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

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ABSTRACT

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

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

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

MATERIALS AND METHODS

The field experiment was conducted at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during *Kharif* season of 2009 and 2010. Ludhiana is situated in Trans-Gangetic Agro-Climatic zone, representing the Indo-Gangetic Alluvial plains at 30°56' N latitude, 75°52' E longitude and at an altitude of 247 m above mean sea level. The maximum temperature remained above 38° C during summer. The total rainfall of 818

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and 627.6 mm were received during 2009 and 2010, respectively. Most of the rainfall was received in vegetative phase from 23rd (at sowing time) to 35th standard meteorological week (80 days after sowing). The soil of the experimental site was loamy sand with normal soil reaction of pH 7.5 and electrical conductivity of 0.16 dS/m. The soil was low in organic C (0.31%) and available N (251.7 kg/ha) and medium in available P (13.5 kg/ha) and K (164.1 kg/ha). The crop was sown with conventional seed-cum-fertilizer drill at 20 cm row to row spacing with seed rate of 35 kg/ha.

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

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

RESULTS AND DISCUSSION

Weed population and dry matter

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

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

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

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

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

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

Crop growth and yield

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

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

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

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

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

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

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

Economics

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

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