Indian Journal of Agronomy **63** (2): 230–233 (June 2018)

Research Communication

Bio-efficacy of sequentially applied herbicides on weed competition and crop performance in dry direct-seeded rice (*Oryza sativa*)

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Received : November 2017; Revised accepted : March 2018

ABSTRACT

A field experiment was planned and executed in a randomized block design at New Delhi, during the rainy season of 2016, to evaluate the bio-efficacy of different pre- and post-emergence herbicides applied sequentially on weed dynamics and crop performance in direct-seeded rice (*Oryza sativa* L.). The soil of the experimental plot was sandy loam in texture with *p*H 7.9, low in organic C (0.49%) and available N (220 kg/ha), and medium in available P (16 kg/ha) and K (255 kg/ha). All the treatments involving pre- and post-emergence herbicides reduced the total weed density and weed biomass significantly. Season-long weedy condition reduced the grain yield to the extent of 81% as compared with weed-free check. Sequential application of pendimethalin (1 kg a.i./ha) as pre-emergence followed by a mixture of penoxsulam + cyhalofop butyl (130 g a.i./ha) as post-emergence exhibited significant reduction in weed density and dry-biomass accumulation, resulting in a considerable increase in weed-control efficiency (84.49%) and productivity (3.92 t/ha).

Key words **:** Brown manuring, Direct-seeded rice, Penoxsulam + cyhalofop butyl, Sequential application, Weed control efficiency

Rice (*Oryza sativa* L.) is the most important food crop of India and plays an important role in ensuring food security. In India, the major rice-establishment method is manual transplanting of seedlings into puddled soil which is water- and labour-intensive. Currently, the looming scarcity of water and labour due to expanding population, urbanization and competition with other non-agricultural sectors threatens the sustainability of the conventional rice-production system. Among the resource-conserving technologies, direct-seeded rice (DSR) is being considered as a suitable alternative to transplanted rice (Mahajan *et al*., 2013), as it requires 35–57% less water and 67% less labour than transplanted rice (Mazid *et al*., 2003; Farooq *et al*., 2011). Direct-seeded rice can fetch higher yields if weeds are managed effectively, as high weed pressure and shift towards more difficult-to-control weed flora are the main biological constraints limiting its productivity (Rao *et al*., 2007; Maity and Mukherjee, 2008). A DSR crop usually lacks a 'head start' over weeds because of dry soil surface, alternate wetting and drying conditions and lack of flooding, making it particularly vulnerable to weed competition during initial stages of its growth (Rao *et al*., 2007). Research studies indicated that about 90 weed species were competing with DSR, causing 23–100% reduction in grain yield (Jabran and Chauhan, 2015). So, it is imperative to identify efficient weed-management strategies to keep weed populations below economic threshold level (ETL) which ultimately result in higher productivity of DSR. During early stages, manual weeding is difficult because of morphological resemblance of many grassy weeds with rice seedling. Chemical weed management with selective herbicides is the most common and popular method of weed management in rice. However, over-dependence on use of particular herbicide can result in evolution of more difficult-to-control herbicide-resistant weeds along with other side-effects. Sequential use of more than one herbicide or herbicide mixtures with different mode of action is very effective in controlling the complex weed flora observed in DSR. Brown manuring (co-culture of *Sesbania* with rice and then knocking down with 2, 4-D) has been reported to smother various weed

Based on a part of the M.Sc. Thesis of the first author, submitted to ICAR-Indian Agricultural Research Institute, New Delhi, in 2017 (unpublished)

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species and enhance rice yield (Chongtham *et al*., 2016). Instead of depending on a single method for managing weeds, integrated use or a combination of two or more methods is more desirable. Keeping this in view, the present experiment was carried out to evaluate the bio-efficacy of various weed management options in DSR.

The experiment was conducted at research farm of Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi (28°38' N, 77°10' E and 228.6 m above mean sea-level) during the rainy season of 2016. The soil of the experimental site was sandy loam with *p*H 7.9, low in organic C (0.49%) and available N (220 kg/ha), and medium in available P (16 kg/ha) and K (255 kg/ha). Eleven treatments were arranged in a randomized complete-block design with 3 replications viz. pendimethalin as pre-emergence (PE) @ 1.0 kg a.i./ha followed by (fb) bispyribac-sodium as post-emergence (PoE) @ 20 g a.i./ha at 25 days after sowing (DAS); pendimethalin (PE) @ 1.0 kg a.i./ha fb a pre-mixture of penoxsulam + cyhalofop-butyl (PoE) @ 130 g a.i./ha at 25 DAS; pendimethalin (PE) @ 1.0 kg a.i./ha fb fenoxaprop-p-ethyl (PoE) @ 75 g a.i. /ha at 25 DAS; pendimethalin (PE) @ 1.0 kg a.i./ha fb Almix (PoE) @ 4 g/ha at 25 DAS; pretilachlor (PE) @ 0.75 kg a.i./ha fb cyhalofop butyl (PoE) @ 80 g a.i./ha at 25 DAS; pretilachlor (PE) @ 0.75 kg a.i./ha fb ethoxysulfuron (PoE) @ 15 g a.i./ha at 25 DAS; pendimethalin (PE) @ 1 kg a.i./ha fb 1 hand-weeding (HW) at 40 DAS; brown manuring (*Sesbania* + 2, 4-D @ 0.5 kg a.i./ha at 4 weeks after sowing); brown manuring fb Almix @ 4 g/ha at 40 DAS; weed-free check (6 hand-weedings starting from 15 DAS); and unweeded control. Rice variety 'Pusa Sugandh 5' was directly sown in unpuddled condition using a seed-drill with a seed rate of 25 kg/ha at 20-cm row spacing. *Sesbania* seed @ 25 kg/ha was sown between the rows of rice. Herbicides were applied with a knapsack sprayer calibrated to deliver 500 litres/ha of spray solution through flat-fan nozzle. The crop was fertilized with recommended dose of 120:40:30 kg of N: P_2O_5 : K_2O/ha. Category-wise weed count and their total dry biomass accumulation were measured at 60 DAS by placing a quadrate of 0.25 m^2 randomly at 3 places in each plot and were subjected to square-root transformation [$\sqrt{(x+0.5)}$] before analysis. Data were analysed using analysis of variance (ANOVA). Treatment means were separated using the least significant difference (LSD) at the 5% level of significance. Differences were considered significant only at $P \leq 0.05$.

The weed species observed at the experimental field were mainly dominated by grass and broad-leaf weeds. Though several weed species were present at the site, the predominant weed flora included *Echinochloa colona* (L.) Link., *E. crus-galli* (L.) Beauv. and *Leptochloa chinensis* (L.) Nees. among the grasses; *Eclipta alba* L., *Digera arvensis* Forssk. and *Trianthema portulacastrum* L. among the broad-leaf weeds; and *Cyperus iria* L. and *C. rotundus* L. among the sedges. In general, *E. crus-galli* and *E. alba* were the predominant weeds among all the weed species. Among sedges, *Cyperus rotundus* appeared during the initial growth stages, while *Cyperus iria* emerged after that. Maity and Mukherjee (2008) also reported the similar findings.

Different herbicidal treatments exhibited significant effects on growth of weeds and reduced total weed density by 68–84.5% and biomass by 71.6–86.7% compared with unweeded control at 60 DAS (Table 1). Sequential application of pendimethalin fb a mixture (pre-mix) of penoxsulam + cyhalofop butyl resulted in significant reductions in weed density and dry biomass by 84.5 and 86.7% respectively, than rest of the treatments but remained at par with brown manuring fb Almix (Table 1). Weed-control efficiency (WCE), based on total weed density at 60 DAS, varied significantly among the treatments and pendimethalin fb penoxsulam + cyhalofop butyl provided satisfactory WCE of 84.5% closely followed by brown manuring fb Almix (82.7%). This is because of the broad-spectrum control of weeds mainly provided by the combination of penoxsulam + cyhalofop (Singh *et al*., 2016). On the other hand, synergistic effect of smothering action of *Sesbania* and suppressive impact of herbicide (Almix) on weed flora provided better weed control (Chongtham *et al*., 2016). Maity and Mukherjee (2008) found that integration of herbicides with brown manuring could enhance weed-control efficiency (WCE) by reducing growth of diverse weeds in direct-seeded rice. Significantly higher total density and biomass of weeds were recorded in the plots treated with pendimethalin fb bispyribac-sodium. This might be due to lower activity of bispyribac sodium in controlling some perennial sedges and grasses like *Dactyloctenium aegyptium* and *L. chinensis*, which are the predominant weed species of the DSR system (Awan *et al*., 2015).

Weed-free check plots recorded the highest plant height, number of tillers, leaf-area index (LAI) and mean crop-growth rate (CGR) at 70 DAS mainly because of the lowest crop-weed competition. Among the weed-management practices, pendimethalin fb penoxsulam + cyhalofop butyl provided higher plant height (59.20 cm), tillers (335/m^2), LAI (4.38) and more mean CGR (9.07 g/m^2/day) compared to others followed by pendimethalin fb bispyribac-sodium and brown manuring fb Almix (Table 1). These effects are mainly due to lower crop-weed competitions for various growth factors during the crop growth period.

Season-long weedy condition reduced the grain yield to

Table 1. Weed dynamics, crop growth and yield of direct-seeded rice as affected by different weed-management practices

Treatment	Weed density (no./m²)			Total weed density (Nos./m²)	Total weed dry weight (g/m²)	WCE (%)	Plant height (cm)	Tillers (Nos./m²)	Leaf-area index	Mean CGR (g/m²/day)	Grain yield (t/ha)	Weed index (%)
	BLWs	Grasses	Sedges									
Pendimethalin (1 kg/ha) fb bispyribac-Na (20 g/ha)	2.70 (7)	5.58 (31)	3.23 (10)	6.94 (48)	7.48 (55.5)	79.83	58.33	329.5	4.26	8.54	3.70	15.86
Pendimethalin (1 kg/ha) fb penoxsulam + cyhalofop butyl (130 g/ha)	2.92 (8)	4.71 (22)	2.65 (7)	6.08 (37)	6.51 (42)	84.49	59.20	335.0	4.38	9.07	3.92	10.98
Pendimethalin (1 kg/ha) fb fenoxaprop-p-ethyl (75 g/ha)	4.55 (20)	5.98 (35)	4.51 (20)	8.72 (76)	9.49 (89.7)	67.98	56.00	275.9	3.44	6.97	2.67	39.47
Pendimethalin (1 kg/ha) fb Almix (4 g/ha)	2.92 (8)	5.89 (34)	2.79 (7)	7.08 (50)	8.07 (65)	78.98	56.89	294.3	3.90	7.52	3.10	29.50
Pretilachlor (0.75 kg/ha) fb cyhalofop butyl (80 g/ha)	4.51 (20)	5.92 (35)	4.34 (19)	8.59 (73)	9.37 (87.4)	68.97	56.45	277.5	3.53	6.97	2.70	38.69
Pretilachlor (0.75 kg/ha) fb ethoxysulfuron (15 g/ha)	2.86 (8)	6.80 (46)	2.53 (6)	7.76 (60)	9.16 (83.6)	74.61	53.78	220.8	3.04	4.96	1.88	57.15
Pendimethalin (1 kg/ha) fb HW	3.02 (9)	5.79 (33)	3.61 (13)	7.44 (55)	8.09 (65.1)	76.72	57.67	310.7	4.03	8.12	3.50	20.39
Brown manuring	2.39 (5)	6.36 (40)	2.39 (5)	7.15 (51)	8.00 (63.5)	78.56	54.22	287.2	3.82	7.27	3.07	30.18
Brown manuring fb Almix (4 g/ha)	2.12 (4)	5.57 (31)	2.59 (6)	6.43 (41)	7.29 (52.8)	82.65	55.56	316.4	4.09	8.50	3.67	16.60
Weed-free check	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	100	60.56	381.4	4.60	10.18	4.40	0.00
Unweeded control	5.36 (28)	14.16 (200)	2.77 (8)	15.39 (236)	17.79 (316)	0	43.33	177.7	2.31	2.87	0.83	81.11
SEm±	0.26	0.26	0.31	0.23	0.23	–	2.28	6.43	0.11	0.31	0.12	–
CD (P=0.05)	0.77	0.75	0.92	0.68	0.67	–	6.73	18.96	0.32	0.91	0.35	–

BLWs, Broad-leaf weeds; WCE, weed-control efficiency; CGR, crop-growth rate; HW, hand-weeding. Data were subjected to square-root transformation [$\sqrt{(x+0.5)}$]. *Figures in parentheses indicate original values

the tune of 81% as compared with weed-free check due to severe weed competition. Similar negative correlation between weed and crop growth was reported by Kaur *et al*. (2013), who stated that with increasing weed density, crop biomass production, effective tillers and ultimately crop yield reduced exponentially. The highest grain yield (4.4 t/ha) was achieved in the weed-free check plots and the lowest in unweeded control situation (0.83 t/ha). Among the weed-control treatments, the highest grain yield (3.92 t/ha) and the lowest weed index (10.98%) were obtained from plots treated with pendimethalin fb penoxsulam + cyhalofop butyl which was followed by pendimethalin fb bispyribac-sodium (3.70 t/ha and 15.86%) and brown manuring fb Almix (3.67 t/ha and 16.60%). This might be owing to improved weed-control efficiencies of these treatments that reduced the inter-specific competition for resources and allowed the crop to grow to its best potential which in turn positively influenced the biomass production and yield of crop (Ganai *et al*., 2014). The findings of the current study were supported by an earlier study in which the plots that received pre-emergence herbicides effectively controlled first flushes of weeds in the early growth stages and the later emerging weeds were controlled by broad-spectrum post-emergence herbicides causing faster crop canopy closure, which suppressed weed growth at later stages (Ahmed and Chauhan, 2014).

Thus, it can be concluded that pre-emergence application of pendimethalin @ 1.0 kg a.i./ha followed by post-emergence application of penoxsulam + cyhalofop butyl @ 130 g a.i./ha increased the weed-control efficiency, resulting in better crop growth and yield and appeared to be the most effective weed-management option for sustaining higher yield in direct-seeded aerobic rice.

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