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Research Paper

Bio-efficacy of herbicides and their mixture on weeds and yield of rice (*Oryza sativa)* under rice–wheat cropping system

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2014 and 2015 at Krishi Vigyan Kendra, Sohna, Siddarthnagar Uttar Pradesh, to assess the efficacy of bispyribac-Na, pretilachlor, penoxsulam, pyrazosulfuron, bispyribac-Na + ethoxysulfuron methyl, bispyribac-Na + almix (metsulfuron methyl 10% + chlorimuron ethyl 10% WP), pretilachlor followed by (fb) ethoxysulfuron methyl, pretilachlor fb almix, pyrazosulfuron fb manual weeding, pretilachlor + bensulfuron in transplanted rice (*Oryza sativa* L.). The highest grain yield (5.2 t/ha) was recorded in weed-free plot, being at par with bispyribac-Na + almix (25 g + 4 g/ha), pretilachlor fb almix (750 g and 4 g/ha), pyrazosulfuron (20 g/ha) fb manual weeding. Uncontrolled weed growth caused 41.9% reduction in the crop yield compared to weed-free treatment. Tank-mix application of bispyribac-Na + almix, pretilachlor fb almix, pyrazosulfuron fb manual weeding and bispyribac-Na + ethoxysulfuron methyl (25 g + 18.75 g/ha) proved better, showing a mean increase in grain yield of 9.54% than mean of alone application of bispyribac-Na, pretilachlor, penoxsulam (22.5 g/ha) and pyrazosulfuron (20 g/h). Tank-mix application of bispyribac-Na + almix being at par with application of pretilachlor fb almix reduced the weed density and weed dry weight compared to rest of the herbicides tested. Application of bispyribac-Na + almix, remaining at par with pretilachlor fb almix, pretilachlor fb ethoxysulfuron methyl, bispyribac-Na + ethoxysulfuron methyl (25 + 18.75 g/ha) at 25 days after transplanting (DAT) was the most effective in enhancing yield attributes and grain yield. The highest net return (₹44,073/ha) and benefit : cost ratio (1.97) were also obtained using bispyribac-Na + almix. Application of penoxsulam (22.5 g/ha) at 12 DAT recorded the lowest weed-control efficiency and grain yield amongst the herbicides tested which was at par with alone application of bispyribac-Na, pretilachlor, pyrazosulfuron. Application of bispyribac-Na + almix 25 + 4 g/ha at 25 DAT, though on a par with pretilachlor fb almix and pyrazosulfuron resulted significantly higher N, P and K uptake than rest of the herbicides tested and weedy check.

Key words : Herbicide, Rice, Weeds, Weed control, Yield

Rice–wheat is the most important cropping system in India. In eastern Uttar Pradesh, rice production is constrained by depletion of natural resources, labour shortage, climate change and weed problem. Infestation of weeds caused 28–45% yield loss in transplanted rice (Singh *et al.*, 2003). It is well known that the yield losses increase with increasing weed density. Hence it is imperative to control them in time to avoid unproductive use of growth factors and minimize the crop-weed competition for better crop growth. Continuous use of similar herbicides for a longer period often changes the composition of weed flora (Rajkhowa *et al.*, 2006). Herbicides are effective against weed species, but most of them are specific and are effective against narrow range of weed species. Several new pre- and post-emergence herbicides have been added to the array of herbicides but there is meager information on their efficacy when used alone or in combination with other herbicides. The present study is an attempt to assess the efficacy of new pre- and post-emergence herbicides and their combination on weed dynamics and productivity of transplanted rice under conditions of eastern Uttar Pradesh.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) season of 2014 and 2015 at Krishi Vigyan Kendra Sohna, Siddharthnagar farm of the Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad.

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The soil was clay loam having *p*H 7.8, organic carbon 0.38% and available N, P and K of 265, 13.2 and 230.5 kg/ha respectively. The treatments comprised 12 weed-control treatments, viz. bispyribac-Na 25 g/ha [25 days after transplanting (DAT)], pretilachlor 1,000 g/ha (3 DAT), penoxsulam 22.5 g/ha (12 DAT), pyrazosulfuron 20 g/ha (3 DAT), bispyribac-Na + ethoxysulfuron methyl 25 g + 18.75 g/ha (25 DAT), bispyribac-Na + almix 25 g + 4 g/ha (25 DAT), pretilachlor 750 g/ha followed by (fb) ethoxysulfuron methyl 18.75 g/ha (3/25 DAT), pretilachlor 750 g/ha fb almix 4 g/ha (3/25 DAT), pyrazosulfuron 20 g/ha fb mechanical weeding (3/25 DAT), pretilachlor (6%) + bensulfuron (0.6%) 6.6% GR @ 660 g/ha (5 DAT) along with weed-free (hand-weeding 20 and 40 days after transplanting) and weedy check. The experiment was laid out in a randomized block design with 3 replications. Twenty-two days old seedlings of rice variety 'BPT 5204' were transplanted on 25 and 27 July 2014 and 2015 respectively. One-third of recommended dose of N (40 kg/ha) and full dose of P_2O_5 and K_2O (50 kg/ha) were applied before transplanting and the remaining N was top-dressed in 2 equal splits, half at active tillering and half at panicle-initiation stage. Herbicides were applied as per treatments. The data on weed population and weed biomass were taken at 60 DAT with the help of random quadrate (1 m × 1 m) at 2 places. These were subjected to square-root transformation $\sqrt{x+1}$ to normalize their distribution.

RESULTS AND DISCUSSION

Weed flora

The major weed flora at the experimental site comprised grassy weeds *Echinochloa crus-galli* and *Echinochloa colona,* broad-leaf weeds *Cyanotis axillaris, Eclipta alba* and sedges *Cyperus* spp. Some other weeds were also present, viz. *Lindernia* spp. and *Cynodon dactylon* etc. The mean relative density of individual weeds species to total weed density over the seasons at 60 days of crop growth under weedy check condition showed that infestation of broad-leaf weeds was greater than grassy weeds and sedges. Among the broad-leaf weeds, *C. axillaris* alone constituted 24.2% of the total weed density at 60 DAS.

Weed density and weed dry weight

All the weed-control treatments significantly reduced the weed population and total dry weight of weeds compared to weedy check (Table 1). The maximum weed density and dry-matter production of weeds were recorded in unweeded check due to uncontrolled weed growth. Among the herbicides, application of bispyribac-Na + almix though being at par with pretilachlor fb almix and pyrazosulfuron fb mechanical weeding reduced the weed population significantly compared to rest of the herbicidal treatments. Similarly, pyrazosulfuron fb mechanical weeding and bispyribac-Na + ethoxysulfuron methyl being at par recorded significantly lower weed population than the other herbicidal treatments. Single application of bispyribac-Na, pretilachlor, penoxsulam and pyrazosulfuron were found less effective in reducing the weed population compared to the application of herbicides as tank-mix or in sequence. Application of penoxsulam alone recorded the highest weed population among the herbicides followed by pyrazosulfuron, pretilachlor and bispyribac-Na. Among the combined application of herbicides, pretilachlor + bensulfuron recorded significantly higher weed population than the other combinations of herbicides. A more or less similar trend was observed in respect of dry weight of weeds. Application of bispyribac-Na + almix recorded significantly the lowest weed dry weight followed by pretilachlor fb almix and pyrazosulfuron + mechanical weeding compared with other herbicidal treatments. This could be attributed to the fact that herbicides with different mode of action when applied in combination effectively control the weed flora. The highest weed-control efficiency of 91.8% and the lowest weed index of 1.84 were recorded with tank-mix application of bispyribac-Na + almix followed by pretilachlor fb almix and pyrazosulfuron fb mechanical weeding owing to effective control of complex weed flora. Bispyribac sodium inhibits the branched amino acid biosynthesis in grassy weeds, while almix inhibits the growth of broad-leaf weeds and sedges in rice crop. Mukherjee and Singh (2005) also reported higher weed-control efficiency with tank-mix application of herbicides than their individual application. The differential behaviour of herbicides could be attributed to their differential reaction to weed species. Penoxulam, being the less effective in suppressing the weed growth, exhibited the lowest weed-control efficiency and the highest value of weed index.

Yield attributes and yield

All the weed-control treatments significantly improved the grain yield compared to weedy check. Weed-free treatment recorded the maximum grain yield, being at par with bispyribac-Na + almix, pretilachlor fb almix, pyrazosulfuron fb mechanical weeding and bispyribac-Na + ethoxysulfuron methyl. The higher grain yield in these treatments could be attributed to better weed control and higher values of yield attributes. Weed-free treatment, being at par with bispyribac-Na + almix and pretilachlor fb almix, showed higher values of yield attributes than the other herbicidal treatments and weedy check. The results are in close conformity with the results of Yadav *et al*.

Table 1. Effect of weed-control treatments on major weed population (per/m^2) and weed weight at 60 days after transplanting (mean of 2 years)

Treatment	Grassy weeds		Broad-leaf weeds		Sedges	Other weeds	Total weeds	Weed dry-matter (g/m^2)	WCE (%)	Weed index
	Echinochloa crusgalli	*Echinochloa colona*	*Cyanotis axillaris*	*Eclipta alba*	*Cyperus* spp.					
Bispyribac-Na 25 g/ha (25 DAT)	2.34 (4.5)	2.34 (4.5)	2.34 (4.5)	2.14 (3.6)	2.34 (4.5)	2.34 (4.5)	5.2 (26.1)	4.01 (15.1)	69.30	9.60
Pretilachlor 1,000 g/ha (3 DAT)	2.14 (3.6)	1.87 (2.5)	2.53 (5.4)	2.14 (3.6)	2.41 (4.8)	2.34 (4.5)	5.04 (24.4)	4.09 (15.7)	68.30	11.62
Penoxsulam 22.5 g/ha (12 DAT)	2.53 (5.4)	2.53 (5.4)	2.53 (5.4)	2.70 (6.3)	2.70 (6.3)	2.53 (5.4)	5.93 (34.2)	4.57 (19.9)	59.80	15.50
Pyrazosulfuron 20 g/ha (3 DAT)	4.05 (15.4)	3.08 (8.5)	1.34 (0.8)	1.58 (1.5)	1.87 (2.5)	2.14 (3.6)	5.77 (32.3)	4.27 (17.2)	65.10	13.30
Bispyribac-Na + ethoxysulfuron methyl 25 g + 18.75 g/ha (25 DAT)	2.14 (3.60)	2.14 (3.6)	1.61 (1.6)	1.41 (1.0)	2.14 (3.6)	1.92 (2.7)	4.13 (16.1)	3.67 (12.5)	74.60	7.93
Bispyribac-Na + almix 25 g + 4 g/ha (25 DAT)	1.90 (2.6)	1.92 (2.7)	1.61 (1.6)	1.64 (1.7)	1.64 (1.7)	1.61 (1.6)	3.59 (11.9)	2.43 (4.9)	91.80	1.84
Pretilachlor fb ethoxysulfuron methyl 750 g/18.75 g/ha (3/25 DAT)	2.34 (4.5)	2.14 (3.6)	1.90 (2.6)	1.51 (1.3)	1.58 (1.5)	2.34 (4.5)	4.35 (18.0)	3.95 (14.6)	70.50	9.04
Pretilachlor fb almix 750 g/4 g/ha (3/25 DAT)	1.92 (2.7)	1.79 (2.2)	1.67 (1.8)	1.92 (2.7)	1.92 (2.7)	1.54 (1.4)	3.80 (13.5)	2.66 (6.1)	81.98	2.80
Pyrazosulfuron 20 g/ha fb mechanical weeding (3/25 DAT)	2.24 (4.0)	2.28 (4.2)	1.67 (1.8)	1.67 (1.8)	1.41 (1.0)	1.67 (1.8)	3.95 (14.6)	3.46 (11)	78.80	4.05
Pretilachlor (6%) + bensulfuron (0.6%) 6.6% GR @ 660 g/ha (5 DAT)	1.84 (2.4)	2.12 (3.5)	2.53 (5.4)	2.34 (4.5)	2.34 (4.5)	2.14 (3.6)	4.99 (23.9)	4.15 (16.2)	67.20	12.54
Weed-free	1.00 (0.0)	1.00 (0)	1.00 (00)	1.00 (00)	1.00 (0)	1.00 (00)	1.00 (00)	1.0 (00)	100	00
Weedy check	4.4 (18.4)	3.60 (10)	4.75 (21.6)	3.25 (9.6)	4.36 (18.0)	3.26 (9.6)	9.49 (89.2)	7.11 (49.6)	00	29.52
SEm±	0.045	0.04	0.04	0.05	0.04	0.04	0.12	0.07	-	-
CD (P=0.05)	0.14	0.13	0.12	0.17	0.12	0.12	0.38	0.22		

DAT, Days after transplanting; WCE, weed-control efficiency. Original values are given in parentheses, transformation $\sqrt{x+1}$

(2009). It is obvious that crop grown under weed-free environment resulted in greater availability of space, sunlight and nutrients etc., which in turn led to greater photosynthesis and better translocation of photosynthates as reflected in more and bigger panicles and grains/panicle (Table 2). Among the herbicidal treatments, tank-mix application of bispyribac-Na + almix, pretilachlor fb almix, and pyrazosulfuron fb manual weeding, bispyribac-Na + ethoxysulfuron methyl and pretilachlor fb ethoxysulfuron methyl being at par recorded significantly higher values of yield attributes of rice, i.e. panicles/m^2 and grains/panicle, compared with weedy check and the other herbicidal treatments. Our results confirm the findings of Halder and Patra (2007) and Gopinath and Kundu (2008).

Nitrogen, phosphorus and potassium removal by weeds

Among the herbicides, bispyribac-Na + almix significantly reduced the N, P and K removal by weeds compared to weedy check and other herbicidal treatments at harvesting stage (Table 3). Besides bispyribac-Na + almix, application of bispyribac-Na + ethoxysulfuron methyl recorded lower N removal than the other herbicidal treatments and weedy check. However, the magnitude of increase in N removal with pretilachlor fb almix and pyrazosulfuron fb mechanical weeding was relatively lower compared with other herbicidal treatments. In case of P removal, pretilachlor fb almix being at par with pyrazosulfuron fb mechanical weeding showed significantly lower P removal than the other herbicidal treatments and weedy check. Pretilachlor fb almix recorded significantly the lowest K removal after bispyribac-Na + almix. The weed growth as characterized by dry-matter of weeds in different treatments reflected the similar trend in nutrient removal by weeds. As usual weedy check recorded the highest N, P and K removal by weeds due to uncontrolled weed growth, whereas there was no nutrient loss through weeds in weed-free plots.

Nitrogen, phosphorus and potassium uptake by rice

The highest N, P and K uptake in rice was recorded in weed-free treatment, being significantly higher than rest of the treatments (Table 3). Among the herbicide treatments, bispyribac-Na + almix being at a par with pretilachlor fb almix and pyrazosulfuron fb mechanical weeding recorded significantly higher N, P and K uptake than rest of the herbicide treatments and weedy check. This could be ascribed to higher grain yield in these treatments. The lowest N, P and K uptake was observed with weedy check which was at par with application of penoxsulam and pyrazosulfuron applied alone. In general, the trend in nutrient uptake in rice crop was more or less similar to that of grain yield.

Economics

The highest net return (₹44,070/ha) and benefit: cost ratio (1.87) were recorded with bispyribac-Na + almix closely followed by weed-free, pretilachlor fb almix and

Table 2. Yield attributes, yield and benefit: cost ratio in rice as affected by herbicide treatments (mean of 2 years)

Treatment	Panicles/ m^2	Panicle length (cm)	Grains/ panicle	1,000-seed weight (g)	Grain yield (kg/ha)	Net returns (× 10^3₹/ha)	Benefit: cost ratio
Bispyribac-Na 25 g/ha (25 DAT)	253	20	166	23	4900	38.87	1.73
Pretilachlor1,000 g/ha (3 DAT)	251	20	165	23	4790	38.19	1.77
Penoxsulam 22.5 g/ha (12 DAT)	250	21	161	21	4580	35.14	1.61
Pyrazosulfuron 20 g/ha (3 DAT)	251	19	157	23	4700	36.79	1.70
Bispyribac-Na + ethoxysulfuron methyl 25 g + 18.75 g/ha (25 DAT)	256	21	171	24	4990	39.68	1.70
Bispyribac-Na + almix 25 g + 4 g/ha (25 DAT)	260	23	193	24	5320	44.07	1.93
Pretilachlor fb ethoxysulfuron methyl 750 g/ 18.75 g/ha (3/25 DAT)	255	21	177	24	5200	41.54	1.84
Pretilachlor fb almix 750 g/4 g/ha (3/25 DAT)	260	21	181	24	5270	42.89	1.87
Pyrazosulfuron 20 g/ha fb mechanical weeding (3/25 DAT)	253	20	168	24	4930	39.44	1.75
Pretilachlor (6%) + bensulfuron (0.6%) 6.6% GR @ 660 g/ha (5 DAT)	246	19	163	23	4740	37.34	1.72
Weed-free	270	23	195	24	5420	43.44	1.76
Weedy check	207	19	151	20	3820	27.62	1.34
SEm±	2	1	5	1	122	–	–
CD (P=0.05)	6	2	17	NS	367	–	–

DAT, Days after transplanting

Table 3. Effect of herbicide treatments on nutrient uptake by rice and nutrient removal by weeds (mean of 2 years)

Treatment	Nutrient uptake by rice crop (kg/ha)			Nutrient removal by weeds (kg/ha)		
	N	P	K	N	P	K
Bispyribac-Na 25 g/ha (25 DAT)	57.4	8.2	65.6	6.87 (46.22)	3.01 (8.12)	5.29 (27.00)
Pretilachlor1,000 g/ha (3 DAT)	52.2	7.2	60.5	6.98 (47.72)	3.06 (8.38)	5.27 (27.87)
Penoxsulam 22.5 g/ha (12 DAT)	38.3	6.1	47.8	7.82 (60.27)	3.25 (10.61)	5.94 (35.37)
Pyrazosulfuron 20 g/ha (3 DAT)	39.5	6.3	52.6	7.32 (52.64)	3.20 (9.24)	5.63 (30.75)
Bispyribac-Na + ethoxysulfuron methyl 25 g + 18.75 g/ha (25 DAT)	66.4	11.1	74.6	3.01 (8.12)	2.78 (6.73)	4.83 (22.37)
Bispyribac-Na + almix 25 g + 4 g/ha (25 DAT)	80.1	14.1	88.9	1.49 (1.24)	1.78 (2.18)	2.87 (7.25)
Pretilachlor fb ethoxysulfuron methyl 750 g/18.75 g/ha (3/25 DAT)	62.5	10.7	68.4	6.74 (44.51)	2.96 (7.82)	5.09 (26.0)
Pretilachlor fb almix 750 g/4 g/ha (3/25 DAT)	77.1	13.1	85.6	4.35 (17.97)	2.23 (3.16)	3.39 (10.5)
Pyrazosulfuron 20 g/ha fb mechanical weeding (3/25 DAT)	70.7	12.7	84.6	5.73 (31.88)	2.56 (5.60)	4.42 (18.62)
Pretilachlor (6%) + bensulfuron (0.6%) 6.6% GR @ 660 g/ha (5 DAT)	43.8	6.5	57.7	7.10 (49.43)	3.11 (8.68)	5.46 (28.87)
Weed-free	96.9	16.4	99.4	1 (00)	1.00 (00)	1.00 (00)
Weedy check	30.8	5.2	44.9	12.29 (150.16)	5.24 (26.50)	9.44 (88.12)
SEm±	3.60	0.49	3.65	0.39	0.13	0.20
CD (P=0.05)	10.48	1.42	10.60	1.14	0.37	0.54

DAT, Days after transplanting; figures in parentheses indicate pretilachlor fb ethoxysulfuron methyl (Table 2). Weedy check had the lowest net return and benefit: cost ratio (Table 2). The higher net return and benefit :cost ratio with bispyribac-Na + almix could be attributed to low cost of treatment and higher yield.

Based on the study conducted for 2 years it may be concluded that weeds associated with transplanted rice in irrigated condition of rice–wheat cropping system in north-eastern plain zone may be effectively managed through application of bispyribac-Na + almix (25 + 4 g/ha) applied at 25 days after transplanting. The effect of bispyribac-Na + almix (25 + 4 g/ha) was consistent and resulted in the highest grain yield and economic return.

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