Indian Journal of Weed Science **52**(2): 179–182, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Bio-efficacy of pre-and post-emergence herbicides on weed control and yield of rainfed lowland rice

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Article information

DOI: 10.5958/0974-8164.2020.00032.5

Type of article: Research note

Received : 15 February 2020
Revised : 1 June 2020
Accepted : 3 June 2020

Key words
Grain yield
Growth parameters
Residual greengram
Seedling vigour index
Weed growth

ABSTRACT

A field experiment was conducted at Sri Venkateswara Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India to study the performance of sequential application of pre-emergence (PE) and post-emergence (PoE) herbicides for broad-spectrum weed control in rainfed lowland rice and their residual effect on succeeding greengram. The major weed flora associated with rainfed lowland rice were *Cyperus rotundus* L. (55%), *Digitaria sanguinalis* L. Scop (12%) and *Commelina benghalensis* L.(7%) and other weeds (26%). The lowest density and dry weight and increased growth and yield components were recorded with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha or halosulfuron-methyl 67.5 g/ha. The higher grain and straw yields and benefit-cost ratio were obtained with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha or halosulfuron-methyl 67.5 g/ha. Pre-emergence application of pretilachlor, oxadiargyl and pendimethalin reduced the plant population of rice by 12.10, 5.94 and 4.46%, respectively compared to unweeded check. Sequential application of PE and PoE herbicides applied to rainfed lowland rice did not affect the germination of greengram, however the best weed management practice in rice continuing its superiority in obtaining higher seedling vigour index and dry matter production at 15 DAS.

Rice (*Oryza sativa* L.) is the most important cereal crop of the world, by contributing staple diet of 70% of world's population and plays a crucial role in the economic and social stability of the world. In India, it is cultivated in an area of 44.50 million hectares with a total production of 115.60 million tonnes and productivity of 2.28 t/ha. The resources for crop production, *viz*. land, water, nutrients and labour are becoming scarce in recent years. Due to increasing scarcity of the water, escalating labour costs and non-availability of labour timely, direct seeding of rice seems to be the only viable alternative to transplanted rice. Weeds are the main constraints in direct-seeded rice since the inherent weed control from standing water at crop establishment is lost. Yield loss due to weeds varies significantly due to nature, extent and intensity of weed problems and depend on the ecology in which the rice crop is grown. Uncontrolled weed growth in direct-seeded rice, wet seeded rice and transplanted rice reduced the grain yield by 75.8, 70.6 and 62.6%, respectively compared to the best weed management practices (Singh *et al.* 2005). PE application of pendimethalin 1.0 kg/ha alone is not sufficient to obtain broad-spectrum weed control due to diversified weed flora and heavy infestation of perennial sedges and broad-leaved weeds. PoE application of bispyribac-sodium 25 g/ha is not effective in controlling perennial sedge and resistant biotypes of grassy and broad-leaved weeds, which are the most common in dry direct-seeded rice (DSR) ecosystem. There is a need to evaluate some of the new generation PoE herbicides for obtaining broad-spectrum weed control including perennial sedge, *Cyperus rotundus* in DSR. Therefore, the present experiment was conducted to find out suitable herbicides for sequential application in rainfed low land rice.

A field experiment was conducted during *Kharif* 2018 at wetland farm of Sri Venkateshwara Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India. The soil was sandy clay loam in texture with low in organic carbon (0.25%), slightly alkaline in reaction (pH-8.2), low available nitrogen (238 kg/ha) and medium in available phosphorus (24.5 kg/ha) and available potassium (268 kg/ha). The experiment was laid out in a randomized block design with twelve treatments and replicated thrice. The weed management practices consisted of sequential application of oxadiargyl, pendimethalin and pretilachlor each at 100, 1000 and 750 g/ha, respectively as PE applied at one DAS followed by new generation PoE herbicides, *viz*. penoxsulam + cyhalofop-p-butyl, florpyrauxifen-benzyl and halosulfuron-methyl each 130, 25 and 67.5 g/ha, respectively were applied at 20 DAS. PE application of pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha, two hand weedings at 20 and 40 DAS and unweeded check were also included (**Table 1**). Rice variety '*MTU-1010*' was sown on 13th August 2018 at 20 x 10 cm with seed rate of 75 kg/ha. The rice crop was irrigated with 5 cm depth of water at each irrigation whenever necessary upto 40 DAS and then the crop was converted to land submergence for better growth and development. A uniform dose of 120 kg N, 60 kg P and 60 kg K per ha was applied in the form of urea, single super phosphate and muriate of potash, respectively. Iron and zinc sulphate was applied each at 50 and 25 kg/ha, respectively at the time of last ploughing to overcome the deficiencies of iron and zinc.

The required quantities of PE and PoE herbicides were applied at one and 20 DAS, respectively by using spray fluid at 500 L/ha with the help of battery operated knapsack sprayer fitted with flat fan nozzle as per the treatments. Category wise weed density and dry weight was recorded at 80 DAS. Weed density and weed dry weight of all categories of weeds were recorded at 40, 60 and 80 DAS and showed more or less similar trend. To avoid repetition of the data, only 80 DAS was presented. Phytotoxicity scoring of all PE and PoE herbicide on rice was evaluated in 0-10 scale at 10th and 5th day after its application as suggested by Singh and Rao (1976). The plant population/m^2 in PE herbicide applied plots was recorded at 15 DAS. The growth parameters, yield attributing parameters and yield of rainfed lowland rice were recorded at harvest. Greengram '*LGG - 460'* was sown in undisturbed layout after the harvest of rice at a spacing of 30 x 10 cm to know the residual effect of herbicides applied to rainfed lowland rice. Germination per cent, dry matter production and seedling vigour index were recorded at 15 DAS. Seedling vigor index was calculated by multiplying the germination per cent and seedling length.

Weed growth

The major weed flora found in the experimental field was *Cyperus rotundus* L. (55%), *Digitaria sanguinalis* L. Scop. (12%), *Commelina benghalensis* L. (7%), *Boerhavia erecta* L. (5%), *Trichodesma indicum* R.Br. (5%), *Dactyloctenium aegyptium* (L.) Willd. (3%), *Digera arvensis* Forssk. (3%), *Cleome viscosa* L. (2%) and other weeds (8%) in unweeded check plots. All the weed management practices significantly influenced the density and dry weight of all the categories of weeds associated with rainfed lowland rice (**Table 1**). The lowest density and dry weight of grasses were noticed with PE application of pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha, which was at par with two HW at 20 and 40 DAS. PE application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha recorded significantly lesser density of sedges, which was comparable with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha whereas the lowest dry weight of sedges was recorded with PE application of oxadiargyl 100 g/ha *fb* halosulfuron-methyl 67.5 g/ha. PoE application of halosulfuron-methyl 67.5 g/ha or florpyrauxifen-benzyl 25 g/ha controlled predominant sedge, *Cyperus rotundus*. Nazreen and Subramanyam (2018) reported that PoE application of halosulfuron-methyl 67.7 g/ha was very effective in controlling purple nutsedge in maize and Mehar Chand *et al.* (2014) also found similar effect in sugarcane.

Pre-emergence application of pretilachlor 750 g/ha *fb* halosulfuron-methyl 67.5 g/ha or florpyrauxifen-benzyl 25 g/ha resulted in reduced density of broad-leaved weeds whereas lesser dry weight was noticed with pendimethalin 1000 g/ha *fb* bispyribac-sodium 25 g/ha or florpyrauxifen-benzyl 25 g/ha. Pendimethalin was effective in controlling broad-leaved weeds and grasses at early stages whereas florpyrauxifen-benzyl was effective in controlling broad-leaved weeds and sedges similar to synthetic aux in herbicides. The highest weed control efficiency was computed with sequential application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha. The best treatment was pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha in recording higher weed control efficiency. All the pre-emergence herbicides *fb* PoE application of penoxsulam + cyhalofop-p-butyl 130 g/ha treatments failed to obtain broad-spectrum weed control due to poor performance of penoxsulam + cyhalofop-p-butyl 130 g/ha against perennial sedge*, Cyperus rotundus.*

Crop growth parameters

All the pre-and post-emergence herbicides did not show any phytotoxicity symptoms on rice crop, however pre-emergence application of oxadiargyl 100 g/ha and pretilachlor 750 g/ha resulted in phytotoxicity rating of '1' and '2', respectively in 0-10 scale where 0 indicate no phytotoxicity and 10 indicates complete destruction of crop plants at 10 DAS and the crop was recovered within 20 DAS. PE application of pretilachlor, oxadiargyl and pendimethalin at 750, 100 and 1000 g/ha, respectively reduced the plant population by 12.10, 5.94 and 4.46%, respectively compared to unweeded control.

Table 1. Weed density, weed dry weight and weed control efficiency as influenced by different pre-and post-emergence herbicides in rain fed lowland rice at 80 DAS

Treatment	Weed density (no./m^2)				Weed dry weight (g/m^2)				WCE (%)
	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total	
Oxadiargyl *fb* penoxsulam + cyhalofop-p-butyl 100+130 g/ha (1 and 20 DAS)	2.82 (7.0)	8.77 (76.0)	4.04 (15.0)	9.96 (98.0)	4.47 (19.0)	13.85 (191.0)	10.07 (101.0)	17.65 (311)	33.2
Pendimethalin *fb* penoxsulam +cyhalofop-p-butyl 1000+130 g/ha (1 and 20 DAS)	2.70 (6.0)	7.95 (62.0)	3.78 (13.0)	9.11 (81.0)	4.24 (17.0)	12.45 (154.0)	9.49 (89.0)	16.17 (260.0)	43.9
Pretilachlor *fb* penoxsulam +cyhalofop-p-butyl 750+130 g/ha (1 and 20 DAS)	2.44 (5.0)	8.62 (73.0)	3.60 (12.0)	9.55 (90.0)	3.85 (14.0)	13.45 (180.0)	9.09 (82.0)	16.63 (276.0)	40.6
Oxadiargyl *fb* florpyrauxifen-benzyl100+25 g/ha (1 and 20 DAS)	3.36 (10.0)	3.69 (13.0)	2.76 (7.0)	5.53 (30.0)	5.00 (24.0)	4.53 (20.0)	8.81 (77.0)	11.03 (121.0)	74.0
Pendimethalin *fb* florpyrauxifen-benzyl 1000+25 g/ha (1 and 20 DAS)	2.88 (7.0)	2.82 (7.0)	3.41 (11.0)	5.09 (25.0)	4.84 (23.0)	4.42 (19.0)	5.74 (32.0)	8.58 (74.0)	84.3
Pretilachlor *fb* florpyrauxifen-benzyl 750+25 g/ha (1 and 20 DAS)	3.26 (10.0)	3.91 (14.0)	2.64 (6.0)	5.57 (30.0)	4.70 (21.0)	5.98 (35.0)	8.48 (71.0)	11.29 (127.0)	72.6
Oxadiargyl *fb* halosulfuron-methyl 100+67.5 g/ha (1 and 20 DAS)	3.10 (9.0)	2.94 (8.0)	3.55 (12.0)	5.38 (29.0)	5.06 (25.0)	4.04 (15.0)	7.98 (63.0)	10.19 (103.0)	77.8
Pendimethalin *fb* halosulfuron-methyl 100+67.5 g/ha (1 and 20 DAS)	3.16 (9.0)	2.64 (6.0)	3.21 (9.0)	5.03 (24.0)	5.27 (27.0)	6.12 (37.0)	6.20 (37.0)	10.10 (101.0)	78.3
Pretilachlor *fb* halosulfuron-methyl 750+67.5 g/ha (1 and 20 DAS)	3.05 (8.0)	3.87 (14.0)	2.36 (5.0)	5.29 (27.0)	5.40 (28.0)	5.70 (32.0)	6.78 (45.0)	10.29 (105.0)	77.4
Pendimethalin *fb* bispyribac-sodium 1000+25 g/ha (1 and 20 DAS)	1.99 (3.0)	7.08 (49.0)	2.36 (5.0)	7.61 (57.0)	3.20 (9.0)	11.02 (121.0)	5.69 (32.0)	12.75 (162.0)	65.2
HW twice (20 and 40 DAS)	2.29 (4.0)	6.27 (38.0)	2.76 (7.0)	7.09 (49.0)	3.67 (13.0)	9.89 (97.0)	6.66 (44.0)	12.41 (154.0)	66.9
Unweeded control	5.70 (32.0)	9.69 (93.0)	5.02 (24.0)	12.25 (149.0)	9.40 (88.0)	15.23 (231.0)	12.14 (146.0)	21.59 (465.0)	-
LSD (p=0.05)	0.40	0.44	0.43	0.43	0.65	0.54	1.03	0.84	

Original figures in parentheses were subjected to square root transformation before statistical analysis; *fb*- followed by

In contrary, Kundu *et al.* (2017) observed that PE application of pretilachlor 30.7% EC at any dose did not show phytotoxic symptoms in DSR on sandy loam soils of Nadia, West Bengal. The reduction in plant population in the present experiment in pre-emergence herbicides applied plots is mainly due to high moisture content in the top layers of the soil as a result of 12 mm of rainfall received at 10 hours after herbicide application. The highest values of the growth parameters, *viz.* plant height, leaf area index and tillers/m^2 were recorded with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha, which was statistically similar to pre-emergence application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha. Sequential application of pendimethalin 1000 g/ha *fb* PoE application of any one of the above said PoE herbicide obtained broad-spectrum weed control, which in turn lead to elevated growth parameters as a result of better availability of growth resources. These results were in-line with the findings of Choubey *et al*. (2006). Pre-emergence application of oxadiargyl 100 g/ha *fb* penoxsulam + cyhalofop-p-butyl 130 g/ha resulted in lesser values of all the growth parameter due to its poor weed control and offered competition for growth resources in penoxsulam + cyhalofop-p-butyl applied plots.

Yield components and yield

Different weed management practices significantly influenced the yield attributing characters and yield of rainfed lowland rice. Yield attributing characters, *viz.* panicles/m^2 and filled grains/panicle recorded at their highest with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha and it was comparable with PE application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha. The increase in yield attributes might be attributed due to complete control of all the categories of weeds. The lowest spikelet sterility was computed with above said treatments. Higher grain and straw yield of rainfed lowland rice was obtained with pre-emergence application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha due to its superiority in suppressing weed growth (**Table 2**). The reduction in grain and straw yield due to heavy weed infestation in unweeded check plots was 73.87 and 66.11%, respectively compared to the best treatment. The lowest values of the yield components and yield were recorded with pre-emergence application of oxadiargyl 100 g/ha *fb* penoxsulam + cyhalofop-p-butyl 130 g/ha due to poor performance of these herbicides in controlling weeds especially perennial sedge, *Cyperus rotundus*. Singh *et al*. (2005) also stated that uncontrolled weed

Table 2. Effect of pre-and post-emergence herbicides on growth parameters at harvest, yield components and yield of rainfed lowland rice and their residual effect on succeeding greengram

Treatment	Plant population /m²	Plant height (cm)	LAI	Tillers/ m²	Panicles /m²	Filled grains /panicle	Spikelet sterility (%)	Grain yield (t/ha)	Straw yield (t/ha)	B:C ratio	Residual crop (greengram) Germination (%)	Residual crop (greengram) SVI	Residual crop (greengram) DMP (kg/ha)
Oxadiargyl *fb* penoxsulam + cyhalofop-p-butyl 100+130 g/ha (1 and 20 DAS)	44.67	64	1.84	136	104	60.67	23.0	1.75	2.68	1.11	91.33	1787	219
Pendimethalin *fb* penoxsulam +cyhalofop-p-butyl 1000+130 g/ha (1 and 20 DAS)	45.67	66	1.91	156	113	65.67	22.0	1.93	2.82	1.20	88.83	1756	229
Pretilachlor *fb* penoxsulam +cyhalofop-p-butyl 750+130 g/ha (1 and 20 DAS)	43.00	65	1.86	140	113	65.67	22.6	1.84	2.72	1.17	90.00	1763	214
Oxadiargyl *fb* florpyrauxifen-benzyl 100+25 g/ha (1 and 20 DAS)	45.00	69	2.41	213	166	73.33	20.0	2.36	3.36	1.57	91.17	1802	236
Pendimethalin *fb* florpyrauxifen-benzyl 1000+25 g/ha (1 and 20 DAS)	47.33	74	3.21	301	201	82.33	17.3	3.52	4.65	2.30	88.37	1785	245
Pretilachlor *fb* florpyrauxifen-benzyl 750+25 g/ha (1 and 20 DAS)	42.67	68	2.18	192	152	72.67	21.3	2.10	3.01	1.41	89.50	1748	230
Oxadiargyl *fb* halosulfuron-methyl 100+67.5 g/ha (1 and 20 DAS)	45.33	69	2.43	259	181	75.00	19.6	2.67	3.69	1.55	90.83	1830	248
Pendimethalin *fb* halosulfuron-methyl 100+67.5 g/ha (1 and 20 DAS)	46.33	72	3.10	283	197	82.00	17.6	3.43	4.57	1.96	89.10	1838	252
Pretilachlor *fb* halosulfuron-methyl 750+67.5 g/ha (1 and 20 DAS)	42.67	72	2.83	273	196	81.33	18.3	3.28	4.43	1.91	90.17	1799	241
Pendimethalin *fb* bispyribac-sodium 1000+25 g/ha (1 and 20 DAS)	46.67	67	2.06	171	149	71.33	22.3	2.05	2.98	1.32	91.23	1830	209
HW twice (20 and 40 DAS)	49.00	70	2.69	266	184	76.67	19.0	2.82	3.88	1.67	89.50	1772	239
Unweeded control	48.67	59	1.45	106	78	53.00	25.3	0.92	1.58	0.67	89.17	1691	198
LSD (p=0.05)	1.86	3.0	0.36	21	12.3	5.21	2.04	0.29	0.34	0.15	NS	26.4	8.26

growth in direct-seeded rice resulted in reduced grain yield by 75.8% in sandy loam soils. Higher benefit-cost ratio was obtained with PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha due to less cost of herbicides. The next best weed management practice in obtaining higher benefit-cost ratio was PE application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.7 g/ha.

Residual effect

All the pre-and post-emergence herbicides applied to rainfed lowland rice did not show any inhibitory effect on growth and development of succeeding greengram. Germination of greengram was not affected by any of the pre-emergence herbicides applied to rice crop. However, the highest seedling vigour index of succeeding greengram was computed with pre-emergence application of pendimethalin 1000 g/ha *fb* halosulfuron-methyl 67.5 g/ha applied to rice. This might be due to effect of sequential application of pendimethalin as PE *fb* halosulfuron-methyl as PoE in rainfed lowland rice and continued their herbicidal activity upto early stages of the succeeding greengram. Nazreen and Subramanyam (2018) also reported that halosulfuron-methyl 67.5 g/ha applied to maize did not affect the germination and growth of succeeding greengram.

Based on the above findings, it might be concluded that PE application of pendimethalin 1000 g/ha *fb* florpyrauxifen-benzyl 25 g/ha or halosulfuron-methyl 67.5 g/ha applied at 20 DAS resulted in higher grain yield and benefit-cost ratio, apart from broad-spectrum weed control. PoE application of halosulfuron-methyl 67.5 g/ha was effective in reducing the density and dry weight of *Cyperus rotundus* and it was closely followed by florpyrauxifen-benzyl 25 g/ha. All the PE and PoE herbicides applied to rice did not show any inhibitory effect on succeeding greengram.

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