of *E. colona* increased from 50 to 400 plants/m^2.

Key words: Crop-weed competition, *Echinochloa colona*, Grain yield, Rice

Rice (*Oryza sativa* L.) is the staple food crop of India, providing 30% of caloric requirement for more than 70% of the population. Jungle rice (*Echinochloa colona*) and Barnyard grass (*Echinochloa crusgalli*) are the two main weeds growing in association with other annual grasses, sedges and broad leaf weeds in rice. The extent of yield reduction due to weeds is around 20-25% in transplanted rice, 30-35% in direct seeded puddled rice and over 50% in direct seeded upland rainfed rice (Mukherjee *et al.* 2009). Higher rice yields can be realized if these major weeds are controlled. Keeping this in view the present study was conducted to assess the impact of varying densities of *Echinochloa colona* on rice.

MATERIALS AND METHODS

Field experiment was conducted at Directorate of Weed Science Research, Jabalpur located at 23.90° North Latitude, 79.58° East Longitude and at an altitude of 411.78 m above mean sea level, during *Kharif* 2005 and 2006 with seven treatments consisting of sole crop, sole weed (*Echinochloa colona*), and increasing densities of weed (50, 100, 200, 300 and 400 plants/m^2) in a randomized block design with three replications. Observations on leaf area index, biomass, chlorophyll content, yield and yield attributes were also recorded. The experimental soil was sandy clay loam in texture with low available nitrogen, medium phosphorus and high potassium and a pH of 6.85 and EC of 0.372 dS/m. Rice crop (*cv. Kranti*) was sown with a seed drill, with a row spacing of 22.5 cm. The required quantity of weed seed was evenly spread in the plots and mixed well with the soil to maintain the desired plant population. After germination the weeds arising in the plots were thinned to the desired density as per the treatment. Thinning of weeds was carried out up to a period of one month after sowing. The recommended dose of $N:P_2O_5:K_2O$ (120:60:40 kg/ha) was applied uniformly to all the plots through prilled urea, single super phosphate and muriate of potash. Entire P and K fertilizers were added as basal while N was applied in three equal splits at sowing, 30 and 60 days after seeding. Plant samples were taken periodically throughout the crop growth season for biomass accumulation. The samples were oven dried at 70^{0}C till a constant weight was reached and weighed for dry matter. Observations on leaf area were made on a leaf area meter equipped with colour image analysis system of Make: Delta T Devices and model W-C230-PCM.

*__Corresponding author:__ mbbprasadbabu@gmail.com
Present Address: *Directorate of Rice Research, Rajendranagar, Hyderabad, Andhra Pradesh 500 030*

RESULTS AND DISCUSSION

Effect on leaf area index

Leaf Area Index (LAI) of rice decreased with increasing density of *E. colona* (Table 1). The LAI increased from 20 DAS to 80 DAS, beyond which it decreased due to the drying up of leaves. LAI of *E. colona* showed an increasing trend with its increasing density. However, it was maximum in sole weed (T_{max}).

Maximum LAI for pure rice crop was observed between 60 DAS (3.4) and 80 DAS (3.7) which show that this period coincides with the maximum vegetative growth period of the crop (Table 1). As the crop was approaching maturity, the LAI decreased considerably. These findings are in agreement with those of Chang *et al.* (2005).

Table 1. Periodic leaf area index (LAI) of rice and weed under different densities of *E. colona* (mean of two seasons)

Density of *E. colona* (plants/m^2)	Leaf area index (DAS)								
	20		40		60		80		100
	Rice	Weed	Rice	Weed	Rice	Weed	Rice	Weed	Rice
Sole rice (T_0)	0.69	0.00	1.8	0.00	3.4	0.00	3.7	0.00	3.1
50 (T_{50})	0.61	0.86	1.6	2.33	2.1	2.47	2.2	2.17	2.0
100 (T_{100})	0.68	1.13	1.5	2.83	1.9	3.03	2.0	2.60	1.8
200 (T_{200})	0.77	1.50	1.4	3.13	1.5	3.33	1.7	2.43	1.6
300 (T_{300})	0.65	1.73	1.0	4.07	1.1	4.17	1.0	2.80	0.8
400 (T_{400})	0.54	2.07	0.8	4.23	1.0	4.13	0.8	2.70	0.6
Sole *E. colona* (T_{Max})	0.00	1.53	0.0	4.00	0.0	4.20	0.0	3.10	0.0
LSD (P=0.05)	0.08	0.09	0.1	0.13	0.17	0.12	0.16	0.17	0.15

Table 2. Dry biomass accumulation (t/ha) of rice under different densities of *E. colona* (mean of two seasons)

Density of *E. colona* plants/m^2	60 DAS		80 DAS		100 DAS	At harvest
	Rice	Weed	Rice	Weed	(Rice)	(Rice)
Sole rice (T_0)	6.71	0.00	9.77	0.00	10.51	10.00
50 (T_{50})	4.40	5.10	5.70	4.79	6.71	6.35
100 (T_{100})	3.73	6.46	4.72	5.96	5.36	5.17
200 (T_{200})	3.08	7.00	3.77	6.62	4.63	4.42
300 (T_{300})	2.35	7.78	3.46	7.54	4.32	3.95
400 (T_{400})	1.90	8.16	3.02	7.83	3.33	3.16
Sole *E. colona* (T_{Max})	0.00	10.12	0.00	9.69	0.00	0.00
LSD (P=0.05)	1.54	0.56	1.74	0.73	1.58	0.93

LAI of *E. colona* showed an increasing trend with its increasing density. However, it was maximum in T_{max}. The LAI in all the treatments increased from 20 DAS to 60 DAS beyond which it decreased as the plants started to dry. This higher LAI of weed with its increasing density caused an increasing light extinction which reduced the tillering of rice. These results are in agreement with the findings of Graf *et al.* (1990).

Effect on biomass accumulation

The biomass accumulation of rice was affected significantly by *E. colona* density at all stages of observation (Table 2). The biomass accumulation depends upon the amount of radiation received, the area of intercepting surface, the efficiency with which the intercepted radiation is utilized in the production of dry matter and loss of dry matter due to physiological, pathological and weed competition factors. Biomass accumulation by the crop decreased with increase in weed population, with the maximum accumulation by the crop being at 100 DAS, which coincided with the grand growth phase of the crop. The reduction in biomass accumulation of rice is due to the severe competition posed by *E. colona*. These findings are also supported by those of Graf and Hill (1992) who reported that even at a density of 100 rice plants/m^2, 10 plants of *E. crusgalli*/m^2 cause a yield loss of about 50 per cent.

The biomass accumulation of *E. colona* was highest in Tmax and least in T_{50}. The biomass accumulation increased significantly as the density of *E. colona* increased from 50 to 400 plants/m^2, up to 60 DAS beyond which it decreased mainly due to seed shedding.

The chlorophyll content of rice and *E. colona* decreased with increasing density of *E. colona* (Table 3). It was higher at 60 DAS in all the treatments as compared to those at 40 DAS. However, rice maintained a higher chlorophyll content than *E. colona*.

Effect on yield contributing characters

The increasing densities of *E. colona* from 0 to 400 plants/m^2 significantly decreased various yield attributes of rice (Table 4). These findings were also supported by those of Dhaliwal *et al.* (1997). The effect was more drastic in case of effective tillers/m^2 resulting in reduced grain yield with increasing density of the weed.

Table 3. Chlorophyll content (mg/g fresh weight) of rice and *E. colona* under different densities of *E. colona* (mean of two seasons)

Treatment (Density of *E. colona* plants)	40 DAS		60 DAS	
	Rice	*E.colona*	Rice	*E. colona*
Sole rice (T_0)	2.26	-	3.64	-
50 (T_{50})	2.13	1.96	3.03	2.93
100 (T_{100})	2.03	2.00	2.78	2.84
200 (T_{200})	1.79	1.90	2.60	2.61
300 (T_{300})	1.74	1.66	2.31	2.41
400 (T_{400})	1.71	1.53	1.99	2.23
Sole *E. colona* (T_{Max})	-	1.43	-	2.14
LSD (P=0.05)	0.06	0.04	0.15	0.05

Table 4. Yield attributes of rice crop under different densities of *Echinochloa colona* (mean of two seasons)

Treatment (Density of *E. colona* plants)	Effective tillers/m^2	Panicle length (cm)	No. of grains/panicle	Test weight (g)
Sole rice (T_0)	340	18.4	84.0	24.1
50 (T_{50})	242	17.9	53.0	23.7
100 (T_{100})	195	16.1	42.7	23.5
200 (T_{200})	167	13.9	37.8	23.3
300 (T_{300})	115	13.5	31.7	22.8
400 (T_{400})	90	12.5	24.7	22.1
Sole *E. colona* (T_{Max})	0	0	0	0
LSD (P=0.05)	15	0.6	2.3	0.2

Effect on grain yield

The decrease in panicle length, number of grains per panicle and 1000 grain weight contributed to reduction in yield with increasing population density of *E. colona* from 0 to 400 plants/m^2. The reduction in grain yield increased from 48% at T_{50} to 86% at T_{400}. Maximum grain yield was recorded in weed free treatment (T_0) where there is no competition for growth factors between the rice plant and weeds (Fig. 1). These findings are also supported by the findings of Walia and Singh (2005).

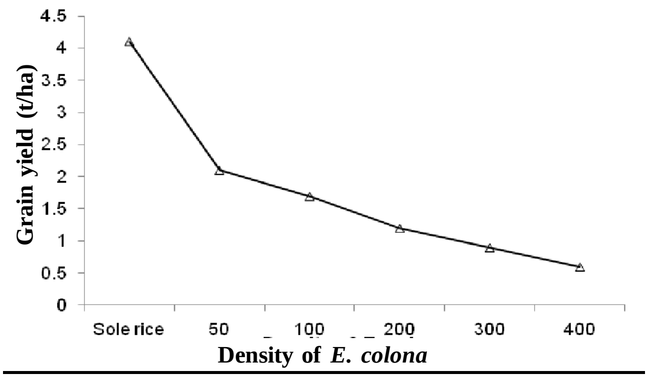

Fig. 1. Impact of increasing density of *E. colona* on grain yield of rice

The study conclusively showed that the productivity of rice decreases drastically as the density of *E. colona* increased from 50 to 400 plants/m^2.

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Indian Journal of Weed Science **44**(1): 46–49, 2012

Effect of integrated weed management practices on weed dynamics and weed control efficiency in lucerne

P. Revathi*, K.B. Suneetha Devi and M. Madhavi
Department of Agronomy, Acharya N.G. Ranga Agricultural University, College of Agriculture, Rajendranagar, Hyderabad, Andhra Pradesh 500 030

Received: 5 December 2011; Revised: 16 March 2012

ABSTRACT

A field experiment was conducted to study the effect of integrated weed management practices on forage quality in lucerne (*Medicago sativa* L.) during 2008-09. The treatments consisted of salt (10%) treatment to seeds of lucerne + hand weeding at 30 DAS and after each cut, salt (10%) treatment to seeds + imazethapyr 75 g/ha at 12 DAS, salt (10%) treatment to seeds + pendimethalin 0.5 kg/ha at 12 DAS, stale seed bed + hand weeding at 30 DAS, pendimethalin 0.5 kg and 0.75 kg/ha as PE, imazethapyr 75 g and 100 g/ha at 12 DAS, pure seed of lucerne + hand weeding at 30 DAS and after each cut, hand weeding at 30 DAS and after each cut (farmers practice), weedy check and weed free check. experiment was laid in RBD with three replications. The results indicated that the density and dry weight of weeds (excluding cuscuta) were significantly lower with weed free check. Higher weed control efficiency and green fodder yield of lucerne at each cut and total was significantly higher with application of imazethapyr 75 g/ha at 12 DAS and was at par with selection of pure seed + hand weeding at 30 DAS and after each cut. *Cuscuta* control efficiency was maximum with application of pendimethalin and imazethapyr and their combination with salt treatment (10%) to seed and selection of pure seed of lucerne + hand weeding at 30 DAS and after each cut.

Key words: *Cuscuta*, Imazethapyr, Lucerne, Pendimethalin, Weed density, Weed dry weight

In India, lucerne is cultivated in an area of 1.0 m ha with a productivity of 60-130 t /ha/yr as green fodder (Hazra and Sinha 1996). It is also called as "Green gold of forage crops' as it is rich in protein (18-22%), amino acids and vitamin 'A' content. However, the area under lucerne is fluctuating and the perennial nature of this fodder crop is not fully exploited by farmers. All this is attributed mainly to the problem related to weeds infestation. Weeds in lucerne are reported to cause yield losses as high as 95 per cent (Dawson and Rincker 1982). Apart from other weeds that interface with crop growth, lucerne has specific problem of *Cuscuta* or dodder (*Cuscuta chinensis*). *Cuscuta* is a complete stem parasite and survives on the host plant and ultimately reduces the forage yield and quality of lucerne. Severe infestation of *Cuscuta* completely devastates the lucerne crop. Many farmers of Andhra Pradesh and also of the country are growing the crop only for few months in a year due to cuscuta problem inspite of its potential to remain productive on field for three years. In recent years, the use of herbicides appears to be more effective approach for control of weeds including *Cuscuta*. The efficacy of pendimethalin (Shivadhar *et al.* 2005) and imazethapyr (Mahadevappa and Bhanumurthy 2005) was established to certain extent on control of weeds in lucerne. However, the optimum dose and time of application of herbicides like pendimethalin and imazethapyr were not standardised for lucerne crop. Further it was observed that cultural methods like 10 per cent salt floatation to berseem seed eliminated infestation of *Chicorium intybus* in berseem crop (Tiwana *et al.* 2002) and the same principle can be practised to remove *Cuscuta chinensis* from lucerne seed as the light weight seed of *Cuscuta* float on the salt solution. Keeping all the above points in view, different integrated weed management practices were evaluated in lucerne for management of weeds in general and *Cuscuta* in particular.

***Corresponding author:** revathi.pallakonda5@gmail.com

MATERIALS AND METHODS

Field experiment was conducted at Student's Farm, College of Agriculture, Rajendranagar, ANGRAU, Hyderabad during *Rabi*, 2008-09. The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH of 8.5) with low organic carbon content (0.5%), low available nitrogen (240.0 kg/ha), phosphorus (23.5 kg/ha) and potassium (326.5 kg/ha). Treatments ware laid out in randomized block design with three replications having plot size of 4.2 x 4 m. The treatments consisted of salt (10%) treatment to seeds of lucerne + farmers practice (hand weeding at 30 DAS and after each cut), salt (10%) treatment to seeds +

imazethapyr 75 g/ha at 12 DAS, salt (10%) treatment to seeds + pendimethalin 0.5 kg/ha at 12 DAS, stale seed bed + hand weeding at 30 DAS, pendimethalin 0.5 kg and 0.75 kg/ha as PE, imazethapyr 75 g and 100 g/ha at 12 DAS, pure seed of lucerne + farmers practice, farmers practice (hand weeding at 30 DAS and after each cut), weedy check and weed free check. A seed rate of 15 kg/hawas used. Pendimethalin 0.50 and 0.75 kg/ha. Uniform dose of N, P_2O_5 and K_2O 30, 80, 40 kg/hawas applied to all the treatments.Nitrogen in the form of urea was applied as split dose after each cut whereas, P_2O_5 and K_2O were applied as basal in the form of single super phosphate and muriate of potash. Prophylactic spraying of acephate 1.0 g/lit was done against sucking pest complex at 20 DAS and 10 days after I cut. Three cuts of forage were taken. The first cut was taken at 68 DAS, II cut at 36 days after I cut and III cut at 32 days after II cut. Density and dry weight of weeds and yield was measured at each cut. Control efficiency of weeds and cuscuta were calculated based on dry weight of weeds and cuscuta respectively.

RESULTS AND DISCUSSION

The weed species found in experimental field were *Cyperus rotundus*, *Cynodon dactylon* and *Dactylacteniuma aegyptium* among sedges and grasses*; Trianthema portulacastrum, Parthenium hysterophorus, Chicorium intybus, Digera arvensis, Euphorbia hirta, Trichodesma indicus* and parastic weed *Cuscuta chinensis* among broad leaved weeds at early stages of crop growth *i.e.* up to 30 DAS. After 30 DAS, *Trianthema portulacastrum, Digera arvensis, Euphorbia hirta, Trichodesma indicus* could not compete with other weeds and slowly vanished. After first cut, the predominant weeds were *Chicorim intybus* and *Parthenium hysterophorus, Cynodon dactylon, Cyperus rotundus* and parastic weed (*Cuscuta chinensis*).

Integrated weed management practices were found effective in reducing weed density that varied between1.91 to 11.56 No/m^2 among the treatments (Table 1). The lowest weed density and dry weight and highest weed control efficiency was recorded in weed free check whereas the highest weed density, dry weight and lowest weed control efficiency was recorded with weedy check at all three cuts. At first cut, pure seed of lucerne followed by hand weeding at 30 DAS and after each cut registered lower weed density and dry weight and higher weed control efficiency and was significantly at par with stale seed bed + hand weeding at 30 DAS, farmers practice (hand weeding at 30 DAS and after each cut), Salt (10%) treatment to seeds *fb* hand weeding at 30 DAS and after each cut and with imazethapyr 75 g/ha at 12 DAS. At II cut, density and dry weight of weeds and weed control efficiency was significantly at par with all treatments except pendimethalin 0.75 kg/ha as PE and weedy check. At third cut, density of weeds was lower with farmers practice (hand weeding at 30 DAS and after each cut) and was at par with Imazethapyr 75 and 100 g/ha at 12 DAS and Salt (10%) treatment to seeds + pendimethalin 0.5 kg/ha at 12 DAS. Whereas lower weed dry weight and higher weed control efficiency was recorded with pure seed of lucerne + farmers practice, imazethapyr 75 and 100 g/ha at 12 DAS, salt (10%) treatment to seeds + pendimethalin 0.5 kg/ha at 12 DAS and with farmers practice (hand weeding at 30 DAS and after each cut). The efficacy of imazethapyr in reducing weed density was reported by Faghihi *et al*. (1998).

Average weed control efficiency (over the three cuts) was highest with weed free check (91.1%) followed by imazethapyr 100 g/ha at 12 DAS (79.17%), sowing pure seed of lucerne + farmers practice (78.0%),farmers practice (77.68%) and imazethapyr 75 g/ha at 12 DAS(72.0%) respectively (Table 2). Average weed control efficiency was low with application of pendimethalin 0.75 kg/ha as PE than 0.5 kg/ha as PE though the above treatment effectively reduced weed density and dry weight of weeds at 30 DAS but at later stages, both the weed density and dry weight was increased because of gaps created in the field due to phytotoxic effect on the lucerne crop. Stale seed bed method controlled the weeds at 30 DAS with average weed control efficiency of 64.05% but after 30 DAS did not controlled weeds and resulted in less weed control efficiency (58.47 and 58.0%) at II and III cut respectively. Green fodder yield of lucerne at each cut and also total was significantly higher with application of Imazethapyr 75 g/ha at 12 DAS and was at par with pure seed of lucerne + hand weeding at 30 DAS and at each cut at all cuts. Salt (10%) treatment to seeds + imazethapyr 75 g/ha at 12 DAS and only imazethapyr 100 g/ha was significantly at par with above treatments at II and III and also at total.

The effect of different treatments on dry weight of *Cuscuta* and its control efficiency was more conspicuous (Table 2). Dry matter production of *Cuscuta* was higher at I cut and reduced with increase in the number of cuts. Application of pendimethalin 0.5 and 0.75 kg/ha as PE, imazethapyr 75 and 100 g/haat 12 DAS or these herbicides in combination with salt (10%) treatment to seeds and selection of pure seed of lucerne + hand weeding at 30 DAS and after each cut completely eliminated the infestation of *Cuscuta*. It clearly showed that herbicides disturbed mitosis, cytokinensis and production of microtubules on shoot tips and effectively controlled cuscuta in lucerne. Among cultural treatments, selection of pure seed (*Cuscuta*

Table 1. Density, dry weight and control efficiency of weeds (excluding *Cuscuta*) as influenced by integrated weed management practices in lucerne

Treatments	Weed density (No/m^2)			Weed dry weight (g/m^2)			Weed control efficiency(%)			Mean
	I cut (68 DAS)	II cut (103 DAS)	III cut (135 DAS)	I cut (68 DAS)	II cut (103 DAS)	III cut (135 DAS)	I cut (68 DAS)	II cut (103 DAS)	III cut (135 DAS)	
Salt (10%) treatment to lucerne seeds before sowing *fb* farmers practice (T_{10})	5.52 (30.00)	5.68 (32.33)	7.19 (51.34)	41.50	44.90	81.80	67.50	70.09	59.13	68.39
Salt (10%) treatment to seeds + imazethapyr75 g/ha at 12 DAS	5.84 (33.66)	7.10 (50.34)	6.39 (41.34)	42.50	47.80	52.20	66.71	68.15	73.92	71.98
Salt (10%) treatment to seeds + pendimethalin 0.5 kg/ha at 12 DAS	7.56 (57.00)	5.96 (35.34)	5.17 (26.34)	78.8	45.80	97.90	38.61	69.48	51.00	58.79
Stale seed bed + hand weeding at 30 DAS	4.89 (24.00)	7.84 (65.00)	6.91 (49.00)	45.90	62.00	152.20	64.05	58.47	58.00	63.92
Pendimethalin 0.5 kg/haas PE	7.28 (52.67)	5.38 (30.00)	6.42 (42.67)	53.00	45.90	69.40	58.48	74.97	65.32	67.74
Pendimethalin 0.75 kg/haas PE	7.16 (51.67)	5.85 (34.34)	6.53 (44.00)	85.46	77.36	143.06	33.09	57.81	28.52	49.47
Imazethapyr 75 g/haat 12 DAS	5.95 (37.00)	5.66 (32.67)	5.81 (33.34)	56.30	59.98	42.80	55.90	67.29	79.61	72.00
Imazethapyr 100 g/haat 12 DAS	7.79 (60.34)	6.53 (46.00)	6.06 (37.00)	57.20	35.08	41.25	55.20	80.87	77.66	79.17
Pure seed of lucerne*fb* farmers practice	4.88 (23.34)	6.46 (41.67)	6.97 (48.34)	28.64	48.80	35.00	77.56	66.30	82.51	78.00
Farmers practice (hand weeding) at 30 DAS and after each cut)	7.70 (39.00)	5.66 (35.00)	4.55 (20.34)	41.70	51.50	54.50	67.34	88.82	72.77	77.68
Weedy check	10.57 (111.34)	10.09 (102.00)	10.41 (108.34)	128.34	150.06	200.16	0.0	0.0	0.0	0.0
Weed-free check	2.94 (8.66)	1.91 (3.97)	4.94 (7.20)	19.40	9.20	23.80	84.88	93.86	88.11	91.15
LSD (P = 0.05)	0.90 (12.9)	2.48 (31.0)	1.60 (21.8)	20.13	20.93	23.24				

Table 2. Dry weight and control efficiency of *Cuscuta chinensis* and green fodder yield of lucerne as influenced by integrated weed management practices

Treatment	*Cuscuta* dry weight (g/m^2)			*Cuscuta* control efficiency (%)			Green fodder yield (t/ha)			Total
	I cut (68 DAS)	II cut (103 DAS)	III cut (135 DAS)	I cut (68 DAS)	II cut (103 DAS)	III cut (135 DAS)	I cut (68 DAS)	II cut (103 DAS)	III cut (135 DAS)	
Salt (10%) treatment to lucerne seeds before sowing *fb* farmers practice (T_{10})	71.5	10.2	5.7	35.9 (34.47)	57.80 (71.64)	64.75 (81.83)	6.66	6.15	5.79	18.61
Salt (10%) treatment to seeds + imazethapyr 75 g/ ha at 12 DAS	0.0	0.0	0.0	90.00 (100.00)	90.00 (100.00)	90.00 (100.00)	9.87	10.80	8.90	29.58
Salt (10%) treatment to seeds + pendimethalin 0.5 kg/ha at 12 DAS	0.0	0.0	0.0	90.00 (100.00)	90.00 (100.00)	90.00 (100.00)	8.45	8.66	8.92	26.04
Stale seedbed + hand weeding at 30 DAS	72.45	12.60	6.60	35.43 (33.60)	53.79 (65.14)	62.80 (79.14)	5.16	4.24	4.58	13.98
Pendimethalin 0.5 kg/ha as PE	0.0	0.0	0.0	90.00 (100.00)	90.00 (100.00)	90.00 (100.00)	6.35	6.40	6.95	19.69
Pendimethalin 0.75 kg /ha as PE	0.0	0.0	0.0	90.00 (100.00)	90.00 (100.00)	90.00 (100.00)	6.59	8.49	8.25	23.33
Imazethapyr 75 g/ha at 12 DAS	0.0	0.0	0.0	90.00 (100.00)	90.00 (100.00)	90.00 (100.00)	11.57	12.20	9.76	33.54
Imazethapyr 100 g/haat 12 DAS	0.0	0.0	0.0	90.00 (100.00)	90.00 (100.00)	90.00 (100.00)	8.01	10.13	8.93	27.67
Pure seed of lucerne *fb* farmers practice (T_{10})	0.0	0.0	0.0	90.00 (100.00)	90.00 (100.00)	90.00 (100.00)	11.07	9.80	9.52	30.39
Farmers practice (hand weeding) at 30 DAS and after each cut	78.15	14.44	11.52	32.20 (28.38)	50.83 (60.06)	52.89 (63.60)	5.20	3.51	3.70	12.37
Weedy check	128.12	36.15	31.65	0.57 (0.0)	0.57 (0.0)	0.57 (0.0)	4.26	2.42	1.94	8.57
Weed-free check	59.62	12.72	7.62	42.36 (45.36)	53.61 (64.81)	60.6 (75.92)	5.75	6.23	5.10	17.08
LSD (P=0.05)							1.68	3.59	2.33	5.95

Figures in parentheses are actual values. Presented in angular transformation free) followed by hand weeding at 30 DAS and after each cut is free from cuscuta infestation and this cultural method is helpful when soil is free from cuscuta infestation. Salt (10%) treatment to seeds and stale seed bed *fb* hand weeding at 30 DAS and after each cut effectively controlled cuscuta by registering lower dry weights with high cuscuta control efficiency than farmers practice and weed free check. This might be due to the removal of cuscuta from seed (10% salt treatment) and soil (stale seed bed). Tiwana *et al*. (2002) reported that 10% salt treatment effectively removed chicory from berseem due to floatation of chicory seed due to difference in density. The same principle was tested to separate cuscuta from lucerne and was found effective.

Total green fodder yield of lucerne over three cuts was significantly higher with application of imazethapyr 75 g/ha at 12 DAS and was found on par with pure seed of lucerne + hand weeding at 30 DAS and after each cut, salt (10%) treatment to seeds + imazethapyr 75 g/ha at 12 DAS (Table 2). Total green fodder yield of lucerne with application of imazethapyr 100 g/ha at 12 DAS was significantly at par with above treatments. The higher yield recorded in these treatments could be attributed to better control of weeds right from crop emergence up to critical period of crop weed competition *i.e.*, 30 DAS which lead to efficient utilization of growth resources by the crop plants. The efficacy of imazethapyr in controlling the weeds in general and cuscuta in particular, thereby increasing green fodder yield of lucerne was supported by Mahadevappa and Bhanu Murthy (2005).

Weed free treatment and farmers practice (hand weeding at 30 DAS and after each cut) though found effective to control other weeds but found ineffective to control complete stem parasitic weed on lucerne i.e *Cuscuta cheninsis*. Hence green fodder yield in these treatment was significantly less than herbicide treatments.

Hence, it was suggested that application of imazethapyr 75 g/ha at 12 DAS or selection of pure seed (*Cuscuta* free) *fb* farmers practice (hand weeding at 30 DAS and at first cut) was found effective in controlling all types of weeds and resulted in higher green fodder yield of lucerne.

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Indian Journal of Weed Science **44**(1): 50–52, 2012

Effect of age of seedlings and weed management under SRI on yield of rice

C. Ramachandra*, N. Shivakumar, M.P. Rajanna and K.N. Kalyanamurthy
ZARS, VC Farm, UAS, Mandya, Karnataka 571 401

Received: 13 October 2011; Revised: 25 February 2012

ABSTRACT

Planting of 10 or 15 days old seedlings did not differed significantly on grain yield of rice. Among weed management practices SRI method of planting with four times cono-weeding at 10 days interval starting from 10 days after transplanting recorded significantly higher grain yield (6003 kg/ha) and was found effective in weed control. However, pre-emergence application of butachlor + one hand weeding at 20 DAT was equally effective alternative weed control in SRI method of cultivation.

Key words: Age of seedlings, B:C ratio, Butachlor, Cono-weeding, Grain yield, SRI

Rice (*Oryza sativa* L.) is a one of the important staple food crops for more than half of the world's population. In India, rice is grown in an area of 44.3 m ha and record production of 103.4 m t was estimated in 2011-12. Demand for rice is growing every year and it is estimated that by 2025 the requirement would be 130 million tones. To sustain present food self sufficiency and to meet future food demands, India has to increase its rice productivity by three per cent per annum (Thiyagarajan and Selvaraju 2011). In India, manual method of transplanting is the most dominant and traditional method of crop establishment in irrigated low land rice, which not only consume more water but also causes wastage of water resulting in degradation of land. Water resource limitations, shortage of labor during peak period of transplanting and escalating labor wages make transplanting more expensive which invariably leads to delay in transplanting and results in reduction of yield and profit (Gangwar *et al.* 2008). To mitigate this problem many methods of cultivation have been developed, one among them is System of Rice intensification (SRI). System of rice intensification is an emerging water saving technology which can help the farmers to overcome the present water crisis. The SRI is considered as a system rather than a technology as it involves the holistic management to give ideal growing condition to rice plant. Besides, it enhances soil health with reduction in input use such as seeds, water, labor *etc.* (Gujja and Thiyagarajan 2009). Age of seedling and weed management practices plays an important role under limited water situation in SRI production system. In SRI, planting of too young seedling (8-10 days) is difficult. Further, weeds are incorporated and controlled through cono-weeding in SRI is very drudgeries and a person has to walk longdistance for cono-weeding in rice. In order to standardize the seedling age and economize the cono-weeding operations, the study was under taken to study the effect of age of seedlings and weed management methods under SRI for enhancing grain yield.

***Corresponding author:** ramaakhil09@gmail.com

MATERIALS AND METHODS

Field experiments were conducted during summer seasons of 2010 and 2011 at ZARS, V.C. Farm, Mandya, Karnataka to standardize the seedling age and economize the cono weeding operation for enhancing grain yield. The soil of the experiment site was red sandy loam, slightly acidic in nature (pH 6.05), medium in available soil nitrogen (274.60 kg/ha), phosphorus (27.2 kg/ha) and potassium (174.30 kg/ha). Treatment consisted two age of seedlings (A_1: 10 days old seedlings and A_2: 15 days old seedlings) and three weed management practices (W_1: 2 times cono weeder at 10 and 20 DAT, W_2: 4 times cono weeder at 10, 20, 30 and 40 DAT and W_3 by pre-emergence herbicide butachlor 1.5 kg/ha 5 DAT followed 1 hand weeding at 20 DAT were laid out in a factorial RCBD with three replications. Under SRI method of rice cultivation, 10 and 15 days old seedlings raised from rice mat nursery were transplanted with a spacing of 25x25 cm in both the seasons. Farm yard manure was applied 10 t/ha uniformly, incorporated and leveled. Recommended dose of fertilizers (125:62.5:62.5 and 100-50-50 kg NPK/ha for summer and *Kharif* seasons, respectively) were applied as per the treatments indicated in the plan. Nitrogenous fertilizer was applied in three splits *viz.*, 50% nitrogen at basal and 25 % N each at active tillering and panicle initiation stage. The entire dose of phosphorus was applied as basal and potassium was applied in two splits *viz.*, 50% at basal and remaining 50% was supplied at panicle initiation stage. Weeding was done with cono-weeding at 10 days interval starting from 10 days after transplanting. Pre-emergence herbicide butachlor was sprayed at 3 DAP using knapsack sprayer with a spray volume of 500 l/ha. Irrigation management i.e. alternate wetting and drying and timely plant protection measures were adopted to raise the crop. Observations on weed dry weight, yield components and productivity of rice were recorded. Data recorded were analyzed statistically as per the procedure prescribed for Factorial RCBD (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Weed flora

The dominating weed flora observed in the experimental field were *Cynodon dactylon, Dactyloctenium aegyptium* and *Chloris barbata* among the grasses, *Alternanthra pungens, Portulaca oleracea, Cleome chelidoni, Eclipta alba, Anagallis arvensis, Spergula arvensis, Melilotus indica* and *Tridax procumbens* among the broad leaved weeds and *Cyprus* sp. among sedges.

Effect of age of seedling on grain yield

Pooled data of the experimental results revealed that age of seedling did not differed significantly on yield of rice. However, planting 15 days old seedlings produced higher grain yield (5696 kg/ha) than planting 10 days old seedling. Higher grain yield might be attributed to greater root development and activity, more flourishing capacity of the seedlings at early transplanting stage and higher number of panicles and panicle weight were consequently improved the grain yield

Effect of weed management practices on dry weight of weeds, yield and yield attributes

Dry weight of weeds recorded during crop growth stages did not differed significantly between the age of seedling planted at 10 and 15 day old. However, lower dry weight of weeds recorded with the seedlings planted in 10 days old (13.37g) than 15 days old (13.43 g). Weed management practices had significant effect on yield and yield attributes of SRI (Table 2). Weed control through conoweeding at 10, 20, 30 and 40 days after transplanting recorded significantly lower weed dry weight (8.70 g) which resulted higher grain yield (6003 kg/ha) followed by application of pre-emergence herbicide butachlor 1.5 kg/ha at 5 DAT followed 1 hand weeding at 20 DAT (day weight grain yield was recorded 11.7 g and 5653 kg/ha respectively) and found significantly superior over other treatments. This might be due to effective control of weeds which in turn significantly increased the number of panicles/m^2 and panicle weight (g) consequently improved the grain yield. Control of weeds by herbicides during early stages of rice resulted in lower competition to the crop for moisture, nutrients and sunlight that influenced the crop to grow better as evidenced in increased yield attributes and yield (Singh *et al.* 2005). The interaction effect between age of seedlings and weed management practices were found significant during both the season of the study.

Economics

In SRI method of rice cultivation, planting of 15 days old seedlings obtained higher net returns and B:C ratio (₹ 37960/ha and 1:46, respectively) than planting 10 days old seedlings. Among weed management practices cono-weeding at 10, 20, 30 and 40 days after transplanting recorded higher B:C ratio (1.50) as compared to pre-emergence herbicide butachlor 1.5 kg/ha at 5 DAT followed by 1 hand weeding at 20 DAT and 2 times cono weeder at 10 and 20 DAT (1.20).

Table 1. Influence of age of seedling and weed management practices on yield and yield components of SRI

Treatment	Grain yield (kg/ha)			Panicle no./m^2			Panicle weight (g)		
	2010	2011	Mean	2010	2011	Mean	2010	2011	Mean
Age of seedling									
A_1 : 10 days old	4485	6570	5528	357	450	404	3.43	3.38	3.41
A_2 : 15 days old	4787	6604	5696	370	460	415	3.47	3.52	3.50
LSD (P=0.05)	NS	NS		NS	NS		NS	NS	
Weed management practices									
W_1 : 2 times conoweeder at 10 and 20 DAT	4134	6224	5179	343	434	389	3.36	3.26	3.31
W_2 : 4 times conoweeder at 10, 20, 30 and 40 DAT	5114	6891	6003	380	470	425	3.49	3.60	3.55
W_3 : Pre-emergence herbicide butachlor 1.5 kg/ha 5 DAT followed 1 hand weeding at 20 DAT	4661	6645	5653	368	471	420	3.50	3.49	3.49
LSD (P=0.05)	598.0	459.2	528.6	21.0	30.5	25.8	NS	NS	

Table 2. Weed dry weight and economics of SRI cultivation as influenced by age of seedling and weed management practices

Treatment	Weed dry weight (g/m^2)	Cost of cultivation ($x10^3$ ₹/ha)	Gross returns ($x10^3$ ₹/ha)	Net returns ($x10^3$ ₹/ha)
Age of seedling				
A_1 : 10 days old	13.37	26.00	61.98	35.98
A_2 : 15 days old	13.43	26.00	63.96	37.96
LSD (P=0.05)	NS			
Weed management practices				
W_1 : 2 times cono weeder at 10 and 20 DAT	19.80	26.50	58.28	31.78
W_2 : 4 times cono weeder at 10, 20, 30 and 40 DAT	08.70	27.00	67.53	40.53
W_3 : Pre-emergence herbicide Butachlor 1.5 kg/ha 5 DAT followed 1 hand weeding at 20 DAT	11.70	28.00	63.33	35.33
LSD (P=0.05)	1.53			

Based on the above study it can be concluded that in SRI, planting 10 or 15 days old seedling was desirable for realizing higher productivity in place of too young seedlings (8-10 days old seedlings) and four time cono-weeding at 10 days interval after transplanting was found most effective in weed control.

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Indian Journal of Weed Science **44**(1): 53–57, 2012

Effects of nitrogen on competition between wheat and grassy weeds

M.B.B. Prasad Babu* and Vikas Jain

Directorate of Weed Science Research, Jabalpur, Madhya Pradesh 482 004

Received: 23 November 2011; Revised: 3 February 2012

ABSTRACT

Field experiments were conducted in microplots to study the effect of N supply on competition between wheat and two prominent grassy weeds *viz*., *Phalaris minor* and *Avena ludoviciana*. Six treatments comprising three species combinations (wheat monoculture, weed monoculture, wheat and weed mixture in equal proportions) and two levels of N fertilization (20 and 120 kg/ha) were studied in a factorial randomized block design with four replications. Results revealed that total dry weight of wheat was significantly lower in mixture than in monoculture. Wheat was more competitive than *P. minor* at high N, but less competitive at low N. *A. ludoviciana*, was more competitive than crop at both N levels. Wheat reduced photosynthesis of weeds to a greater extent as compared to pure weed population. *A. ludoviciana* exhibited higher values of *P*n as compared to *P. minor* at both N levels in both stand (monoculture and mixture) types. Leaf area index and leaf chlorophyll content of both wheat and weed were at par in mixture at high N and in monoculture at low N, indicating a higher competitiveness (for nitrogen) of *A. ludoviciana.*

Key words: *Avena ludoviciana*, Crop-weed competition, *Phalaris minor*, Wheat

Littleseed canary grass (*Phalaris minor*) and wild oat (*Avena ludoviciana*) are the two most troublesome winter season grassy weeds reducing the yields of wheat (*Triticum aestivum* L.) crop in rice-wheat system of Indo-Gangetic plains (Brar *et al*. 2002). These weeds resemble wheat so closely that hand-weeding at the critical seedling stage is extremely difficult. A single plant of *Phalaris minor* may produce as many as 1,100 seeds and 150 plants/m^2 will reduce the wheat yield by 30% (Balyan and Malik 1989). The loss due to *P. minor* may range from 30-80% (Brar and Singh 1997). It is a major problem in the states of Haryana, Punjab and Uttar Pradesh (Malik and Singh 1995). Wild oat is a very troublesome weed in non-paddy rotations in light to medium textured soils and 30 plants/m^2 can cause nearly 50% yield losses in wheat (Walia and Brar 2001). Nitrogen (N) is a major nutrient required by crop plants for optimum vegetative and reproductive growth. Increasing application of N may improve the ability of cereals to suppress weeds. However, the effects on individual weed species differ. Although growth of some weed species is decreased as a result of greater crop competition, growth of others may be increased to the extent that they can gain a competitive advantage (Okafor and De Datta 1976, Carlson and Hill 1985). Wheat has a high demand for N during grain filling. If this cannot be met by uptake from soil, premature senescence occurs as N is remobilized from leaves to meet the requirements of the developing grains, resulting in a lower photosynthetic rate (Frederick and Camberato 1995). Therefore, decreased N supply may reduce yields of wheat directly by reducing photosynthetic productivity, and indirectly by resulting in increased weed competition. Hence, the present field study was made to assess the effect of N supply on competition between wheat and *P. minor* and *A. ludoviciana*.

MATERIALS AND METHODS

Field experiments were conducted during *Rabi* seasons (November to April) of 2007 and 2008 at the Directorate of Weed Science Research, Jabalpur located at 23.90° N latitude, 79.58° E longitude and at an altitude of 411.78 m above mean sea level. The experimental soil was clay loam in texture, neutral in reaction (pH 7.5) with medium organic carbon (0.65%) content and low in available N (225 kg/ha). Six treatments comprising three species combinations [wheat monoculture, weed monoculture (*P. minor* and *A. ludoviciana*), wheat and weed mixture in equal proportions] with two levels of N (20 and 120 kg/ha) were studied in a factorial randomized block design with four replications. Replacement series technique (De Wit 1960) was used in which the overall plant density was kept constant. Sowing of wheat *cv. GW-273* was done in microplots of 1 m^2 by drilling the seeds in rows 20 cm apart. All plots uniformly received 60 and 40 kg P_2O_5 and K_2O/ha applied before sowing. Fertilizer N was applied as urea, as full basal dose in case of low N

***Corresponding author:** mbbprasadbabu@gmail.com
Present address: *Directorate of Rice Research, Rajendranagar, Hyderabad, Andhra Pradesh 500 030*

(20 kg/ha) and as 50% basal and 25% each at first and second irrigation in case of high N (120 kg/ha). Other weeds which emerged later were manually removed. However, after 35 days, no attempt was made to remove freshly germinated weeds, if any, except in weed free plots. All broadleaved weeds and grassy weeds other than *P. minor* and *A. ludoviciana* were removed by hand pulling.

Gas exchange measurements were made by using portable infrared gas analyzer (IRGA, model LI 6400 P, LI COR Biosciences, Inc. 4421 Superior Street, Lincoln, Neraska 68504). A constant volume flow rate of 500 cm^3 $/min^1$ dry air was used. To minimize fluctuations in CO_2 concentration, the inlet air was drawn through a sampling mast located around 5 m away from the IRGA. Broadleaf chamber (maximum 6 cm^2) was used for wheat, *P. minor* and *A. ludoviciana*. Measurements were made starting at 09.30 GMT and were done on 4 plants of each species per plot. During measurement, the leaf chamber was clamped over the central portion of the leaf with the adaxial surface of the uppermost leaf. Light Emission Device (LED) was used and PAR of 1000 µmoles/m^2/s was maintained. In wheat and both weeds, measurements were made on flag leaf of the main stem as it became fully expanded at that time *i.e.* 60 DAS. Leaf Area Index was determined by using an automatic area measurement system (Delta-T Devices Ltd.).

Two sets of analyses were performed on the data. The effects of N supply and competition were determined by computing analyses of variance on the data recorded for each separate species. The effects of N supply on the relative competitive ability of the two species were determined by calculating relative yields, the relative yield total of the mixture and relative crowding coefficient. According to method of Spitters and Van den Bergh (1982), the relative yield (RY) of each species was calculated as: (yield per plot in mixture/yield per plot in monoculture). The relative yield total (RYT) was calculated according to de Wit and Van den Bergh (1965) as the mean of the relative yields 0.5X (RY_{crop} + RY_{weed}) and relative crowding coefficient (RCC) as the ratio of the relative yields (RY_{crop}/ RY_{weed}). RY, RCC and RYT were determined for total dry weight and total N uptake.

RESULTS AND DISCUSSION

A significant decrease in total dry weight and ears/m row length of wheat was recorded at low N level (Table 1). Wheat grain yield and total N uptake were significantly lower at low N with both weed species. Total dry weight of wheat was significantly lower in mixture than in monoculture at both N levels. The data for grain yield followed the similar trend of dry weight. In both the experiments lower grain dry weight in mixture was due to significant decrease in number of ears/m row length. In the experiment with both weed species, the number of grains/ ear was lower in mixture at low N level with a significant reduction at low N with *A. ludoviciana*. Iqbal and Wright (1997) also obtained similar results in their study on effects of nitrogen supply on competition between wheat and three annual weed species.

Averaged over the two N levels, *A. ludoviciana* was more competitive than *P. minor*. It resulted in decrease in

Table 1. Effects of nitrogen and weed competition on wheat dry weight, grain yield and yield components and N uptake of wheat and weeds

Parameter	Weed species	High		Low		LSD (P=0.05)
		Monoculture	Mixture	Monoculture	Mixture	
Wheat						
Total dry weight (g/m^2)	*P. minor*	1334	1153	1032	874	120.5
	A. ludoviciana	1310	1061	996	735	133.1
Grain yield (g/m^2)	*P. minor*	572	404	361	230	69.2
	A. ludoviciana	556	295	357	242	64.1
No. of ears/m row length	*P. minor*	68.2	46.2	42.3	39.2	3.0
	A. ludoviciana	70.2	38.4	39.3	30.1	0.9
No. of grains/ear	*P. minor*	57.2	51.1	52.3	50.4	2.6
	A. ludoviciana	55.1	53.2	49.6	41.3	2.9
Total N uptake (g/m^2)	*P. minor*	8.1	6.3	6.1	4.2	0.3
	A. ludoviciana	8.3	5.9	5.7	3.9	0.3
Weeds						
Total dry weight (g/m^2)	*P. minor*	598	396	283	245	60.7
	A. ludoviciana	542	472	305	341	52.1
Total N uptake (g/m^2)	*P. minor*	4.2	4.0	3.4	3.2	0.4
	A. ludoviciana	6.1	9.1	4.8	5.7	0.3

Table 2. Influence of N on relative yield of wheat and weeds, relative crowding coefficient (RCC) and relative yield total (RYT)

	Species	High N		Low N	
		Dry weight	N uptake	Dry weight	N uptake
RY_{wheat}	*P minor*	0.86	0.77	0.84	0.75
	A. ludoviciana	0.80	0.71	073	0.75
RY_{weed}	*P minor*	0.66	0.95	0.86	0.94
	A. ludoviciana	0.87	1.49	1.11	1.18
RCC	*P minor*	1.30	0.81	0.97	0.79
	A. ludoviciana	0.91	0.47	0.65	0.63
RYT	*P minor*	0.76	0.86	0.85	0.84
	A. ludoviciana	0.83	1.10	0.92	0.96

wheat plant dry weight, grain yield and total N uptake by 22%, 41% and 30%, respectively. The corresponding decrease in these parameters because of competition from *P. minor* was 14%, 19% and 26%.

Low N supply significantly decreased plant dry weight of all species, however, its effect on weeds was greater than that on wheat. The decrease in wheat plant dry weight at low N varied from 23% to 26% while it was 35% and 20% for *P. minor* and wheat, respectively. *A. ludoviciana* depleted significantly higher amount of N in mixture than in monoculture while it was just reverse for *P. minor.* This shows the high competitive ability of *A. ludoviciana.*

Competitive ability of wheat and weeds

The effects of N supply on competitive ability were examined by calculating plant relative yields (RY), relative yield total (RYT) and relative crowding coefficient (RCC) (Table 2). In both experiments, RY of wheat was <1, indicating greater effects of interspecific competition than that of intraspecific competition. In the study with *P. minor,* for both species and N treatments, relative yields (RY) were <1 for both dry weight and N uptake. The effect of low N was to decrease the relative yield of wheat (for dry weight and N uptake) and increase the relative yield of weeds (for dry weight). The RYT was <1 for dry weight and N uptake, indicating that mutual antagonism or allelopathy was occurring. The values of RCC indicate that wheat was more competitive than *Phalaris minor* at high N, but less competitive at low N. The results were in conformity with those obtained by Iqbal and Wright (1997).

In the study with *A. ludoviciana,* RY of weed was greater than that of wheat for both dry weight and N uptake. This shows that, for this species, the effects of intraspecific competition were greater than those of interspecific competition. RYT was close to unity at both N levels, indicating both species competing for limiting sources. RCC was <1 indicating, weed was more competitive than crop at both N levels.

Gas exchange

Significant reduction in photosynthesis of wheat was found by lowering the N dose in monoculture (Table 3). *A. ludoviciana* significantly lowered the rate of photosynthesis (*P*n) at low N application rate. Averaged over the two stand types (monoculture and mixture), the decrease in *P*n of wheat was 38.5% and 40.3% with *P. minor* and *A. ludoviciana*, respectively, while it was 24.2% and 36.5% for *P. minor* and *A. ludoviciana*, respectively. Photosynthetic rate of *P. minor* and *Avena ludoviciana* decreased significantly in mixture at low N level than pure cultures at high N. At low N wheat suppressed *P. minor* by increasing its *P*n. Photosynthesis of both weed species was found to be less than wheat crop. Wheat reduced photosynthesis of weeds to a greater extent as compared to pure weed population. In case of monoculture *A. ludoviciana* at low N also showed significant reduction in *P*n as compared to high N. *A. ludoviciana* exhibited higher values of *P*n as compared to *P. minor* at both N levels and both stand types (monoculture and mixture). Hence *A. ludoviciana* had more suppressive effect on wheat than *P. minor.*

There is no detectable effect of competition from *P. minor* and *A. ludoviciana* on stomatal conductance (g_s) of wheat. In contrast stomatal conductance of both weed species reduced significantly in mixtures at low N level.

In wheat sub-stomatal CO_2 conductance (C_i) decreased in mixture with *P. minor* and increased with *A. ludoviciana* indicating poor efficiency of CO_2 consumption of wheat with *A. ludoviciana.* C_i of *A. ludoviciana* was significantly higher in mixture with low N, indicating poor utilization of CO_2 in the process of photosynthesis. *P. minor* showed poor efficiency of CO_2 utilization than *A. ludoviciana* at both N levels.

Leaf parameters

Low N significantly decreased the LAI and leaf chlo-

Table 3. Effects of nitrogen supply and competition on net photosynthesis (*P*n), stomatal conductance (g_s) and substomatal CO_2 conductance (C_i) of the flag leaf of wheat and weeds

Parameter	Species	High N		Low N		LSD (P=0.05)
		Monoculture	Mixture	Monoculture	Mixture	
Wheat						
*P*n (µmol $CO_2/m^2/s$)	*P. minor*	12.26	9.96	5.56	8.10	4.2
	A. ludoviciana	12.73	9.23	7.10	6.0	2.9
g_s(mol/m^2/s)	*P. minor*	0.19	0.20	0.11	0.16	0.12
	A. ludoviciana	0.20	0.15	0.12	0.13	0.06
C_i(µL/L)	*P. minor*	228.63	217.06	262.25	251.21	19.0
	A. ludoviciana	218.50	242.75	230.41	272.12	18.2
Weeds						
*P*n (µmol $CO_2/m^2/s$)	*P. minor*	6.41	5.37	5.06	3.87	1.6
	A. ludoviciana	9.82	7.60	5.41	5.65	2.7
g_s(mol/m^2/s)	*P. minor*	0.13	0.08	0.13	0.07	0.03
	A. ludoviciana	0.17	0.12	0.10	0.09	0.06
C_i(µL/L)	*P. minor*	255.88	226.0	264.03	254.0	30.5
	A. ludoviciana	205.6	220.1	241.50	242.13	21.7

Table 4. Effect of nitrogen supply on leaf area index and leaf chlorophyll content of wheat and weeds

Parameters	Species	High N		Low N		LSD (P=0.05)
		Monoculture	Mixture	Monoculture	Mixture	
Wheat						
LAI	*P. minor*	4.37	2.83	2.47	2.37	0.25
	A. ludoviciana	4.07	2.10	2.13	1.93	0.25
LC (mg/g fresh wt.)	*P. minor*	3.69	3.10	2.73	2.47	0.23
	A. ludoviciana	3.63	2.97	2.73	2.60	0.34
Weeds						
LAI	*P. minor*	3.43	2.97	2.47	1.90	0.34
	A. ludoviciana	4.57	2.93	2.70	2.20	0.25
LC (mg/g fresh wt.)	*P. minor*	2.37	2.00	1.77	1.50	0.15
	A. ludoviciana	3.20	2.20	2.10	1.70	0.23

rophyll content of wheat and *P minor*, both in monoculture and mixture (Table 4).

Leaf Area Index (LAI) and leaf chlorophyll (LC) content of both wheat and weeds were at par in mixture at high N and in monoculture at low N, indicating higher competitiveness (for nitrogen) of *A. ludoviciana.* Averaged over the two stand types (monoculture and mixture) and both weed species, low N decreased LAI of wheat by 33% and LAI of *P. minor* and *A. ludoviciana* by 32% and 35%, respectively. Both weed species resulted in a significant reduction in LAI of wheat. Averaged over the two N levels these were 24% and 35% for *P. minor* and *A. ludoviciana,* respectively. There was significant decrease in wheat leaf chlorophyll content with *P minor* at both N levels and with *A. ludoviciana* at high N level. In weeds, the LAI was also significantly lesser in mixture than in monoculture at both N levels. Leaf chlorophyll content was significantly lower in mixture than in monoculture in both weed species.

The results of the present investigation have shown that wheat was more competitive than *P. minor* at high N, but less competitive at low N. However, *A. ludoviciana*, was more competitive than crop at both N levels.

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Short communication

Indian Journal of Weed Science **44**(1): 58–59, 2012

Evaluation of pre-emergence herbicides for cost-effective weed control in tapioca

P. Prameela*, Meera V. Menon, P.S. John and C.T. Abraham

College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala 680 656

Received: 7 October 2010; Revised: 8 September 2011

Key words : Chemical control, Pre-emergence herbicides, Tapioca, Weed control efficiency

Tapioca (*Manihot esculenta* Crantz.) commonly known as cassava is a high carbohydrate tropical tuber crop relished for its taste by the people of Kerala. It is important as a cheap source of calorie and is an attractive crop in terms of net profit. India has the highest productivity of tapioca (24.5 t/ha) in the world. Kerala leads with 50 per cent of the total area and production of this crop in India.

Both the method of planting adopted and growth habit of cassava give opportunities for luxurious weed growth during the initial stage of the crop and hence the crop is prone to weed competition during the first 2-3 months after planting. Weed management in tapioca is very important in these initial months of planting after which the canopy closes leaving no room for further weed growth.

In tapioca, weeding usually is done using spade or some hand tools and is accompanied by earthing up. When weeding with implements, it is important to avoid any disturbance to the roots of the crop, as it will adversely affect the tuber production. The first weeding is done 25-30 days after planting (DAP) and the second at 60 DAP. Chemical weeding in cassava using selective pre emergence herbicides is a good option as manual weeding is costly in most of the places due to high labour charges and scarcity of labour

The major weeds affecting cassava production are *Panicum maximum*, *Pennisetum* spp, *Andropogon* spp, *Imperata cylindrica* for the grasses and *Mimosa invisa*, *Mucuna pruriens* for the broad leaves, but many others can cause problems. Weed competition during the first two months can reduce yields by 50%. Weeding after four months will not increase yield and late weed infestations occurring before harvest appear to have little impact on yield, though this can disturb the harvest and lower the quality of stakes of the future crop (Lebot 2009). Weeding requires 20 to 200 man-days/ha depending on the severity of weed infestation making it one of the highest cost factor in total cost of cultivation. Use of herbicides, mulching, intercropping *etc.* can reduce weeding costs. No herbicide has been developed especially for cassava but glyphosate and paraquat are commonly used between rows and for blanket spray before land preparation and planting of the crop. For pre emergence control herbicides such as the substituted ureas, alachlor, butachlor, oxyflourfen *etc.* can be used. Spraying can be carried out immediately after planting within four days and before sprouting. In Thailand, the best results are obtained with pre emergence application of metolachlor (1.56 kg/ha) with or without post emergence spraying of paraquat (0.5 kg/ha) as a cost efficient alternative (Lebot 2009). Protective shields must be used to avoid contact with the shoots in the case of post emergence application.

The present study was carried out with the objective of identifying a good pre emergence herbicide for tapioca as a labour saving and cheaper option.

The experiment was carried out in the farm of Department of Agronomy, College of Horticulture, Vellanikkara in 2008. The soil of the experimental field was sandy loam with a pH of 5.3. The treatments consisted of five pre emergence herbicides in two doses.

The treatments were replicated thrice and the design adopted was RBD. Plot size was 50 m^2 and tapioca setts were planted on mounds spaced at 90 x 90 cm. Immediately after planting of tapioca, green gram seeds were sown at three spots on each mound, 20cm away from the sett with the aim of producing green manure, which could be later incorporated or mulched in the plot. The herbicides were uniformly applied on the soil surface using a backpack sprayer with a flat fan nozzle. The mortality of green gram seedlings was recorded two weeks after spraying (Table 1). The weed dry matter production per square meter was recorded at 40 and 60 days after spraying and weed control efficiency was worked out.

Dicots constituted the major weed flora of the experimental site, followed by sedges. The major weeds were *Mimosa invisa, Mollugo distica, Synidrella nodiflora* among dicots and *Cyperus rotundus* among sedges. Among the different pre emergence herbicides tested, Diuron was the most effective one at both the rates of application as evidenced by the lowest weed dry matter production and highest weed control efficiencies (WCE)

*Corresponding author: prameelaagron66@yahoo.com

Table 1. Effect of pre-emergence herbicide application on intercropped green gram and on weed dry matter production in tapioca

Treatment	Cost of weed control (₹/ha)	Mortality of green gram (%)	Weed dry matter production (g/m²)		Weed control efficiency (%)		Tuber yield (t/ha)
			*40 DAS	60DAS	40 DAS	60DAS	
Oxyflourfen 0.15 kg/ha	1937	100	53.00(7.31)^{c}	63.0(7.97)^{def}	72	77	16.84
Oxyflourfen 0.20 kg/ha	2372	100	38.00(6.19)^{d}	45.67(6.79)^{f}	80	84	17.12
Pretilachlor 0.75 kg/ha	3625	16	96.33(9.85)^{b}	100.7(10.08)^{b}	48	64	17.75
Pretilachlor 1 kg/ha	4625	20	86.33(9.32)^{b}	90.67(9.57)^{bc}	54	67	18.45
Fluchloralin 0.75 kg/ha	4825	0	60.33(7.79)^{c}	69.67(8.39)^{cde}	68	75	20.15
Fluchloralin 1 kg/ha	6250	0	60.00(7.76)^{c}	74.67(8.68)^{cde}	68	73	19.73
Pendimethalin 1 kg/ha	6447	60	62.00(7.94)^{c}	85.00(9.26)^{bcd}	67	69	18.00
Pendimethalin 1.5 kg/ha	9015	80	34.00(5.91)^{d}	53.30(7.34)^{ef}	82	81	16.50
Diuron2 kg/ha	1865	100	8.00(2.95)^{e}	47.00(6.92)^{f}	96	83	19.65
Diuron3 kg/ha	2835	100	5.67(2.56)^{e}	28.00(5.36)^{g}	97	90	18.92
Control (no herbicide application)		0	186.67(13.68)^{a}	277.30(16.66)^{a}	0	0	21.11
LSD (P=0.05)	-	-	17.59	25.70	-	-	NS

DAS – Days after spraying, *Weed dry matter production are $\sqrt{x+1}$ transformed values and the values in the parenthesis are original values, In a colume the values followed by same alphabet (superscript do not differ significantly duncan's multiple range test (DMRT)

(Table 1). However, the WCE declined by 13 and seven per cent respectively at lower and higher doses. This does not seem to be a good herbicide in tapioca intercropped with legume either for green manure or grain purpose due to the 100% mortality of the green gram. The scope of using diuron 1.6 kg/ha was reported for chemical weed control in tapioca grown in sandy loams (I.C.T.A. 1975).

Fluchloralin at both the rates of application was found to give moderate control of weeds with 68% WCE. In fluchloralin trented plots, WCE was recorded 75 and 73% at the of 0.75 and 1 kg/ha , respectively by 6th day indicating the long residual action of the herbicide compared to Diuron. The mortality percentage of green gram sown was zero indicating its at most suitability in tapioca and legume intercropped situation.

Pretilachlor cannot be considered as a suitable herbicide because of the mortality caused to the legume, higher weed dry matter and consequent lower WCE. Though the use of oxyflourfen at higher rates is comparable with diuron in WCE, it also caused 100% mortality to the legume.

With regard to the phytotoxicity to the herbicides to the tapioca crop, no such effect was observed for any of the herbicides tested, since the pre emergence herbicidal action is mainly on the germinating seeds.

Diuron 2 kg/ha resulted in the lowest cost of weed control, which is only 15% of the cost of hand weeding. Weed control by oxyflourfen also resulted in a more or less similar expenditure. The cost of weed control with fluchloralin at the lower dose of 0.75 kg/ha was 39% of that for hand weeding. Pendimethalin was the costliest among the herbicides.

It can be inferred that in legume intercropped tapioca, fluchloralin 0.75 kg/ha can result in good weed control with a saving of 61% over hand weeding. In a pure tapioca crop the herbicide Diuron 2kg/ha is effective for excellent weed control with the least cost with a saving of 86% in costs compared to manual weeding.

SUMMARY

Tapioca (*Manihot esculenta* Crantz) is a high carbohydrate tropical tuber crop relished for its taste by the people of Kerala. Both the method of planting adopted and growth habit of cassava gives opportunities for luxurious weed growth during the initial stage of the crop and hence the crop is prone to weed competition during the first 2-3 months after planting. The present study was carried out with the objective of identifying a good pre emergence herbicide for tapioca as a labour saving and cheaper option. Diuron was the most effective herbicide as evidenced by the lowest weed dry matter production and highest weed control efficiency (WCE). This was not found a good herbicide in tapioca intercropped with legume either for green manure or grain purpose due to the 100% mortality of the green gram. In legume intercropped tapioca, fluchloralin 0.75 kg/ha resulted in good weed control with a cost saving of 60% over hand weeding. In a pure tapioca crop the herbicide Diuron 2 kg/ha resulted in excellent weed control with least cost. A saving of 86% in costs was effected compared to manual weeding.

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Short communication

Indian Journal of Weed Science **44**(1): 60–61, 2012

Leaching behaviour of pendimethelin in sandy-clay loam soil of northern Madhya Pradesh

Asha Arora*

R.V.S.K.V.V., College of Agriculture, Gwalior, Madhya Pradesh 474 002

Received: 15 January 2012; Revised: 24 March 2012

Key words : Bioassay, Leaching, Pendimethalin, PVC columns

Chemical weed control in crop cultivation has become indispensable, particularly due to high cost and acute scarcity of labors during the peak period of demand. As a result, herbicide consumption in the country has shown an increasing trend during the recent years. With the increasing awareness and concern for environmental quality, it is important that we consider not only the effectiveness of a pesticide, but also its persistence and mobility in soil.

The relative vertical movement (leaching) of herbicide in soil influences the weed control effectiveness, carryover and the potential for the environmental problem. Typically, pesticide leaching is of critical concern, when it moves into ground water or another location posing an increased risk to human being and/or the environment. Movement of herbicide in soil depends upon many factors, including chemical properties of herbicide, soil factors as well as intensity and frequency of rainfall or applied water. In general, the mobility of a given class of herbicide is inversely related to their adsorptivity by soil.

Pendimethalin (N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitroaniline) belonging to dinitroaniline group, have proved its effectiveness as herbicide in number of crops. It controls wide spectrum of annual broad leaved weeds and grasses (Tripathi *et al.* 1993). A laboratory column experiment was conducted to understand leaching behaviour of pendimethalin in sandy clay loam soils of Northern Madhya Pradesh,

Surface soil sample (0-15cm) from the surrounding area of the Research Farm College of Agriculture, RVSKVV, Gwalior that was never treated with any herbicide were collected, air-dried and passed through a one mm sieve. The soil was sandy clay loam in texture (sand 55.2%, silt 19.4% and clay 25.4%) with organic carbon 0.30% and pH 7.4. Polyvinyl chloride (PVC) columns (10 cm internal diameter and 60 cm long) were used in experiment and arranged in a completely randomized design with three replications. Columns were cut vertically into two parts and two cut halves were joined together using adhesive tape. The muslin cloth was tied to one end and from the open end processed untreated soil was added into columns. The known amount of soil (6 kg) was packed by gently tapping the columns. One day before the herbicide application, 500 ml water was added from the top to pre condition the soil and allowed to drain naturally. Pendimethalin was added directly to column after dilution with 10 ml water at recommended dose (1.0 kg/ha) and double the recommended dose (2.0 kg/ha). The herbicide required was calculated based on open surface area (surface area of a circle $=\pi r^2$). 200 ml of water was added in two split doses of 100 ml at 8.0 AM and 5.0 PM every day to encourage movement of herbicide. A set of columns was used without herbicide for comparison. At the end of the trial (7 days) adhesive tape was cut and the column was split vertically into two halves by passing metal wire along the joint. The herbicide activity was determined at different depths through bioassay by using maize as sensitive plant by following the standard procedure. Plant height, fresh weight and dry weight of maize plant were recorded 21 days after sowing and presented below (Table 1).

The growth of maize due to pendimethalin was affected in the upper layer of soil up to 5 cm at recommended dose (1.0 kg/ha) and up to 10 cm at double the recommended dose. This reveals that pendimethalin does not leach below 10 cm in soil even at double the recommended dose. Gowda *et al.* (1993) reported that mobility of pendimethalin in the 0-5 cm layer was greater than 5-10 cm depth and very little movement occurred at 10-15 cm depth. Sondhia (2007) reported that approximately 80% of applied pendimethalin was found distributed in 0-12 cm soil depth indicating slow mobility of pendimethalin in clay loam soil. Low leaching potential of pendimethalin may be due to strong absorption of this dinitroanilin herbicide as intrinsic mobility of herbicide in soil in inversely related to its sorption to soil surface (Gustafson 1995). It indicates that under normal conditions of average rainfall the risk of ground water contamination with pendimethalin is negligible.

***Corresponding author:** ashaaroragwl@gmail.com

Table 1. Effect of pendimethalin on growth of maize plant in soil from different depths

Soil depth (cm)	Recommended dose (1.0 kg/ha)			Double the recommended dose (2.0 kg/ha)		
	Plant height (cm)	Fresh weight (g/plant)	Dry weight (g/plant)	Plant height (cm)	Fresh weight (g/plant)	Dry weight (g/plant)
0 – 5	10.12	0.347	0.043	8.68	0.266	0.038
5 – 10	14.35	0.491	0.057	9.73	0.393	0.044
10 – 15	15.00	0.492	0.064	13.01	0.491	0.054
15 – 20	13.70	0.515	0.060	13.44	0.486	0.059
20 – 25	13.24	0.469	0.060	13.45	0.508	0.062
25 – 30	14.61	0.497	0.065	14.14	0.485	0.063
30 – 35	14.47	0.481	0.061	13.67	0.492	0.060
35 – 40	14.00	0.517	0.059	14.00	0.500	0.059
40 – 45	14.44	0.498	0.061	14.47	0.498	0.060
45 – 50	14.33	0.504	0.062	13.73	0.501	0.062
Control (no herbicide)*	14.14	0.505	0.064	14.14	0.505	0.064

* Mean of all (10) values at different depths

SUMMARY

A laboratory column experiment was conducted to study the leaching behaviour of pendimethalin in sandy clay soil of Madhya Pradesh. Soil sample (0-15cm) was packed in PVC columns and conditioned by adding water one day before the herbicide application. Pendimethalin was added directly to column after dilution with 10 ml water at recommended dose (1.0 kg/ha) and double the recommended dose (2.0 kg/ha). Water was added every day to encourage movement of herbicide. After seven days, the column was split vertically into two halves. The herbicide activity was determined at different depths through bioassay by using maize as sensitive plant. The growth of maize due to pendimethalin was affected in the upper layer of soil up to 5 cm at recommended dose (1.0 kg/ha) and up to 10 cm at double the recommended dose. This reveals that pendimethalin does not leach below 10 cm in soil even at double the recommended dose.

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Indian Journal of Weed Science **44**(1): 62–64, 2012

Floristic composition of weeds in mixed winter crop on Gujar lake's margins in Uttar Pradesh

Mayank Singh*, O.P. Singh and M.P. Singh

Department of Botany, T.D.P.G. College, VBS Purvanchal University, Jaunpur, Uttar Pradesh 222 002

Received: 26 May 2011; Revised: 5 December 2011

Key words: Crop and weeds, Mixed winter crop, Phytosociology, Weed flora

Weeds are posing a serious problem in winter crop. Floristic composition in such habit represents the kind of weed species that occur in the particular agro ecosystem. In contrast, lake margins are specialized terrestrial habitats that are characterized by slight slopping topography, host of agricultural operations mainly during winter season due to cyclic inundation or submergence and some time extreme dry conditions due to scarcity of rainfall in rainy season, and extremely dry condition in summer. The sites are usually cultivated every year during winter season for mixed crop of wheat and mustard (*Rabi*). Lake margins are literally passing through critical phase of ecological transition and are being converted into 'weed bowls' at alarming rate leading to swampification (Sinha and Jha 2008). Various workers have given accounts of weed flora production and competition in certain agro-ecosystems (Soni and Ambasht 1977, Singh and Ambasht 1986). There is still paucity of information of such kind of study on a lake margin.

The study was carried out near 'Gujar Tal' (24p 6'-25p 5'N and 80-82p E longitude) in the North western region of Jaunpur (Uttar Pradesh) 28 km to the west of Khetasarai market. The study site (50×200m) was of 5-15p slope. The texture of soil was more or less sandy clay loam (0-10 cm) and clay loam at two depths (10-20 and 20-30cm), pH of soil varied from 7.8 to 8.0 in the respective three depths and soil moisture 14.79 to 19.30% (Singh *et al.* 2010). The climate is typically monsoonic with three different season's *viz.*, summer, rainy and winter. The total annual rainfall from April, 2008 to March, 2009 was 1346.8 mm out of which 1295.4 mm was in rainy season. But rainfall during winter cropping period was 2 and 1.2 mm in the respective months of January and February, 2009.

After the flood-water receded, ploughing was done at the study site in the second week of November, 2008. Wheat (*Triticum aestivum*, *variety* '*Malvi* 234') and mustard (*Brassica compestris variety* '*Varuna'* Type, 59) were sown together by applying 32 kg nitrogen and 23 kg phosphorous/ha.

***Corresponding author:** mahendrapratapsinghtdpg@gmail.com

Floristic composition and quantative characters study was done by transect method through 50×50 cm quadrat laid at every one meter alternative segments from top upland to lower lake margins at bimonthly intervals as recommended by Hanson and Churchill (1965) and Muller Dombois and Ellenberg (1974) by using following formulae:

$$F = \frac{\text{Number of quadrats in which species occurs}}{\text{Total number of quadrats sampled}} \times 100$$

$$D = \frac{(\text{ F= Frequency})}{\text{Total number of qudrats sampled}} \times 100$$

(D =Density)

Basal cover = Average basal area × density
Average basal area = $\pi r2$ cm.
(Where r is radius of stem at emergent point)

The collected weeds were identified by using floras of Bor (1958), Srivastava (1976) and Sanni *et al.* (2010). The collected plant materials have been deposited in the Herbarium of Botany Deptt. of T.D. College Jaunpur (U.P.).

The weed species encountered during mixed winter cropping at bimonthly intervals are listed (Table 1). There were total 36 and 39 weed species recorded on the two sampling dates *i.e.* 28th Dec., 2008 and 27th Feb., 2009. The maximum number of weeds was of Poaceae followed by Asteraceae and others. Among these weed species, some were present throughout the cropping period. Some appeared at later stage of crop and few showed shorter life cycle. The maximum frequency (65 and 72%), density (54.19 and 99.80/m^2) and basal cover (1.084 and 2.994 cm^2/m^2) was of *Cynodon dactylon* followed by *Cyperus rotundus* with its peak frequency (55 and 41%), density (12.04 and 10.92/m^2) and basal cover (0.241 and 0.328 cm^2/m^2) on the two respective sampling dates. It clearly indicates that these weeds have flourished well by vegetative propogation and by their competitive ability in comparison to other weeds. It provided a clue to species diversity in a community and each species that has its own range of ecological amplitude which indicate the condition of the habitat.

Table 1. Floristic composition, frequency, density and basal cover of herbaceous weeds and mixed winter crop

Plant species	Family	Frequency (%)		Density/m^2		Basal cover (cm/m^2)	
		Dec	Feb	Dec	Feb	Dec	Feb
Alternanthera sessilis (Linn.) Dc.	Amaranthaceae	2	4	0.09	0.26	0.004	0.018
Amaranthus viridis Linn.	Amaranthaceae	2	4	0.03	0.14	0.006	0.014
Anagallis arvensis Linn.	Primulaceae	47	36	3.21	2.95	0.225	0.018
Avena sterilis Linn. Var. culta	Poaceae	2	3	0.03	0.07	0.002	0.005
Blumea laciniata (Rox.) Dc.	Asteraceae	3	5	0.14	0.21	0.011	0.025
Brassica campestris Linn.	Brassicaceae	98	76	7.03	2.08	0.913	0.437
Chenopodium album Linn.	Chenopodiaceae	52	43	2.12	2.09	0.170	0.200
Chrozophora rottleri A. Juss.	Euphorbiaceae	3	4	0.04	0.07	0.004	0.064
Cynodon dactylon (Linn.) Pers.	Poaceae	65	72	54.19	99.80	1.084	2.994
Cyperus rotundus Linn.	Cyperaceae	55	41	12.04	10.92	0.241	0.328
Dichanthium annulatum (Forssk.) Stapf	Poaceae	21	19	3.20	1.30	0.064	0.039
Eclipta prostrata (Linn.) Linn.	Asteraceae	16	8	1.57	0.41	0.031	0.025
Eragrostis atrovirens (Desf.) Trin.	Poaceae	9	5	1.41	1.91	0.056	0.076
Euphorbia thymifolia Linn.	Euphorbiaceae	11	9	0.89	0.72	0.031	0.012
Gnaphalium indicum Linn.	Asteraceae	9	7	0.29	0.31	0.008	0.012
Ipomoea aquatica Forsk.	Convolvulaceae	3	-	0.09	-	0.001	-
Lathyrus sativus Linn.	Fabaceae	8	4	0.24	0.18	0.013	0.011
Launaea asplenifolia Hk. F.	Asteraceae	6	10	0.16	0.29	0.006	0.015
Linum usitatissimum Linn.	Linaceae	8	5	0.19	0.14	0.009	0.018
Lippia nodiflora A. Rich.	Verbenaceae	6	4	1.43	1.01	0.057	0.051
Melilotus indica (L.) All. Fl.	Fabaceae	8	11	0.29	0.41	0.017	0.029
Nicotiana plumbaginifolia Viv.	Solanaceae	3	7	0.15	0.29	0.011	0.026
Oryza rufipogon Griff.	Poaceae	-	3	-	0.14	-	0.005
Parthenium hysterophorus Linn.	Asteraceae	7	14	0.29	1.47	0.012	0.074
Paspalidium flavidum (Retz.) A. Camus	Poaceae	-	9	-	1.10	-	0.209
Phalaris minor Retz.	Poaceae	17	14	1.10	1.61	0.022	0.029
Polygonum barbatum Linn.	Polygonaceae	3	4	0.24	0.19	0.006	0.005
Polygonum plebeium Linn.	Polygonaceae	-	4	-	0.43	-	0.017
Polypogon monsplensis Linn.	Polygonaceae	4	3	0.02	0.09	0.006	0.004
Potentilla supina Linn.	Rosaceae	-	3	-	0.12	-	0.004
Rumex dentatus Linn.	Polygonaceae	9	13	0.56	0.76	0.050	0.076
Salvia plebeia R. Br. Linn.	Lamiaceae	7	1	0.25	0.02	0.004	0.008
Solanum nigrum Linn.	Solanaceae	3	5	0.08	0.10	0.004	0.008
Triticum aestivum Linn.	Poaceae	100	100	102.66	108.07	7.186	12.968
Typha angustata Linn.	Typhaceae	5	4	0.05	0.03	0.010	0.007
Vaccaria pyramidata Medik	Caryophyllaceae	4	3	0.10	0.08	0.015	0.014
Verbascum chinense Linn.	Scrophulariaceae	3	4	0.06	0.10	0.001	0.004
Vicia hirsute (Linn.) S.F. Gray	Fabaceae	3	4	0.05	0.14	0.001	0.005
Volvulopsis nummularia (Linn.) Roberty	Convolvulaceae	2	4	0.06	0.12	0.001	0.003
Xanthium strumarium Linn.	Asteraceae	1	3	0.03	0.05	0.002	0.007

SUMMARY

Floristic study and variation in frequency, density and basal cover of crop and weeds were studied at bimonthly intervals in a mixed wheat and mustard crop at Gujar lake margin in district Jaunpur (Uttar Pradesh). The total number of weed species recorded on 28th December, 2008 and 27th February, 2009 were 34 and 37, respectively. Maximum number of weeds was of Poaceae and followed by Asteraceae. *Cynodon dactylon* was the most dominated weed. The maximum frequency (65 and 72%), density (54.19 and 99.80/m^2) and basal cover (1.084 and 2.994 cm^2/m^2) were of *Cynodon dactylon* followed by *Cyperus rotundus*. It was mainly due to their vegetative mode of propagation and by their competitive ability in the favourable soil moisture, texture and nutrients conditions.

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Short communication

Indian Journal of Weed Science **44**(1): 65–67, 2012

Predominant weed flora of cropped and non-cropped fields of Bastar in Chhattisgarh

Adikant Pradhan*, A.S. Rajput and and A. Thakur

S.G.College of Agriculture & Research Station, Jagdalpur, Chhattisgarh 490 001

Received: 29 March 2011; Revised: 15 November 2011

Key words: Cropped fields, Non-cropped fields, Weed flora

Southern track of Chhattisgarh has been heavily infested by different weed flora throughout the year. The Southern Chhattisgarh comprises the geographical area of 32.63 lakh ha, out of which 6.56 lakh ha (20.1%) cultivated and 21.63 lakh ha (65%) forest area (Anonymous 2008). The cultivated area of upland have serious weeds problems which reduce the yield of upland crops. Some weeds have dominated this region because of congenial environment leading higher intensity. The crops suffer heavily in early growth stage from the weeds. Critical period of crop weed-competition has been identified as 20-30 DAS in upland capable to reduce the yield production by 47 to 92 % (Bhadoria *et al.* 2000, Yadav 1998). Type of crop and soil properties has greatest influence on the occurrence of weed species (Streibig *et al.* 1984, Andreasen *et al.* 1991). The infestation of weeds is significantly influenced by cropping pattern, weed control measures, moisture availability period and environmental factors (Saavendra *et al.* 1980). Therefore, the knowledge of weed species occurrence in crops of the region is necessary to plan and execute a proper and economical weed management schedule depending.

Survey was carried out in five weed dominated blocks namely Bakawand, Batar, Tokapal, Lohandiguda and Jagdalpur from 7 villages.in Bastar district during August-September and February-March, 2008 and 209, respectively. For studying the composition of weeds in cropped and non-cropped areas, 70 fields were surveyed and routes were planned to establish sampling localities as possible distance of about 5 Kms avoiding inhabited areas and duplication. Five observations on density of individual weeds were recorded per field at single spot using quadrate (0.5 x 0.5m) at 150 metre deep inside the fields as suggested by Raju (1977). Average values of relative weed density, relative frequency of individual weeds and importance value index (IVI) were calculated by given formula for each blocks separately.

$$\text{Relative density} = \frac{\text{No.of individual species}}{\text{No.of total species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{No.of individual species in each block}}{\text{Total no. of species in each block}} \times 100$$

Importance value index = Relative density + Relative frequency

Weed flora of upland crops

Total 20 weed species were found to infest the upland crops at 20-35 days after sowing. Among these species, 10 species were grasses, 1 was sedges and 9 belonged to broad leaved weeds (Table 1).

In all the blocks, *Spilanthes acmella, Celosia argentea* and *Digitaria adscendens* were the most dominant weeds. The respective relative density of these weeds varied from 7.14 to 27.16% in five blocks, but higher percentages (27.16%) of density was recorded by *Spilanthes acmella* in Bastar block. The *Spilanthes acmella* alone constituted 15.17, 27.16, 13.30, 15.17 and 12.02 % in Bakawand, Bastar, Tokapal, Lohandiguda and Jagdalpur, respectively and followed by *Celosia argentea* (Andreasen *et al.*, 1991).

Among grasses, relative density of *Digitaria adscendens* was found to be higher (8.45, 12.35, 7.80, 8.43 and 7.36% in Bakawand, Bastar, Tokapal, Lohandiguda and Jagdalpur, respectively) than other grasses observed on cropped fields. *Setaria glauca* was occupied next to *Digitaria adscendens* in relative density, but little lower in *Eleusine indica* (5.06%) and *Dinebra retroflexa* (5.06%). The relative frequency (RF) and important value index (IVI) followed similar trend in occupying the floral composition in cropped lands in all blocks of Bastar district. Misra (1968) also recorded *Digitaria adscendens* and *Setaria glauca* as more rampant weeds in upland which need to be controlled on priority basis in early stage of flushing.

Weed flora of *Rabi* crops

Wheat and mustard are more prominent crops or mixed cropping in *Rabi* under assured irrigation in the region otherwise fields are left in fallow (Rice-fallow system). This system provides good seed bank of weeds for coming *Kharif* season. In *Rabi* , all 70 sites taken under survey were found to infest with 13 major weeds, of which 4 were grassy, 9 broad leaved weeds. The *Rabi* season

*Corresponding author: adi_197753@rediffmail.com

Table 1. Weed flora in different blocks of Bastar district in upland cropping

Upland cultivation	Bakawand			Bastar			Tokapal			Lohandiguda			Jagdalpur		
	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)
Celosia argentia	8.43	10.42	18.84	12.35	9.09	21.44	7.80	14.29	22.08	8.43	14.29	22.71	7.36	10.42	17.78
Ageratum conyzoides	6.74	6.25	12.99	8.64	6.06	14.70	6.42	7.14	13.56	6.74	7.14	13.88	6.20	6.25	12.45
Spilanthes acmella	15.17	10.42	25.59	27.16	9.09	36.25	13.30	14.29	27.59	15.17	14.29	29.45	12.02	10.42	22.43
Amaranthus virdis	3.37	2.08	5.45	1.23	3.03	4.26	3.67	0.00	3.67	3.37	0.00	3.37	3.88	2.08	5.96
Physallis minima	1.69	2.08	3.77	0.00	3.03	3.03	2.29	0.00	2.29	1.69	0.00	1.69	2.71	2.08	4.80
Euphorbia geniculata	2.81	4.17	6.98	0.00	4.55	4.55	3.21	3.57	6.78	2.81	3.57	6.38	3.49	4.17	7.66
Mpllugo pentaphylla	3.37	4.17	7.54	1.23	3.03	4.26	3.67	3.57	7.24	3.37	3.57	6.94	3.88	4.17	8.04
Phyllanthus niruri	4.49	4.17	8.66	3.70	4.55	8.25	4.59	3.57	8.16	4.49	3.57	8.07	4.65	4.17	8.82
Digitaria adscendens	8.43	6.25	14.68	12.35	6.06	18.41	7.80	7.14	14.94	8.43	7.14	15.57	7.36	6.25	13.61
Eleusine indica	5.06	4.17	9.22	4.94	4.55	9.48	5.05	3.57	8.62	5.06	3.57	8.63	5.04	4.17	9.21
Chloris barbeta	2.25	2.08	4.33	0.00	3.03	3.03	2.75	0.00	2.75	2.25	0.00	2.25	3.10	2.08	5.18
Brachiaris raptans	3.37	4.17	7.54	1.23	4.55	5.78	3.67	3.57	7.24	3.37	3.57	6.94	3.88	4.17	8.04
Echinochloa colona	3.93	6.25	10.18	2.47	6.06	8.53	4.13	7.14	11.27	3.93	7.14	11.08	4.26	6.25	10.51
Dactylocticum aegypticum	3.37	4.17	7.54	1.23	3.03	4.26	3.67	3.57	7.24	3.37	3.57	6.94	3.88	4.17	8.04
Ischaemum rugosa	3.37	4.17	7.54	1.23	4.55	5.78	3.67	3.57	7.24	3.37	3.57	6.94	3.88	4.17	8.04
Dicanthium annulatum	5.06	6.25	11.31	4.94	6.06	11.00	5.05	7.14	12.19	5.06	7.14	12.20	5.04	6.25	11.29
Cyperus iria	3.37	6.25	9.62	1.23	6.06	7.30	3.67	7.14	10.81	3.37	7.14	10.51	3.88	6.25	10.13
Dinebra retroflexa	5.62	2.08	7.70	6.17	3.03	9.20	5.50	0.00	5.50	5.62	0.00	5.62	5.43	2.08	7.51
Paspalum dilatum	3.37	4.17	7.54	1.23	4.55	5.78	3.67	3.57	7.24	3.37	3.57	6.94	3.88	4.17	8.04
Setaria glaica	6.74	6.25	12.99	8.64	6.06	14.70	6.42	7.14	13.56	6.74	7.14	13.88	6.20	6.25	12.45

RD - Relative density; RF - Relative frequency; IVI - Importante value index

was dominated by broad leaved weeds than grassy weeds. Over all *Sphaeranthus indicus* (17.65, 15.14, 22.41, 15.00 and 11.40 % in Bakawand, Bastar, Tokapal, Lohandiguda and Jagdalpur, respectively) was most dominant weeds followed by *Chenopodium album* (14.12, 12.96, 17.14, 20.00 and 14.81% in respective blocks) and *Digitaria adscendens* (12.94, 12.04, 15.52, 15.00 and 7.41 % in Bakawand, Bastar, Tokapal, Lohandiguda and Jagdalpur, respectively). *Melilotus indica, Melilotus alba, Physalis minima* and *Cleome viscosa* were major broad leaved weeds in Bakawand and Jagdalpur (Table 2).

Under grassy weeds, heavy infestation of *Digitaria adscendens* was found in wheat crop under late sown (December-January). This weed was reported to suppress wheat (Bhan 1992). The grasses like *Dicanthium annulatum* and *Phalaris minor* were lesser in relative density in Bakawand, Bastar, Tokapal, but little higher in Lohandiguda and Jagdalpur. Distribution of weed flora was found dependable on land situation (Streibig *et al.* 1984).

In *Rabi* season, IVI ranged from 0% of *Phalaris minor* in Tokapal, block and 42.02% of *Chenopodium album* in Jagdalur block. The maximum important value index was noticed in *Chenopodium album* (30.25, 35.19, 15.94, 12.40 and 42.02 5 in Bakawand, Bastar, Tokapal, Lohandiguda and Jagdalpur, respectively) during survey (Table2).

Weed flora of non-cropped areas

Non-cropped area constituted of forest plantation, wastelands, roadsides and extreme uplands in the study. In all blocks, 11 species were observed in surveyed areas of which 3 were grassy and 8 were broadleaved weeds (Table 3). *Chromalaena odorata* (20.54, 23.33, 17.93, 22.73 and 17.27 in Bakawand, Bastar, Tokapal, Lohandiguda and Jagdalpur, respectively) was higher in arresting relative density whereas *Hyptis suaveolens* . (22.32, 25.36, 19.31, 25.31 and 19.09% in respective blocks) was next to *Chromalaena odorata* in plantation forest and boundaries of forest.

SUMMARY

The cultivated area of upland is having serious problem of weed infestation which declines the yield of upland crops. Some weeds spread fast in this region because of favourable environment in crops, forest plantation and natural forest. Weed dominated blocks namely Bakawand, Batar, Tokapal, Lohandiguda and Jagdalpur selecting 7 villages from each block of Bastar district during August-September and February-March, 2008 under national Agricultural Innovative Project. In all the blocks, *Spilanthes acmella, Celosia argentia and Digitaria adscendens* were the most dominant weeds in upland cropping. Among these weeds, *Sphaeranthes indicus* (17.65, 15.14, 22.41, 15.00 and 11.40% in Bakawand, Bastar, Tokapal, Lohandiguda

Table 2. Weed flora in different blocks of Bastar district in *Rabi* cropping

Rabi cultivation	Bakawand			Bastar			Tokapal			Lohandiguda			Jagdalpur		
	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)
Chenopodium album	14.12	16.13	30.25	12.96	22.22	35.19	17.24	37.50	15.94	20.00	35.94	12.40	14.81	27.21	42.02
Melilotus indica	7.06	9.68	16.74	7.41	11.11	18.52	6.90	12.50	7.25	10.00	17.25	7.44	11.11	18.55	29.66
Melilotus alba	8.24	6.45	14.69	8.33	5.56	13.89	8.62	0.00	8.70	5.00	13.70	8.26	7.41	15.67	23.08
Anagalis arvensis	5.88	6.45	12.33	6.48	5.56	12.04	5.17	0.00	5.80	5.00	10.80	6.61	7.41	14.02	21.43
Vicia sativa	4.71	3.23	7.93	5.56	0.00	5.56	3.45	0.00	4.35	10.00	14.35	5.79	3.70	9.49	13.19
Medicago denticulata	7.06	6.45	13.51	7.41	5.56	12.96	6.90	0.00	7.25	5.00	12.25	7.44	7.41	14.85	22.26
Physalis minima	3.53	3.23	6.76	1.85	0.00	1.85	0.00	0.00	0.00	0.00	0.00	2.48	3.70	6.18	9.88
Cleome viscosa	5.88	6.45	12.33	6.48	5.56	12.04	5.17	0.00	5.80	5.00	10.80	6.61	7.41	14.02	21.43
Dicanthium annulatum	7.06	6.45	13.51	7.41	5.56	12.96	6.90	0.00	7.25	5.00	12.25	7.44	7.41	14.85	22.26
Trianthema portulacastrum	3.53	3.23	6.76	4.63	0.00	4.63	1.72	0.00	2.90	0.00	2.90	4.96	3.70	8.66	12.36
Phalaris minor	2.35	6.45	8.80	3.70	5.56	9.26	0.00	0.00	1.45	5.00	6.45	4.13	7.41	11.54	18.95
Sphaeranthes indicum	17.65	12.90	30.55	15.74	16.67	32.41	22.41	25.00	20.29	15.00	35.29	14.88	11.11	25.99	37.1
Digitaria sangunalis	12.94	12.90	25.84	12.04	16.67	28.70	15.52	25.00	14.49	15.00	29.49	11.57	7.41	18.98	26.39

RD - Relative density; RF - Relative frequency; IVI - Importante value index

Table 3. Weed flora in different blocks of Bastar district in non-cropped areas

Non-cropped area	Bakawand			Bastar			Tokapal			Lohandiguda			Jagdalpur		
	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	RF (%)	IVI (%)	RD (%)	R.F. (%)	IVI (%)
Chromalaena odorata	20.54	19.23	39.77	23.33	13.89	37.22	17.93	26.67	44.60	22.73	26.67	49.39	17.27	19.23	36.50
Hyptis suaveolens (L.)	22.32	15.38	37.71	25.56	13.89	39.44	19.31	20.00	39.31	25.76	20.00	45.76	19.09	15.38	34.48
Blumea lacera	14.29	15.38	29.67	15.56	13.89	29.44	13.10	20.00	33.10	12.12	20.00	32.12	10.91	15.38	26.29
Lantana camera	4.46	7.69	12.16	3.33	8.33	11.67	5.52	6.67	12.18	3.03	6.67	9.70	5.45	7.69	13.15
Rumex dentatus	3.57	3.85	7.42	2.22	5.56	7.78	4.83	0.00	4.83	1.52	0.00	1.52	4.55	3.85	8.39
Gnaphalium supinum	12.50	11.54	24.04	13.33	11.11	24.44	11.72	13.33	25.06	9.09	13.33	22.42	9.09	11.54	20.63
Tribulus terrestris	3.57	3.85	7.42	2.22	5.56	7.78	4.83	0.00	4.83	3.03	0.00	3.03	5.45	3.85	9.30
Themeda triandra	7.14	3.85	10.99	6.67	5.56	12.22	7.59	0.00	7.59	0.00	0.00	0.00	3.64	3.85	7.48
Cynodon dactylon	3.57	3.85	7.42	2.22	5.56	7.78	4.83	0.00	4.83	7.58	0.00	7.58	8.18	3.85	12.03
Eragrostis pilosa	5.36	7.69	13.05	4.44	8.33	12.78	6.21	6.67	12.87	6.06	6.67	12.73	7.27	7.69	14.97
Paspalidium flavidum	2.68	7.69	10.37	1.11	8.33	9.44	4.14	6.67	10.80	9.09	6.67	15.76	9.09	7.69	16.78

RD - Relative density; RF - Relative frequency; IVI - Important value index

and Jagdalpur, respectively) was most dominant weeds followed by *Chenopodium album* (14.12, 12.96, 17.14, 20.00 and 14.81% in respective blocks) and *Digitaria adscendens* (12.94, 12.04, 15.52, 15.00 and 7.41% in Bakawand, Bastar, Tokapal, Lohandiguda and Jagdalpur, respectively). *Chromalaena odorata* (20.54, 23.33, 17.93, 22.73 and 17.27 in Bakawand, Bastar, Tokapal, Lohandiguda and Jagdalpur, respectively) and *Hyptis suaveolens* L. (22.32, 25.36, 19.31, 25.31 and 19.09% in respective blocks) were higher in arresting relative density in respective blocks.

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Short communication

Indian Journal of Weed Science 44(1): 71–72, 2012

Evaluation of new herbicides for weed control and crop safety in rainy season sorghum

J.S. Mishra*, S.S. Rao and Anil Dixit[1]

Directorate of Sorghum Research, Rajendranagar, Hyderabad, Andhra Pradesh 500 030

Received: 11 December 2011; Revised: 7 February 2012

Key words: Chemical control, Herbicide, Sorghum

Sorghum (*Sorghum bicolor* (L.) Moench) is a staple cereal grown during both rainy (*Kharif*) and post-rainy (*Rabi*) seasons in the semi-arid and arid parts of India on marginal and least fertile soils where only few other crop can survive. Weeds are a major deterrent in increasing the sorghum productivity, especially during rainy season due to wider row spacing, slow initial crop growth rate, and congenial weather conditions for weed growth. Sorghum is mostly grown in rainfed areas, where soil moisture and nutrients are the most limiting factors. Weeds compete with sorghum for light, soil moisture and nutrients (Burnside and Wicks 1969, Smith *et al*. 1990) and reduce the grain yield by 15 to 83% depending on crop cultivars, nature and intensity of weeds, spacing, duration of weed infestation and environmental conditions (Mishra 1997, Stahlman and Wicks 2000). Therefore, appropriate weed management would help to improve sorghum productivity and input use-efficiency. Presently atrazine as pre-emergence is the most widely used herbicide for weed control in grain sorghum. However, as sorghum is grown in moisture stress conditions, lack of soil moisture may decrease the efficacy of pre-emergence herbicides. There is no effective post-emergence herbicide for broad-spectrum weed control in sorghum. The present experiment was therefore conducted to evaluate new herbicides for weed control and crop safety in grain sorghum.

A field experiment was conducted during rainy season of 2009 at the Directorate of Sorghum Research, Rajendranagar, Hyderabad (AP) consisting of ten treatments in a randomized block design with three replications (Table 1). The soil was sandy loam in texture, low in organic carbon, available nitrogen and phosphorus and medium in potassium content with pH 7.8. The crop (*cv. CSH 23*) was sown in rows at 60 x 15 cm apart on 8 July 2009. The crop was fertilized with 80 kg N and 40 kg P_2O_5 and 40 kg K_2O/ha. Entire dose of phosphorus and potassium and half dose of nitrogen were applied as basal and remaining half dose of nitrogen was side dressed at 30 days after sowing (DAS). Herbicides, as per treatments, were applied in 500 l/ha spray volume with Knapsack sprayer fitted with flat-fan nozzle. Pre-emergence herbicides were applied next day after sowing and post-emergence herbicides at 25 DAS. In weed free check, weeds were removed manually twice at 20 and 45 DAS. Weed density (species-wise) and total weed dry matter were recorded at harvest from 1m^2 area by placing a 50- by 50-cm quadrate randomly at four places in each plot. The oven-dried samples of weeds at harvest were analysed for nutrient content. Nitrogen was estimated by Micro-kjeldahl method, phosphorus by vanado-molybdo phosphoric method in nitric acid system and potassium with flame photometry (Jackson 1967). The nutrient depletion was determined by multiplying the per cent nutrient content in the plant with their respective dry weights at harvest. The data on weeds were subjected to square root transformation before statistical analysis.

The field was infested mainly with broad-leaved weeds (66.6%) (*Parthenium hysterophorus* (24.7%), *Tribulus terrestris* (11.9%), *Euphorbia hirta* (8.77%), *Digera arvensis* (7.15%), *Corchorus olitorius* (6.1%), and others (*Amaranthus viridis, Ageratum conyzoides, Trianthema portulacastrum, Alternanthera sessilis, E. geniculata, Cleome viscosa, Achyrantheus aspera, Cyanotis axillaris*, (7.72%), followed by grasses (27.8%) (*Brachiaria ramosa, Chloris barbata, Dactyloctenium aegyptium* (15.07%), *Digitaria sanguinalis* (9.06%), and others (*Echinochloa colona, Dinebra retroflexa, Panicum repens* (3.57%) and sedges (5.6%) (*Cyperus rotundus*). Application of herbicides reduced the weed population but all the post-emergence herbicides and oxyfluorefen (pre-emergence) caused severe phytotoxicity on sorghum resulting in poor crop yields (Table 1). Post-emergence herbicides *viz.*, Atlantis (mesosulfuron+idosulfuron), Almix (chlorimuron+metsulfuron) and Total (sulfosulfuron + metsulfuron) caused complete mortality of sorghum plants. In absence of competition from crop, weeds grew profusely and accumulated higher dry matter even more than that of weedy check. Infestation of weeds throughout

***Corresponding author:** jsmishra31@gmail.com

[1]*Directorate of Weed Science Research, Jabalpur, Madhya Pradesh –482 004*

Table 1. Effect of herbicides on weeds, nutrient depletion and grain yield of sorghum

Treatment	Dose (g/ha)	Time of application	Weed population at harvest (no./m^2)*				Total weed dry weight (g/m^2)	Grain yield (kg/ha)	Nutrients depletion by weeds (kg/ha)		
			Broad-leaf	Grasses	Sedges	Total			N	P	K
Atrazine	500	Pre-em.	7.24 (51.9)	5.82 (33.4)	1.29 (1.16)	9.24 (85)	123	2390	15.13	3.08	15.72
Pendimethalin	500	Pre-em.	8.24 (67.4)	1.47 (1.7)	2.64 (6.5)	8.72 (76)	192	2053	29.57	6.14	29.11
Oxyfluorefen	200	Pre-em.	4.80 (22.5)	1.18 (0.89)	6.84 (46.3)	8.06 (64)	77	521	10.55	2.31	9.67
Metsulfuron methyl	4	Post-em.	3.72 (13.6)	8.22 (67.1)	1.29 (1.2)	9.18 (84)	405	834	71.28	15.79	64.31
Carfentrazone	20	Post-em.	4.27 (17.7)	8.07 (64.6)	1.65 (2.2)	9.28 (80)	349	764	53.75	12.56	57.01
Atlantis (mesulfuron + idosulfuron)	400	Post-em.	5.44 (29.1)	7.59 (57.1)	0.71 (0)	9.36 (87)	320	0	33.28	9.92	46.98
Almix (chlorimuron + metsulfuron)	20	Post-em.	2.18 (4.2)	8.83 (75.5)	1.00 (0.5)	9.23 (85)	349	0	53.75	11.17	52.63
Sulfosulfuron + metsulfuron	40	Post-em.	1.44 (1.6)	8.29(68.2)	1.58 (2.0)	8.55 (73)	184	0	22.63	4.60	19.54
Weed free check	-	-	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0	2924	0	0	0
Weedy check	-	-	7.57 (57.1)	6.95 (47.8)	1.65 (2.2)	10.35(107)	243	1458	31.59	6.56	30.38
LSD (P=0.05)			1.66	1.46	1.03	2.29	83	683	6.3	3.8	8.4

*Data subjected to square root transformation ($\sqrt{x+0.5}$). Values in parentheses are original
Pre-em.=Pre-emergence (1 DAS); Post-em.=Post-emergence (25 DAS); DAS=Days after sowing

the crop growth period caused 50% reduction in grain yield of sorghum. Atrazine and pendimethalin each at 0.50 kg/ha applied as pre-emergence were found safe to crop and resulted in good weed control and higher grain yield (2390 and 2053 kg/ha, respectively). Pendimethalin was very effective against grassy weeds, resulting in dominance of broad-leaved weeds like *P. hysterophorus, T. terrestris, Euphorbia* spp. and *C. olitorius*. Metsulfuron methyl, Almix (chlorimuron+metsulfuron) and Total (sulfosulfuron+metsulfuron) provided good control of broad-leaved weeds but these herbicides were not effective against grasses. Vigorous growth of *D. aegyptitium* and *D. sanguinalis* suppressed other weeds in weedy check. Application of herbicides significantly influenced the nutrient removal by weeds. Pre-emergence application of atrazine, pendimethalin and oxyfluorfen significantly reduced the nutrient depletion by weeds as compared to weedy check (Table 1), mainly due to reduction in weed dry matter accumulation of weeds. Application of post-emergence herbicides caused greater depletion of nutrients from soil due to vigorous weed growth in absence of crop. Satao and Nalamwar (1993) also reported that uncontrolled weeds in sorghum depleted 29.94-51.05, 5.03-11.58 and 48.74-74.34 kg/ha NPK, respectively from soil. The findings gave an indication that newly developed post-emergence herbicides recommended in other cereal crops are not safe for sorghum crop and hence screening of more new herbicides is required.

SUMMARY

A field experiment was conducted during rainy season of 2009 at the Directorate of Sorghum Research, Hyderabad to evaluate the efficacy of new herbicide molecules in grain sorghum. The experimental field was dominated with broad-leaved weeds (66.6%) followed by grasses (27.8%) and sedges (5.6%). Infestation of weeds caused 50% reduction in grain yield of sorghum. Application of oxyfluorefen as pre-emergence, and metsulfuron methyl, carfentrazone, atlantis (mesosulfuron+idosulfuron), almix (chlorimuron+metsulfuron) and total (sulfosulfuron +metsulfuron) as post-emergence caused mild to severe phytotoxicity on grain sorghum resulting in poor yields. This showed that newly developed post-emergence herbicides recommended in other grain crops are not safe for sorghum and therefore, screening of more number of new herbicides is required.

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Format

Full length article should be suitably divided into the following sub-sections; ABSTRACT, Key words, introduction, MATERIALS AND METHODS, RESULTS AND DISCUSSION and REFERENCES. The heading, introduction need not be mentioned in the text.

Title: The title of article should be informative but concise and should not contain abbreviations. It should indicate the content of the article essential for key word indexing and information retrieval. It should be set in small and bold letters. A good title briefly identifies the subject, indicates the purpose of study and introduces key terms and concepts. Title should not be started with the waste words like 'a study of', 'effect of', 'influence of' , 'some observations on', 'a note of' *etc.* The title should indicate preferably English name or most popular common name of the crops or organisms studied, wherever relevant. Scientific name can be given in abstract and introduction. Authority for such a name should be given at first mention in the text. A short title should be given for running headlines and should cover the main theme of the article.

Author(s) name(s) and affiliations: The name(s) of the author(s) should be given in small letters with sentence case separated by 'comma' or by 'and'. Institute name where the research was carried out should be given in italics. If authors are of different institutes, these can be mentioned by allotting number like 1, 2 or 3 as superscript over the name of author. The affiliation of such author may by given below of the corresponding author email address. Sometimes authors retire and change frequently and wish to give their current address, this should be given as foot note. Email address of main author or corresponding author should be given at the bottom.

Abstract: The abstract should contain at least one sentence on each of the following: objective of investigation (hypothesis, purpose, collection, result and conclusions). Give complete scientific name for plants or other organisms and full name of any symbol or abbreviations used. There is a need to mention place, name and priod of study in abstract. Emphasis should be given to highlight the results and the conclusion of the study. It should not exceed a total length of 200-250 words. Abstract should not have the words like 'will be explained or will be discussed'. Key words (5-6) should be given at the end of the abstract and should be arranged alphabetically. Each key word should be started with capital letter and separated by comma (,) from other words.

Introduction: Introduction should be brief and to the point, cover the problem and should justify the work or the hypothesis on which it is based. In introduction, a detail review is not necessary. However, to orient readers, important references about previous concepts and research should be given. It should briefly state the currently available information and should identify the research gap that is expected to be abridged through this investigation. Give preference to recent references from standard research publication unless it is of historical importance or a landmark in that field.

Materials and Methods: This part should begin with information relating to period/season/year and place of study, climate or weather conditions, soil type *etc.* Treatment details along with techniques and experimental design, replications, plot size *etc.* should be clearly indicated. Use of symbols for treatments may be avoided and an abbreviation should be fully explained at its first mention. Crop variety, methodology for application and common cultivation practices should be mentioned. Known methods may be just indicated giving reference but new techniques developed and followed should be described in detail. Methods can be divided into suitable sub-headings, typed in bold at first level and in italics at second level, if necessary.

Results and Discussion: Results may be reported and discussed together to avoid duplication. Do not mention and recite the data in the text as such given in the table. Instead interpret it suitably by indicating in terms of per cent, absolute change or any other derivations. Relate results to the objectives with suitable interpretation of the references given in the introduction. If results differ from the previous study, suitable interpretation and justification should be given. Repeated use of statements like 'our results are in agreement' or 'similar results were reported' 'should be avoided. At the end of results and discussion, conclusion of the study should be given in 2-3 sentences along with suggestion for further study, if any. All statistical comparisons among treatments may be made at P=0.05 level of probability. There is a need to give SEm± along with LSD (P= 0.05) value.

Acknowledgement: The authors may place on record the help and cooperation or any financial help received from any source, person or organization for this study. This should be very brief.

References: Only relevant and recent references of standard work should be quoted. Preference should be given to quote references of journals over proceedings or reports. In general, not more than 15 references should be quoted in full paper and 5 in short communication. However, in review article, emphasis should be given to quote more references with each valid statement/findings in the text. There is no need to give references for standard procedures of soil and plant analysis, and for routine statistical analysis in practice, only the methodology may be indicated. As a thumb rule, all the references quoted in the text must appear at the end of the article and vice-verse. It has been decided to use full name of the journal after the year 2011 onwards. Therefore, references should include names of all authors, year, full title of the article quoted, full name of the journal in italics (no abbreviations), volume number (in Bold), issue number (in brackets) and pages. For books, monographs, theses *etc.* full title in italics, publisher or university name, volume no., if any, and relevant page range or total no. of pages should be given. The list of references should be arranged alphabetically on author's names and chronologically per author. Author name should be started with surname and initial letter with capital letter. There is no need to separate author's initials by full stop but it should be given in capital letters without gap. Each author name should be separated by comma (,) and last author name by 'and'.

A few examples of correct citation of references for *Indian Journal of Weed Science* are given below:

Singh Samunder, Punia SS, Yadav A and Hooda VS. 2011. Evaluation of carfentrazone-ethyl + metsulfuron-methyl against broadleaf weeds of wheat. *Indian Journal of Weed Science* **43**(1&2): 12-22.

Neeser C and Varshney Jay G. 2001. Purple nutsedge; biology and principles for management without herbicides, *Indian Journal of Pulses Research* **14**(1): 10-19.

Naseema A, Praveena R and Salim AM. 2004. Ecofriendly management of water hyacinth with a mycoherbicide and cashew nut shell liquid. Pakistan *Journal of Weed Science Research* **10**(1&2): 93-100.

Arya DR, Kapoor RD and Dhirajpant. 2008. Herbicide tolerant crops: a boon to Indian agriculture, pp 23-31. In: *Biennial Conference on Weed Management in Modern Agriculture: Emerging Challenges and Opportunities.* (Eds. Sharma RS, Sushilkumar, Mishra JS, Barman KK and Sondhia Shobha), 27-28 February 2008, Patna. Indian Society of Weed Science, Jabalpur.

Anonymous. 2006. Long-term herbicide trial in transplanted lowland rice-rice cropping system, pp 62-68. In: *Annual Progress Report,* AICRP on Weed Control, Tamil Nadu Agricultural University, Coimbatore.

DWSR. 2010. Annual Report, 2010-11, pp 35-37. Directorate of Weed Science Research, Jabalpur

Gopal B and Sharma KP. 1981. *Water hyacinth (Eichhornia crassipes) the most troublesome weeds of the world.* Hindasia Publisher, New Delhi, 129p

Sushilkumar, Sondhia S and Vishwakarma K. 2003. *Role of insects in suppression of problematic alligator weed (Altemanthera philoxeroides) and testing of herbicides for its integrated management.* Final Report of ICAR Adhoc Project, 39 p.

Length

Full length manuscript should not exceed a final length of 12 printed pages including space required for figures, tables and list of references. Short communications can be up to 4 printed pages, with not more than 2 figures or tables. One season/year data should invariably be presented as short communication only.

Units, abbreviations and nomenclature

For physical units, unit names and symbols, the SI system should be employed. Biological names should be given according to the latest international nomenclature. Biological and zoological names, gene designations and gene symbols should be italicized. Yield data should be reported in kg/ha or t/ha. All such letters such as *viz., et al., in situ, ex situ, Rabi, Kharif, i.e., etc.* should be italicized.

Tables and figures

Tables and figures should be concise and limited to the necessary minimum. We encourage the authors to set tables and figures at the appropriate places in the article but if it is not possible, the same may be given separately. The title should fully describe the contents of the table and explain any symbol or abbreviations used in it. The standard abbreviations of the units of different parameters should be indicated in parentheses. Vertical lines should not be given in the tables and horizontal lines should be used to separate parametres and end of the table.

Figures may be preferred in place of table. In no case the same data should be presented by both tables and figures. While presenting data through line graphs, vertical bars, cylinders, pie charts *etc,* the same should be preferred with black lines or bars having different clear symbols and shades. The graphs chosen with colours reproduce poorly and should not be given unless it become necessary.

Some useful tips

Avoid numerals and abbreviations at the beginning of a sentence. Don't use superscript for per hectare, ton or meter (kg ha^{-1} or t ha^{-1}) instead use kg/ha or g/m^2, t/ha, mg/g, ml/l *etc.* Prefer to mention yield data in t/ha only. If it becomes necessary, give yield in kg/ha but not in quintal. Don't use lakh, crores or arabs in text, instead give such figures in million. Only standard abbreviations should be used and invariably be explained at first mention. Avoid use of self-made abbreviations like iso., buta., rizo., *etc.* Don't use first letter capital for names of plant protection chemicals but it should be used for trade names. Use of treatment symbols like T_1 T_2 T_3 *etc.* should be avoided. All weights and measurements must be in SI or metric units. Use % after double digit figures, not per cent, for example 10% not 10 per cent. In a series of range of measurement, mention the units only at the end, e.g. 3,4,5 kg/ha instead of 3 kg/ha, 4 kg/ha and 5 kg/ha. Nutrient doses as well as concentration in soil and plant should be given in elemental form only, i.e. P and K should not be given as P_2O_5 K_2O_5. A variety may be mentioned within single quotes in italic such as '*Pusa Basmai*', '*Kufri Sinduri*' *etc.* Statistical data should be given in LSD (P=0.05) instead CD (P=0.05).

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NAME OF THE PROCEEDINGS

1. Proceeding of the Second Weed Control Seminar, HAU, Hisar (Abstracts) 1966
2. Proceeding of Weed Science Conference held at APAU, Hyderabad (Abstracts) 1977
3. Proceeding of Weed Science Conference held at MAU, Parbhani (Abstracts) 1979
4. Annual Conference of ISWS held at UAS, Bangalore (Abstracts) 1981
5. Proceeding of ISWS Conference held at GAU, Anand (Abastracts) 1985
6. Proceeding of ISWS Conference held at Assam Agri. Univ., Jorhat (Abstracts) 1987
7. Proceeding of the Asian-Pacific Weed Science Conference (1 & 2) 1981
8. Proceeding of ISWS conference held at CCS HAU, Hisar (Abst.) 1992
9. Proceeding of ISWS International Symposium held at CCS HAU, Hisar 1993 (2 Vol.)
10. Proceeding of ISWS Conference held at CCS HAU, Hisar (Abstracts) 2007
11. Proceeding of ISWS Biennial Conference held at RAU, Patna (Abstracts) 2008
12. Proceeding of ISWS National Symposium held at TANU, Coimbatore (Abstracts) 2009
13. Proceeding of ISWS Biennial Conference held at IGKV, Raipur (Abstracts) 2010
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