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Integrated weed management in cotton under irrigated conditions of Haryana

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ABSTRACT

To study the effect of selective and non-selective post-emergence herbicides on weeds and yield of cotton, a field experiment was conducted during two consecutive seasons of *Kharif* 2014 and 2015 at CCS Haryana Agricultural University, Hisar.The experimental field was pre-dominantly infested with natural population of jungle rice (*Echinochloa colona* L.) and carpet weed (*Trianthema portulacastrum* L.) to the extent of 79 and 21% in 2014 and 71 and 29% during 2015, respectively. Application of pendimethalin at 1.0 kg/ha supplemented with other two hoeings at 20 and 50 DAS or one hoeing and post-emergence application of quizalofop-p-ethyl at 60 g/ha or one hoeing and post-emergence application of propaquizafop-p-ethyl at 62.5 g/ha at 60 DAS caused significant reduction in density and dry wt. of weeds as compared to weedy check up to harvest in both the years. Protected spray of glyphosate (0.5%) integrated with pendimethalin or paraquat (0.3%) with parthiobac Na *fb* quizalofop-p-ethyl being at par with three mechanical weedings (at 20,40 and 60 DAS) helped to significantly reduce the population and dry weight of weeds at 90 DAS over weedy check. Weeds throughout the crop growing season reduced seed yield by 49.9 and 47.2% during 2014 and 2015, respectively. During 2014, all the treatments involving directed spray of either glyphosate or paraquat caused 8.3 - 10% toxicity to cotton crop where in 2015 the toxicity in these treatments was 5-8%. In 2014, maximum WCE (96.9%) was obtained with use of pendimethalin *fb* directed spray of glyphosate but during 2015, it was 83.3 with application of parthiobac-Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate.Pendimethalin *fb* parthiobac-sodium caused maximum uptake of nitrogen during 2014 and 2015, which was 23.37 kg/ha and 24.68 kg/ha, respectively.

INTRODUCTION

Cotton known as "*King of Fiber*" and "White Gold" is one of the most important fiber and commercial cash crop of India and of Haryana. It is also grown on an area of 6.56. lakh ha in the state under irrigated conditions (Anonymous 2017). Weed competition is one of the important biological constraints in cotton cultivation. Carpet weed (*Trianthema portulacastrum* L.), jungle rice (*Echinochloa colona* L.) and purple nut sedge (*Cyperus rotundus* L.) are major weeds that invade cotton crop in North-West India and cause yield losses ranging from 10-70% or more depending upon type and density of weeds (Balyan *et al.* 1983, Brar and Brar 1992). Cotton is very sensitive to weed competition in the first 60 days of crop growth. The period of weed interference, crop damage and the critical period of crop-weed competition is 30 to 60 days, which occupied 50% of the whole cotton growing period (Ayyadurai *et al.* 2013). Cotton is sown in wide spacing and grows slowly in summer due to very high temperature varying from 41 to 47°C (Prasad *et al.* 1997) and weeds get an ample space to grow profusely particularly in the initial two months of crop stage Manual weed control without herbicide application is the most labour intensive, expensive and impractical (due to labour scarcity) method in modernagricultural production system. Under such circumstances, herbicides have remained the principal tool and foundation of most effectiveweed control programmes (Zhang 2003, Norsworthy *et al.* 2012). Pre-emergence application of pendimethalin was found effective for the control of these weeds (Panwar *et al.* 1989) as it minimizes the early weed

competition, however, as the pre-emergence herbicide loses its efficacy after few weeks thus problem of late emerging weeds becomes more serious. To manage late emerging weeds and more effective weed control during the crop growth period, manual or chemical methods need to be integrated with these pre-plant or pre-emergence herbicides. Information on efficacy of selective post-emergence herbicides and directed spray of glyphosate and paraquat in a wide spaced crop like cotton is limited under Haryana conditions. Therefore, the present study was undertaken to study the bio-efficacy of combination of herbicides against complex weed flora and their effect on growth and yield of cotton.

MATERIALS AND METHODS

The present study was conducted during rainy *(Kharif)* 2014 and 2015 at Department of Agronomy, CCS Haryana Agricultural University, Hisar under irrigated conditions. The soil of the experimental field was sandy loam in texture, having pH 8.1, low in organic carbon (0.29%) and available nitrogen (182 kg/ha), medium in available phosphorus (18 kg/ha) and high in available potassium (380 kg/ha) content. Fourteen treatments were tried in randomized block design replicated thrice in a plot size of 10x 6 m^2. The treatments were pendimethalin (pre-emergence) *fb* 2 hand weeding , pendimethalin (pre-emergence) *fb* hoeing *fb* quizalofop-p-ethyl/ propaquizafop-p-ethyl (post-emergence), pendimethalin *fb* parthiobac-sodium, pendimethalin *fb* hoeing *fb* parthiobac-sodium, pendimethalin *fb* quizalofop-p-ethyl, parthiobac Na *fb* quizalofop-p-ethyl,parthiobac sodium*fb* quizalofop-p-ethyl *fb* mechanical weeding, parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of paraquat/glyphosate, pendimethalin *fb* directed spray of glyphosate, three mechanical weedings, weed free and weedy check. The cotton hybrid '*RCH 134*' was dibbled with 90 x 60 cm spacing on 17th May and 14th May during 2014 and 2015, respectively. The standard package of practices other than weed control treatments recommended for cotton were adopted. Rainfall received during July, August and September during cotton growing period was 180 mm in 2014 and 391 mm in 2015. Data on weed count and dry matter accumulation by weeds were recorded at 90 DAS and at harvest using a quadrate of 0.25 m^2. Seed cotton yield was recorded on net plot basis. Phytotoxic effect of different herbicides on cotton was recorded at 90 days after sowing (DAS0 using 0-100 scale.

RESULTS AND DISCUSSION

Weed flora

The experimental field was pre-dominantly infested with natural population of jungle rice (*Echinochloa colona* L.) and carpet weed (*Trianthema portulacastrum* L.) to the extent of 79 and 21% in 2014 and 71 and 29% during 2015, respectively.

Effect on weeds

All the weed control treatments significantly reduced density and dry weight of weeds at both stages as compared to untreated check at 90 DAS and harvest. Pendimethalin at 1.0 kg/ha as pre-emergence followed by two hand hoeing provided effective control of *T. portulacastrum* and *E. colonum* and this effect remained consistent up to 90 DAS (**Table 1**). When pre-emergence application of pendimethalin at 1.0 kg/ha was supplemented with two hoeings at 20 and 50 DAS, one hoeing at 30 DAS and post emergence application at 60 DAS of either quizalofop-p-ethyl at 60 g/ha or propaquizafop-p-ethyl at 62.5 g/ha at 60 DAS, it caused significant reduction in density and dry weight of weeds as compared to weedy check up to harvest. Veeraputhiran and Srinivasan (2015) reported excellent efficacy of pendimethalin *fb* hoeing *fb* post-emergence application of quizalofop-ethyl against weeds in cotton under Tamil Nadu conditions. Treatments involving use of parthiobac-Na at 20 DAS were not much effective in controlling weeds due to less moisture in the field and higher air temperature at the time of spray. Directed spray of glyphosate (0.5%) integrated with pendimethalin and paraquat (0.3%) with parthiobac Na *fb* quizalofop-p-ethyl being at par with three mechanical weedings helped to significantly reduce the population and dry weight of weeds at 90 DAS over weedy check (**Table 1** and **2**). Pendimethalin integrated with non-selective herbicides (paraquat or glyphosate) proved superior over application of pendimethalin *fb* quizalofop-p-ethylor parthiobac Na *fb* quizalofop-p-ethyl against both weeds as shown by weed control efficiency. Chaudhari *et al.*(2017) reported efficacy of pendimethalin as pre-emergence *fb* directed spray of glyphosate in cotton under Gujarat conditions During 2014, all the treatments involving directed spray of either glyphosate or paraquat caused 8.3 - 10% toxicity to cotton crop where in 2015, the toxicity in these treatments ranged between 5-8%. Weed control efficiency in all treatments except pendimethalin *fb* parthiobac-Na (72.8% and 60.7%) or parthiobac-Na

fb quizalofop-p-ethyl (65.1% and 53%) varied between 88-99% at 90 DAS and 89-100% at harvest during 2014. However, WCE (%) ranged between 59.4-83.7% at 90 DAS and 53.4-83.3% at harvest for these treatments during 2015.

Effect on crop

All the weed control treatments gave significantly higher seed cotton yield over weedy check during both the years. (**Table 3**) except pendimethalin *fb* pyrithiobac-Na during 2015. Number of bolls/plant was affected significantly due to different herbicide treatments. In weed free treatment, number of bolls/plant was maximum (52 and 46 during 2014 and 2015, respectively) in weed free, which were significantly higher than all treatments except three mechanical weedings during both the years and parthiobac-Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate in 2015. Maximum seed cotton yield (2.41 and 2.36 t/ha during 2014 and 2015, respectively) was obtained in weed free plots, which was at par with three mechanical weedings (2.37 t/ha) at 20,40 and 60 DAS during 2014 and significantly higher than all other treatments. Among herbicidal treatments, pre-emergence application pendimethalin *fb* hoeing *fb* quizalofop-ethyl gave seed cotton yield of 2.30 t/ha during 2014, which was significantly higher than that obtained with pendimethalin at 1.0 kg/ha supplemented with protected spray of glyphosate (0.5%) or paraquat although with higher WCE. It might be due to phytotoxic effect of non-selective herbicides and beneficial effect of hoeing employed at 30 DAS. (**Table 3**). However, during 2015, parthiobac-Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate resulted in higher seed cotton yield among different herbicide treatments. During 2014, maximum WCE (96.9%) was obtained with use of pendimethalin *fb* directed spray of glyphosate but during 2015 it was 83.3 with application of parthiobac-Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate. The reduction in dry weight of weeds under these conditions might be due to pendimethalin which inhibits cell division and root and shoot growth of weeds in the initial stages and excellent control by glyphosate in the later stages. Similarly superior yield

Table 1. Density and dry weight of weeds and weed control efficiency at different crop growth stages as affected by different treatments in cotton during 2014

Treatment	Dose (g/ha)	Time of application	Weed density (mo./m^2) 90 DAS				Harvest				Phytotoxicity on crop (%) at 90 DAS
			T. portula castrum	*Echino-chloa* spp.	Dry wt. (g/m^2)	WCE (%)	*T. portula castrum*	*Echino-chloa* spp.	Dry wt. of weeds (g/m^2)	WCE (%)	
Pendimethalin *fb* 2 HW	1000	Pre, 20 & 50 DAS	3.1 (8.6)	1.7 (2.0)	3.92 (14.4)	88.5	8.1 (2.8)	1.7 (2.0)	3.09 (8.53)	92.3	0
Pendimethalin *fb* hoeing *fb* quizalofop-p-ethyl	1000/ 60	Pre *fb* 30 DAS *fb* 60 DAS	1.7 (2.0)	1.7 (2.0)	3.09 (8.6)	93.2	1.7 (3.0)	1.5 (1.2)	2.73 (6.43)	92.2	0
Pendimethalin *fb* hoeing *fb* propaquizafop-p-ethyl	1000/ 65	Pre *fb* 30 DAS *fb* 60 DAS	2.2 (4.0)	1.4 (1.0)	2.89 (7.4)	94.1	2.2 (2.4)	1 (0.0)	2.68 (6.20)	93.7	0
Pendimethalin *fb* parthiobac-sodium	1000/ 62.5	Pre *fb* 20 DAS	3.2 (9.2)	3.1 (8.4)	5.95(34 .4)	72.8	3.2 (7.1)	3.1 (8.4)	6.31 (38.83)	60.7	0
Pendimethalin *fb* hoeing *fb* parthiobac-sodium	1000/ 62.5	Pre *fb* 30 DAS *fb* 50 DAS	2.4 (4.6)	2.1 (3.5)	3.66 (12.4)	90.2	2.4 (2.4)	1.8 (2.3)	3.10 (8.63)	89.0	0
Pendimethalin *fb* quizalofop-p-ethyl	1000/ 60	Pre *fb* 20 DAS	2.7 (6.2)	1.7 (2.0)	3.95 (14.6)	88.4	2.7 (3.7)	2.1 (3.5)	3.18 (9.13)	90.7	0
Parthiobac Na *fb* quizalofop-p-ethyl	62.5/ 60	20 & 60 DAS	1.5 (11.4)	2.6 (5.6)	6.72 (44.2)	65.1	3.5 (19.2)	1.8 (2.4)	6.88 (46.40)	53.0	0
Mechanical weeding(3)	-	20, 40 and 60 DAS	1.4 (1.0)	1.9 (2.5)	2.39 (4.7)	96.2	1.4 (3.5)	1.7 (2.0)	2.62 (5.87)	92.8	0
Parthiobac Na *fb* quizalofop-p-ethyl*fb* Mechanical Weeding	62.5/60	20, 50 and 70 DAS	1.5 (1.2)	1 (0.0)	1.56 (1.4)	98.8	1.5 (2.5)	2 (3.2)	2.93 (7.60)	91.1	0
Parthiobac Na *fb* quizalofop-p-ethyl*fb* directed spray of paraquat	62.5/60 / 360	20, 50 and 70 DAS	1.4 (1.0	1 (0)	1.37 (0.9)	99.3	1.4 (5.8)	1.8 (2.3)	3.53 (11.50)	87.1	10
Parthiobac Na *fb* quizalofop-p-ethyl*fb* directed spray of glyphosate	62.5/60 /1000	20, 50 and 70 DAS	1 (0)	1 (0)	1(0)	100	1 (0)	1 (0)	1 (0)	100	10
Pendimethalin *fb* directed spray of glyphosate	1000/0. 5%	PE and 60 DAS	1.5 (1.3)	1 (0)	1.4 (0.97)	99.2	1.5 (2.0)	1 (0.0)	1.69 (1.87)	96.9	8.3
Weedy check	-	-	8.1 (65.0)	4.1 (18.4)	11.28 (126.5)	0	8.1 (46.3)	3.5 (11.7)	9.99 (98.83)	0	0
Weed free	-	-	(0)	1 (0)	1 (0)	100	1 (0)	1 (0)	1 (0)	100	0
LSD (p= 0.05)			0.5	0.2	0.29		0.5	0.4	0.22		

*Original figures in parentheses were subjected to square root transformation ($\sqrt{x+1}$) before statistical analysis.

Table 2. Density and dry weightof weeds and WCE at different crop growth stages as affected by different treatments in cotton 2015

Treatment	Dose (g/ha)	Time of application	Weed density (no./m^2) 90 DAS				Harvest				Phytotoxicity on crop (%) at 90 DAS
			T. portula castrum	*E. colona*	Dry wt. (g/m^2)	WCE *(%)*	*T. portula castrum*	*E. colona*	Dry wt. of weeds (g/m^2)	WCE (%)	
Pendimethalin *fb* 2 HW	1000	Pre, 20 & 50 DAS	2.93 (7.6)	2.0 (3.0)	3.83 (13.70)	63.1	2.04 (3.2)	1.8 (2.3)	3.22 (9.41)	65.7	0
Pendimethalin *fb* hoeing *fb* quizalofop-p-ethyl	1000/60	Pre *fb* 30 DAS *fb* 60 DAS	2.2 (4.0)	1.4 (1.0)	2.91 (7.50)	72.0	1.5 (2.5)	1 (0)	2.61 (5.82)	72.2	0
Pendimethalin *fb* hoeing *fb* propaquizafop-p-ethyl	1000/60	Pre *fb* 30 DAS *fb* 60 DAS	2.44 (5.0)	1 (0)	2.74 (6.54)	73.6	1.71 (2.0)	2.04 (3.2)	2.77 (6.70)	70.5	0
Pendimethalin *fb* parthiobac-sodium	1000 /62.5	Pre *fb* 20 DAS	3.78 (14.3)	3.53 (11.5)	6.44 (40.5)	38.0	3.71 (12.8)	3.22 (9.4)	7.78 (59.56)	17.1	0
Pendimethalin *fb* hoeing *fb* parthiobac-sodium	1000/62.5	Pre *fb* 30 DAS *fb* 50 DAS	2.12 (3.5)	2.23 (2.0)	3.43 (11.77)	63.1	1.71 (2.0)	2.64 (6.0)	3.55 (11.64)	62.1	0
Pendimethalin *fb* quizalofop-p-ethyl	1000 / 60	Pre *fb* 20 DAS	3.30 (8.9)	2.12 (3.5)	4.22 (16.89)	59.4	2.72 (6.4)	8.30 (5.9)	4.34 (17.85)	53.4	0
Parthiobac Na *fb* quizalofop-p-ethyl	62.5/ 60	20 and 60 DAS	4.03 (15.3)	2.61 (5.82)	7.72 (58.60)	25.7	5.37 (27.9)	3.22 (9.4)	7.72 (58.7)	17.8	0
Mechanical weeding(3)	-	20, 40 and 60 DAS	1.81 (2.3)	2.23 (4.0)	2.93 (7.62)	71.8	2.40 (5.8)	2.36 (4.6)	2.92 (7.57)	69.0	0
Parthiobac Na *fb* quizalofop-p-ethyl *fb* mechanical weeding	62.5/60	20, 50 and 70 DAS	1 (0)	1.51 (1.3)	1.58 (1.51)	80.9	1.5 (2.5)	2 (3.2)	2.93 (7.60)	68.7	0
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of paraquat	62.5/60 / 360	20, 50 and 70 DAS	1.71 (2)	1 (0)	2.13 (3.56)	79.5	2.62 (5.9)	1.71 (1.0)	3.72 (12.87)	60.3	8
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate	62.5/60 /1000	20, 50 and 70 DAS	1 (0)	1.71 (2)	1.85 (2.43)	82.2	1.71 (2)	1 (0)	1.56 (1.45)	83.3	0
Pendimethalin *fb* directed spray of glyphosate	1000/0.5 %	PE and 60 DAS	1 (0)	2.0 (3)	1.69 (1.86)	83.7	1.5 (2.0)	1 (0)	1.69 (1.87)	82.0	5
Weedy check	-	-	7.68 (59)	5.04 (24.5)	10.4 (109.7)	0	6.44 (40.58)	3.93 (14.5)	9.39 (87.21)	0	0
Weed free	-	-	1 (0)	1 (0)	1 (0)	100	1 (0)	1 (0)	1 (0)	100	0
LSD (p=0.05)			0.5	0.2	0.29		0.5	0.4	0.22		

*Original figures in parentheses were subjected to square root transformation $(\sqrt{x+1})$ before statistical analysis

Table 3. Seed cotton yield, no. of bolls/plant and nutrient uptake by weeds as affected by different treatments (2014 and 2015)

Treatment	Dose (g/ha)	Time of application	No. of bolls/plant		Seed cotton yield (t/ha)		N uptake by weeds (kg/ha)		P uptake by weeds (kg/ha)	
			2014	2015	2014	2015	2014	2015	2014	2015
Pendimethalin *fb* 2 HW	1000	Pre, 20 and 50 DAS	39	41	2.16	1.98	5.16	5.32	1.55	1.65
Pendimethalin *fb* hoeing *fb* quizalofop-ethyl	1000/60	Pre *fb* 30 DAS *fb* 60 DAS	42	42	2.30	2.15	3.89	3.77	1.18	1.28
Pendimethalin *fb* hoeing *fb* propaquizafop-p-ethyl	1000/65	Pre *fb* 30 DAS *fb* 60 DAS	40	42	2.15	2.17	3.74	4.05	1.16	1.65
Pendimethalin *fb* pyrithiobac-sodium	1000 /62.5	Pre *fb* 20 DAS	37	34	1.87	1.26	23.37	24.68	6.60	7.53
Pendimethalin *fb* hoeing *fb* pyrithiobac-sodium	1000/62.5	Pre *fb* 30 DAS *fb* 50 DAS	42	39	2.21	1.87	5.19	6.85	1.47	1.95
Pendimethalin *fb* quizalofop-p-ethyl	1000 / 60	Pre *fb* 20 DAS	42	40	1.96	1.92	5.57	7.85	1.61	2.15
Pathiobac Na *fb* quizalofop-p-ethyl	62.5/ 60	20 & 60 DAS	37	33	1.81	1.36	29.2	31.5	8.49	9.78
Mechanical weeding(3)	-	20, 40 and 60 DAS	51	45	2.37	2.28	3.63	4.52	10.1	1.35
Parthiobac Na *fb* quizalofop-p-ethyl *fb* mechanical weeding	62.5/60	20 ,50 and 70 DAS	44	42	2.26	1.98	4.78	5.42	1.33	1.56
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of paraquat	62.5/60 / 360	20 ,50 and 70 DAS	39	40	1.94	1.93	6.91	3.91	2.01	2.58
Pathiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate	62.5/60 /1000	20 ,50 and 70 DAS	41	44	1.97	2.24	0	0	0	0
Pendimethalin *fb* directed spray of glyphosate	1000/0.5%	PRE and 60 DAS	45	43	2.08	2.20	0.72	4.95	0.33	1.32
Weedy check	-	-	30	30	1.21	1.25	62.3	62.3	17.88	17.88
Weed free	-	-	52	46	2.41	2.36	0	0	1(0)	1(0)
LSD (p=0.05)			3.5	2.9	0.06	0.06	0.44	0.74	0.26	0.24

attributes in Bt cotton due to pre-emergence pendimethalin followed by post emergence herbicide quizalofop-ethyl application at 50 g/ha + one hoeing were recorded earlier also by Prabhu *et al.* (2011) and Chaudhari *et al.* (2017).

Pendimethalin *fb* parthiobac-sodium caused maximum uptake of nitrogen during 2014 and 2015 which was 23.37 kg/ha and 24.68 kg/ha, respectively. Among herbicide treatments, highest P uptake (except weedy checks) during 2014 and 2015 was

8.49 and 9.78 kg/ha was recorded with the application of parthiobac-Na *fb* quizalofop-p-ethyl. (**Table 3**). Weedy condition throughout crop growth period accounted for 49.9% and 47.2% reduction in seed cotton yield during 2014 and 2015, respectively.

Application of pendimethalin at 1.0 kg/ha supplemented with other two hoeings at 20 and 50 DAS or one hoeing and post-emergence application of quizalofop-p-ethyl at 60 g/ha or one hoeing and post-emergence application of propaquizafop-p-ethyl at 62.5 g/ha at 60 DAS caused significant reduction in density and dry wt. of weeds as compared to weedy check up to harvest in both years. Protected spray of glyphosate (0.5%) integrated with pendimethalin or paraquat (0.3%) with parthiobac-Na *fb* quizalofop-p-ethyl being at par with three mechanical weedings (at 20,40 and 60 DAS) helped to significantly reduce the population and dry weight of weeds at 90 DAS over weedy check. Weeds throughout the crop growing season reduced seed yield by 49.9 and 47.2% during 2014 and 2015, respectively. Maximum wed control efficiency (WCE) can be obtained with use of pendimethalin *fb* directed spray of glyphosate and with application of parthiobac-Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate. Maximum seed cotton yield (2.41 and 2.36 t/ha during 2014 and 2015, respectively) was obtained in weed free plots, which was at par with three mechanical weedings (2.37 t/ha) at 20, 40 and 60 DAS during 2014 and significantly higher than all other treatments.

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