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Efficacy of Sequential Combination of Pendimethalin or Oxadiargyl with Bispyribac-Sodium for Control of Complex Weed Flora in Direct Seeded *Basmati* Rice (*Oryza sativa*)

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Abstract Based on four years study *kharif* season of 2010 and 2011 and multi-location farmers' filed trials in Kaithal and Karnal districts during *kharif* season of 2013 and 2014 in basmati direct seeded rice (DSR), it was found that bispyribac 25 g ha^{-1} applied as post-emergence (25 DAS), oxadiargyl 100 g ha^{-1} as pre- emergence (PRE) or pendimethalin 1000 g ha^{-1} (PRE) alone did not provide satisfactory control of one or the other weeds in DSR. Pendimethal in 1000 g ha^{-1} (PRE) *fb* bispyribac-sodium 25 g ha^{-1} at 25 DAS proved one of the best sequential combination to provide effective control (85—99%) of most of weeds with significant improvement in grain yield of DSR.

Keywords Direct seeded basmati rice, Bispyribac sodium, Weed flora, Pendimethalin.

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Introduction

In regions where wages are high (e.g., Haryana and Punjab states of India), the labor cost savings in rice through direct seeding can reach US$ 50 ha^{-1} [1]. The labor and water costs are likely to increase in future which will make direct seeded rice (DSR) economically viable and even more attractive to the farmers. Direct seedling of basmati rice has already been reported remunerative in Punjab and Haryana [2—4]. However, weed control is the major constraint for the success of DSR [5—8]. Weeds under DSR cause severe competition due to more diversified and severe infestation because of absence of size differential between the crop plants and weeds and the suppressive effect of standing water on weed growth at crop establishment. Due to intermitten flushes of more diversified weed flora in DSR, there is also a strong need of using more than one herbicide either in combination or in sequence because single shot would not be sufficient. Keeping this in view, the present study was undertaken to find out suitable herbicidal combination against complex weed flora in dry direct seeded (*vattar*) basmati rice.

Materials and Methods

A field experiment on herbicide evaluation in dry direct seeded rice (DSR) (Basmati) under *vattar* condition (optimum soil moisture at filed capacity) was conducted at Research Farm of Chaudhary Charan

Singh Haryana Agricultural University, Regional Research Station, Uchani, Karnal during *kharif* 2010 and 2011. The experiment including thirteen treatments viz., oxadiagyl 100 g ha^{-1}, pendimethalin 750, 1000, 1250 and 1500 g ha^{-1} each as pre-emergence (PRE), bispyribac-sodium alone 25 g ha^{-1} 25 days after sowing (DAS), oxadiargyl (PRE), *fb* bispyribac at 25 DAS 100/25 g ha^{-1}, pendimethalin (PRE) *fb* bispyribac (25 DAS) 750 / 25, 1000/25, 1250/25 and 1500/25 g ha^{-1}, weed free and weedly check was laid out in randomized block design with three replications. Besides this, multi-locational farmers' filed trials were also conducted for testing the efficacy of pendimethalin (1000 g/ha PRE) *fb* bispyribac-sodium 25 g/ha at 25 DAS in basmati DSR in Kaithal and Karnal districts during *kharif* season of 2013 and 2014. PRE herbicides (pendimethalin and oxadiargyl) were sprayed just after sowing and post-emergence herbicide (bispyribac-sodium) was sprayed at 25 DAS in a spray volume of 500 1 water / ha with knapsack sprayer fitted with flat fan multi-nozzle boom. Basmati rice cultivar CSR30 seeds after soaking and treatment (seeds were soaked in water along with with carbendazim @ 1 g/l water solution per kg seed for 24 h and then water was completely drained, the seeds were spread and dried for 2 h in shade before sowing) was sown in the evening with zero-till seed-cum-fertilizer drill having inverted T-type furrow openers (20 cm row spacing) and inclined plate type seed metering mechanism on 20 June during both the years using seed rate of 20 kg/ha at 3–5 cm depth followed by light planking under non-puddled conditions. Fertilizers were applied similar to the transplanted crop as per the recommendation of the state university.

The crop during both years was harvested at full physiological maturity on 12th November. Data on density and dry weight of weeds at 75 DAS, and yield parameters and yield at crop maturity was recorded to draw inference of results.

Results and Discussion

Effect on weeds

There was decrease in the population and dry weight of all weeds with successive increase in dose of pendimethalin (Tables 1 and 2). Pendimethalin significantly lowered the density and dry weight of *L. chinensis* and other grassy weeds but its efficacy against *E. cruss-galli* was not satisfactory. Bispyribac 25 g ha^{-1} provided excellent controlled of *E. cruss-galli* among all the herbicides but it was not effective against *L. chinensis* and other aerobic grassy weeds. Oxadiargyl 100 g ha^{-1} resulted into highest infestation of *E. cruss-galli* but it provided better control of other aerobic grassy weeds and infestation of *A. baccifera* was also reduced however only to the extent of < 50%. The treatments of bispyribac, oxadiargyl or pendimethalin alone were at par with each other against *E. cruss-galli*. Bispyribac in sequential application was better in controlling of aerobic grassy weeds but it was less effective against *A. baccifera*. The treatments of bispyribac alone as well as its sequential application provided better control of sedges at all the growth stages during both the years. Bispyribac-sodium was found very effective in controlling grassy weeds particularly *Echinochloa* spp. in direct seeded rice but not against aerobic weeds like *Leptochloa chinensis*, *Eragrostistenella*, *Elusine indica* and *Dactyloctenium aegyptium* [9]. Similar trend was found in respect of dry weight of different weeds (Table 2). Based on dry weight of weeds, bispyribac alone and sequential herbicide application recorded higher WCE against *E. cruss-galli* (83.7–99.9 in 2010 and 80.8–90.3% in 2011) and also sedges, while lowest against *L. chinensis* (0–5.2%) during both the years. Pendimethalin provided higher WCE against *L. chinensis* (76.7–100%) and aerobic weeds (70.6–100%) during both years but lower against *E. cruss-galli* (46.8–51.9%) and sedges (0.0–41.9%) during 2011 and *A. baccifera* (0–17.5%) during 2010. Across farmers' field trials (2013 and 2014), pendimethalin at 1000 g/ha (PRE) *fb* sequential spray of bispyribac-sodium 25 g/ha at 25 DAS provided 86–91% control of complex weed flora compared to 87–96% in plots subjected to two manual weeding at 25 and 45 DAS (data not given).

This implies that when the crop is infested with *E. cruss-galli* along with other grassy weeds and sedges, it will be worth to apply bispyribac in sequence with pendimethalin otherwise bispyribac alone

Table 1. Effect of different herbicides alone and as sequential application on the population of the different weeds at 75 DAS in direct seeded basmati rice. Original figures in parentheses were subjected to square root transformation ($\sqrt{X + 1}$) before statistical analysis, T_1–Bispyribac 25 g/ha 25 DAS, T_2–Oxadiargyl 100 g/ha JAS, T_3–Pendimethalin 750 g/ha JAS, T_4–Pendimethalin 1000 g/ha JAS, T_5–Pendimethalin 1250 g/ha JAS, T_5–Pendimethalin 1500 g/ha JAS, T_7–Oxadiargyl *fb* bispyribac 100/25 g/ha JAS/25 DAS, T_8–Pendimethalin *fb* bispyribac 750/25 g/ha JAS/25 DAS, T_9–Pendimethalin *fb* bispyribac 1000/25 g/ha JAS/25 DAS, T_{10}–Pendimethalin *fb* bispyribac 1250/25 g/ha JAS/25DAS, T_{11}–Pendimethalin *fb* bispyribac 1500/25 g/ha JAS/25 DAS, T_{12}–Weed free, T_{13}–Weedy check.

	Population of the different weeds (No. m^{-2})									
Treat-	*E. cruss-galli*		*Leptochloa chinensis*		Sedges		*Ammania baccifera*		Other grassy weeds	
ments	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T_1	2.3 (4.7)	3.1 (8.7)	6.2 (37.3)	5.5 (29.3)	2.4 (6.0)	2.5 (6.7)	8.3 (68.7)	4.3 (18.0)	3.0 (8.7)	4.2 (17.3)
T_2	6.2 (37.3)	6.0 (35.3)	1.7 (2.0)	3.6 (12.0)	5.4 (28.7)	1.0 (0.0)	9.1 (82.0)	5.3 (27.3)	2.9 (7.3)	2.4 (4.7)
T_3	4.8 (25.3)	7.7 (59.3)	1.0 (0.0)	2.5 (5.3)	4.6 (20.7)	4.4 (20.0)	13.0 (168.7)	6.6 (43.3)	1.8 (2.7)	1.7 (2.0)
T_4	3.7 (14.7)	6.9 (46.7)	1.0 (0.0)	2.5 (5.3)	4.6 (20.7)	4.4 (19.3)	11.4 (130.0)	6.3 (40.0)	1.2 (0.7)	1.2 (0.7)
T_5	3.2 (9.3)	6.7 (44.0)	1.0 (0.0)	1.4 (1.3)	4.0 (16.0)	4.1 (16.0)	10.9 (118.0)	6.2 (37.3)	1.2 (0.7)	1.2 (0.7)
T_6	3.0 (8.7)	5.9 (34.0)	1.0 (0.0)	1.0 (0.0)	3.3 (10.0)	3.8 (13.3)	9.7 (95.3)	5.6 (30.7)	1.0 (0.0)	1.0 (0.0)
T_7	2.2 (4.0)	3.7 (13.3)	1.8 (2.7)	3.6 (12.7)	1.7 (2.0)	1.0 (0.0)	9.0 (80.0)	4.5 (19.3)	3.2 (9.3)	2.3 (4.7)
T_8	3.2 (9.3)	3.3 (10.7)	1.2 (0.7)	3.7 (13.3)	2.1 (4.0)	2.1 (4.0)	10.4 (107.3)	6.0 (36.0)	1.2 (0.7)	1.7 (2.0)
T_9	2.6 (6.0)	2.7 (6.7)	1.2 (0.7)	3.3 (10.0)	1.9 (3.3)	1.8 (3.3)	9.9 (99.0)	5.7 (32.0)	1.0 (0.0)	1.2 (0.7)
T_{10}	2.4 (4.7)	2.6 (6.0)	1.2 (0.7)	2.1 (4.0)	1.8 (2.7)	1.2 (0.7)	9.4 (88.0)	5.0 (24.7)	1.0 (0.0)	1.0 (0.0)
T_{11}	2.1 (3.3)	2.4 (5.3)	1.0 (0.0)	2.0 (3.3)	1.2 (0.7)	1.2 (0.7)	8.4 (70.0)	4.3 (18.7)	1.0 (0.0)	1.0 (0.0)
T_{12}	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
T_{13}	6.6 (43.3)	8.2 (66.0)	4.3 (18.0)	6.8 (46.0)	7.4 (54.7)	4.6 (21.3)	12.3 (151.3)	7.1 (50.7)	4.5 (19.3)	4.1 (16.0)
SEm±	0.5	0.4	0.2	0.3	0.5	0.5	0.6	0.4	0.3	0.3
CD at 5%	1.4	1.1	0.6	0.9	1.4	1.5	1.9	1.2	0.8	0.8

will be sufficient if fields are infested only with *E. cruss-galli*. Bispyribac in sequence with pendimethalin has already been reported very effective against complex weed flora in DSR [10—12].

Effect on crop

Number of effective tillers, panicle length, grains per panicle and 1000-grain weight were significantly higher in plots kept weed free throughout crop season as compared to weedy check during both the years (Table 3). Among alone herbicidal applications, lowest number of effective tillers were recorded in plots treated with oxadiargyl 100 g ha^{-1} during 2010 and with pendimethalin 750 g ha^{-1} during 2011. But these yield attributes were superior in plots which received sequential herbicidal treatments due to their better efficacy against complex weed flora. The grain yield was recorded highest in weed free check (3262 kg ha^{-1} in 2010 and 2670 g ha^{-1} 2011) and lowest in weedy check during both years (Table 3). The next lower grain yield close to weedy check was obtained in plots treated with oxadiargyl 100 g ha^{-1} (203 kg ha^{-1}) and pendimethalin 750 g ha^{-1} (1331 kg ha^{-1})

Table 2. Effect of different herbicides alone and as sequential application on the dry mater accumulation by weeds at 75 DAS in direct seeded basmati rice. T_1–Bispyribac 25 g/ha 25 DAS, T_2–Oxadiargyl 100 g/ha JAS, T_3–Pendimethalin 750 g/ha JAS, T_4–Pendimethalin 1000 g/ha JAS, T_5–Pendimethalin 1250 g/ha JAS, T_5–Pendimethalin 1500 g/ha JAS, T_7–Oxadiargyl *fb* bispyribac 100/25 g/ha JAS/25 DAS, T_8–Pendimethalin *fb* bispyribac 750/25 g/ha JAS/25 DAS, T_9–Pendimethalin *fb* bispyribac 1000/25 g/ha JAS/25 DAS, T_{10}–Pendimethalin *fb* bispyribac 1250/25 g/ha JAS/25DAS, T_{11}–Pendimethalin *fb* bispyribac 1500/ 25 g/ha JAS/25 DAS, T_{12}–Weed free, T_{13}–Weedy check.

	Dry mater accumulation (g m^{-2})									
Treat-	*Echinochloa cruss-galli*		*Leptochloa chinensis*		Sedges		*Ammania baccifera*		Other grassy weeds	
ments	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T_1	1.3	22.9	80.5	31.6	1.9	1.9	12.3	2.4	72.9	97.6
T_2	178.2	99.0	7.9	14.3	6.1	0.0	9.8	3.3	17.6	29.1
T_3	103.0	156.7	0.0	8.9	16.7	8.5	29.1	8.0	16.6	3.6
T_4	95.3	121.5	0.0	2.8	10.6	6.2	30.5	5.3	1.5	1.1
T_5	75.7	119.4	0.0	0.6	9.7	5.3	25.3	3.4	0.5	0.3
T_6	62.9	102.9	0.0	0.0	7.4	4.3	24.5	1.3	0.0	0.0
T_7	21.2	33.9	14.4	8.3	2.3	0.0	12.4	2.8	32.5	22.2
T_8	17.9	45.3	7.3	4.1	6.2	5.0	18.3	3.4	3.6	16.1
T_9	15.7	28.0	4.9	1.7	4.3	3.5	17.1	3.7	0.0	3.6
T_{10}	13.0	24.7	2.3	0.8	2.0	1.6	14.8	2.5	0.0	0.0
T_{11}	9.3	23.2	0.0	0.2	0.6	0.6	10.6	2.1	0.0	0.0
T_{12}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T_{13}	302.6	235.3	84.9	28.2	19.8	7.4	29.7	9.9	56.4	94.2
SEm±	8.9	13.0	5.6	3.7	2.2	1.5	3.1	1.6	4.1	5.5
CD at 5%	25.9	38.0	16.3	10.8	6.5	4.3	9.0	4.8	11.9	16.2

during 2010 and 2011, respectively. Among sequential herbicidal treatments, the highest grain yield was obtained in plots treated with pendimethalin *fb* bispyribac 1250/25 g ha^{-1} which was statistically similar with pendimethalin *fb* bispyribac 1000–1500/25 g ha^{-1} and weed free check during 2010. While during 2011, it was highest under pendimethalin *fb* bispyribac 1000/25 g ha^{-1} and statistically superior to pendimethalin *fb* bispyribac 750/25 (2308 kg ha^{-1}).

Data on farmers' field trials (2013 and 2014) also revealed that pendimethalin at 1000 g/ha (PRE) *fb* sequential spray of bispyribac-sodium 25 g/ha at 25 DAS produced grain yield (41.4–45.5 q/ha) similar to plots subjected to two manual weeding at 25 and 45 DAS (42.3–46.0 q/ha) (data not given).

Bispyribac alone [3] and in sequence with pendimethalin has been reported to produce higher grain yield in DSR earlier also [10—12]. The yield reduction in unweeded plots was as high as 96.9% in 2010 and 80.1% in 2011. Yield reduction to the tune of 80–97% due to uncontrolled weeds in DSR in present study clearly indicates that weeds are the major constraints in the way of achieving potential productions and scale as realized by many workers earlier also [3, 5, 7, 8, 13].

Conclusion

The DSR crop was infested with complex weed flora comprising mainly *E. cruss-galli*, *L. chinensis*, BLW (*A. baccifera*), sedges (*Cyperus rotundus*) and other aerobic grassy weeds (*Eragrostis* spp. and *D. aegyptium*) during four seasons across different locations. Weeds growing throughout the crop season reduced grain yield to the extent of 80–97% during two years at Research Farm. Pendimethalin 1000 g ha^{-1} as pre-emergence *fb* bispyribac-Na 25 g ha^{-1} at 25 DAS was realized as one of the best herbicidal combination which provided excellent control (85–99%) of most of weeds except *A. baccifera* with significant improvement in grain yield of DSR. Present

Table 3. Effect of different herbicides alone and as sequential application on yield attributes in direct seeded basmati rice. T_1–Bispyribac 25 g/ha 25 DAS, T_2–Oxadiargyl 100 g/ha JAS, T_3–Pendimethalin 750 g/ha JAS, T_4–Pendimethalin 1000 g/ha JAS, T_5–Pendimethalin 1250 g/ha JAS, T_5–Pendimethalin 1500 g/ha JAS, T_7–Oxadiargyl *fb* bispyribac 100/25 g/ha JAS/25 DAS, T_8–Pendimethalin *fb* bispyribac 750/25 g/ha JAS/25 DAS, T_9–Pendimethalin *fb* bispyribac 1000/25 g/ha JAS/25 DAS, T_{10}–Pendimethalin *fb* bispyribac 1250/25 g/ha JAS/25DAS, T_{11}–Pendimethalin *fb* bispyribac 1500/25 g/ha JAS/25 DAS, T_{12}–Weed free, T_{13}–Weedy check.

Treatments	Plant height at harvesting (cm)		Effective tillers (No./m.r.I.)		Panicle length (cm)		Grains/ panicle (No.)		1000-grain weight (g)		Grain yield (kg ha^{-1})	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
T_1	93.2	99.8	36.3	59.5	20.1	22.3	54.5	64.4	21.2	22.2	869	2095
T_2	86.3	93.4	23.5	42.5	18.2	20.3	46.9	52.6	20.3	21.7	203	1543
T_3	90.8	94.6	33.3	40.3	19.5	20.3	54.0	53.2	21.0	22.3	853	1331
T_4	93.4	93.0	34.2	45.0	19.7	20.7	56.9	54.1	22.0	22.5	1166	1504
T_5	94.5	96.6	43.5	49.3	20.3	20.7	58.5	55.1	22.2	22.2	1869	1616
T_6	94.5	95.8	42.0	50.2	20.3	21.2	62.0	54.1	22.7	22.5	2092	1644
T_7	94.4	98.3	37.5	67.5	20.2	21.4	67.7	67.6	22.7	21.8	2022	2520
T_8	94.2	99.2	44.5	66.8	20.3	21.3	70.7	65.9	22.5	22.8	2290	2308
T_9	95.7	98.6	45.0	70.2	20.3	22.1	74.8	67.3	23.0	22.5	2674	2621
T_{10}	97.0	98.2	46.7	69.0	20.7	22.1	75.6	67.1	23.0	22.7	2716	2611
T_{11}	97.5	98.1	50.0	68.7	21.0	21.4	71.0	67.3	22.7	22.5	2616	2607
T_{12}	96.2	99.8	51.8	71.8	21.1	23.2	73.3	68.0	23.3	22.7	2836	2806
T_{13}	77.5	80.0	5.3	25.7	16.0	18.4	42.3	43.7	19.2	18.3	89	559
SEm±	2.6	1.6	4.8	3.1	0.7	0.8	2.5	2.2	0.5	0.4	111	104
CD at 5%	7.7	4.8	14.1	9.0	2.1	2.2	7.4	6.5	1.3	1.1	325	303

study reaffirms that DSR can be a viable alternative to displace PTR provided weeds are controlled effectively.

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