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Integrated weed management in rainfed upland rice (*Oryza sativa*)

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ABSTRACT

Field experiments were conducted at Naira, Andhra Pradesh for two consecutive rainy (*kharif*) seasons of 2005 and 2006 to study the efficacy of different herbicides applied alone and their integration with star weeding in rainfed upland rice (*Oryza sativa* L.). The reduction in grain yield due to uncontrolled weed growth was 62.6% compared with weed-free check. Pre-emergence application of metsulfuron methyl 10% + chlorimuron ethyl 10% @ 6.0 g/ha resulted in better weed control but the improved efficacy could not be translated to better yield due to its phytotoxicity on rice. Among the herbicide treatments, pre-emergence application of oxadiargyl @ 80 g/ha + working with star weeder at 40 days after sowing, followed by pre-emergence application of oxadiargyl @ 80 g/ha alone resulted in improved weed-control efficiency, better yield attributes, and higher grain and straw yields, besides fetching higher net returns and benefit : cost ratio compared with weed-free check.

Key words: Herbicides, Integrated weed management, Pre-emergence application, Rainfed upland rice

Upland rice (*Oryza sativa* L.) constitutes 17% area under rice in India. It is generally cultivated in zones where the annual rainfall is 700–1,100 mm. However, its contribution to rice production is meagre (Sinha *et al.,* 1996). The productivity of rainfed upland rice is low, seldom exceeding 1.0 t/ha. Weed menace is one of the major factors affecting productivity in direct-seeded rice, leading to more than 50% loss in yield (Singh *et al.,* 2000). The slow initial growth of rice under moisture-stress conditions and favourable environment for multiplication of weeds as well as wide spectrum of weed flora have become a serious hindrance to productivity in rainfed upland rice ecosystem. Though hand-weeding is effective, it is highly expensive. The heavy demand for labour during peak period and its scarcity in the recent times due to distressed migration from rural to urban areas necessitates the use of alternative methods of weed control. Since broad-spectrum weed flora may not be controlled by herbicides alone, the present investigation was undertaken to identify appropriate integrated weed-management practices to combat the menace of weeds in this fragile rice-production system.

MATERIALS AND METHODS

Field experiments were carried out in the upland block of Agricultural College farm, Naira of Acharya N.G. Ranga Agricultural University (latitude 18° 24'N, longitude 84° 20'E, altitude 30 m above mean sea-level) for two consecutive rainy (*kharif*) seasons of 2005 and 2006. The soils of the experimental site were sandy loam, with pH 7.2, low in organic C (0.35 %), medium in available P (13.1 kg/ha), and high in available K (382.2 kg/ha). Rice 'Pushkala' (105 days duration) was sown directly in rows, 20 cm apart, at 90 kg/ha in the first fortnight of July in both the years. During the crop-growing period, 981.2 mm rainfall in 45 rainy days and 714.4 mm in 41 rainy days were received in 2005 and 2006, respectively. The crop received 60.0 kg N + 17.47 kg P + 25.0 kg K + 20.16 kg Zn/ha. The experiment comprised 12 treatments, viz. T_1 farmers' practice (three hand-hoeings at 2, 4 and 6 weeks after sowing; taken as weed-free check in view of negligible weed density); T_2, weedy check; T_3, pre-emergence application of pretilachlor @ 1.0 kg/ha; T_4, butachlor @1.25 kg/ha; T_5, metsulfuron methyl 10% + chlorimuron ethyl 10% @ 6 g/ha; T_6, oxadiargyl @ 80 g/ha; T_7, working with star weeder at 20 and 40 days after sowing (DAS); T_8, T_3 + working with star weeder at 40 DAS; T_9, T_4 + working with star weeder at 40 DAS; T_{10}, T_5 + working with star weeder at 40 DAS; T_{11}, T_6 + working with star weeder at 40 DAS; and T_{12}, mixing horse gram seed @ 8 kg/ha with the recommended seed rate of rice and incorporating horsegram at 40 DAS. The herbicides were applied (all pre-emergence) with knapsack sprayer fitted with flat-fan nozzle, using spray volume of 500

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litres/ha. The experiment was laid out in randomized block design with three replications.

The density and dry weight of weeds were taken at 20 and 40 DAS using a quadrate of 0.25 m^2 from four places in each plot. In the treatments where star weeder was integrated with herbicides, weeding was done after recording the data on weed parameters. The data on the number (weed counts) and dry weight of weeds were subjected to square-root transformation and statistically analysed following standard procedure.

RESULTS AND DISCUSSION

Effect on weeds

The predominant weeds observed in the experimental plots were: *Echinochloa cruss-galli* (L.) P. Beauv (2.8%), *Echinochloa colonum* (L.) Link (12.9%), *Cynodon dactylon* (L.) Pers (4.7%), *Leptochloa chinensis* (8.5%), *Dactyloctenium aegyptium* (5.4%) and *Digitaria sanguinalis* Scop. (5.8%) among grasses; *Cyperus rotundus* (15.4%), *Fimbristlis miliacea* Vahl (3.5%) and *Cyperus iria* (4.5%) among sedges (together 23.4%); and *Celosia argentea* (22.4%), *Trianthema portulacastrum* (4.4%) and *Boerhavia diffusa* (3.7%) among dicotyledonous weeds.

All the weed-control treatments significantly reduced grasses, sedges, dicotyledonous weeds as well as total weed density and dry weight of weeds. The lowest density of grasses was recorded with weed-free check, which was on a par with application of metsulfuron methyl 10% + chlorimuron ethyl 10%, metsulfuron methyl 10% + chlorimuron ethyl 10% + working with star weeder, and oxadiargyl + working with star weeder. The trend of density of sedges remained the same as that of grasses. However, the weed-free check was also comparable with oxadiargyl + working with star weeder, mixing horsegram seed with rice seed and pretilachlor + working with star weeder. Similar trend was observed for reduction in the density of dicotyledonous weeds and total weed density at both the intervals of sampling. The highest weed density was recorded with weedy check.

All the weed-control treatments significantly reduced dry weight of weeds compared with the weedy check at both the stages (Table 1). The lowest dry weight of weeds was recorded with weed-free check (farmers' practice), which was however in parity with metsulfuron methyl 10% + chlorimuron ethyl 10% and oxadiargyl + working with star weeder at 40 DAS. It was also comparable with metsulfuron methyl 10% + chlorimuron ethyl 10% + working with star weeder and pretilachlor + working with star weeder. Weed-free check recorded the highest weed-control efficiency (95.8%), closely followed by oxadiargyl + working with star weeder (92.8%) and metsulfuron methyl 10% + chlorimuron ethyl 10% + working with star weeder (92.2%). This may be due to effective suppression of weed growth at the early stages by pre-emergence herbicides, followed by its integration with star weeding at later stage of crop growth.

Table 1. Effect of weed-control treatments on weed parameters at 40 DAS in rainfed upland rice (pooled data of 2005-2006)

Treatment	Weed density (no/m^2)				Dry weight of weeds (g/m^2)	Weed-control efficiency (%)
	Grasses	Sedges	Dicots	Total		
T_1, Weed-free	1.17 (1.37)	1.39 (1.93)	1.20 (1.44)	2.19 (4.80)	2.51 (6.30)	95.8
T_2, Weedy check	3.09 (9.55)	2.95 (8.70)	2.71 (7.34)	5.07 (25.71)	12.73 (162.05)	
T_3, Pretilachlor @ 1.0 kg/ha	1.75 (3.06)	1.93 (3.73)	1.93 (3.73)	3.24 (10.50)	5.47 (29.92)	81.8
T_4, Butachlor @1.25 kg/ha	1.91 (3.65)	1.98 (3.92)	1.94 (3.76)	3.37 (11.36)	5.74 (32.95)	81.3
T_5, Metsulfuron methyl 10% + chlorimuron ethyl 10% @ 6 g/ha	1.60 (2.56)	1.70 (2.89)	1.57 (2.47)	2.84 (8.07)	4.15 (17.22)	89.2
T_6, Oxadiargyl @ 80 g/ha	1.76 (3.10)	1.88 (3.53)	1.75 (3.06)	3.14 (9.86)	4.76 (22.66)	86.3
T_7, Working with star weeder at 20 and 40 DAS	1.60 (2.56)	4.14 (17.14)	1.79 (3.20)	3.14 (9.86)	4.07 (16.57)	90.6
T_8, T_3 + working with star weeder at 40 DAS	1.63 (2.66)	1.73 (2.99)	1.48 (2.19)	2.76 (7.62)	3.68 (13.54)	91.4
T_9, T_4 + working with star weeder at 40 DAS	1.60 (2.56)	1.91 (3.65)	1.52 (2.31)	2.93 (8.59)	3.81 (14.52)	91.1
T_{10}, T_5 + working with star weeder at 40 DAS	1.50 (2.25)	1.72 (2.96)	1.45 (2.10)	2.77 (7.67)	3.42 (11.70)	92.2
T_{11}, T_6 + working with star weeder at 40 DAS	1.37 (1.88)	1.73 (2.99)	1.53 (2.34)	2.72 (7.40)	3.41 (11.63)	92.8
T_{12}, Mixing horsegram seed @ 8 kg/ha with recommended seed rate of rice and incorporating at 40 DAS	1.81 (3.28)	1.76 (3.10)	1.57 (2.46)	2.98 (8.88)	4.09 (16.73)	87.9
SEm±	0.12	0.13	0.09	0.15	0.42	
CD (P=0.05)	0.37	0.39	0.27	0.46	1.31	

*Data were subjected to square-root transformation. Figures in parentheses are means of original values

Effect on crop

Application of metsulfuron methyl 10% + chlorimuron ethyl 10% or its integration with star weeding recorded the lowest plant height both at 20 and 40 DAS of sampling, and was significantly inferior even to weedy check, indicating the phytotoxic effect of these herbicides on rice crop at the early stage of its growth (Table 2). However, at flowering significantly lower plant height was recorded in weedy check, followed by metsulfuron methyl 10% + chlorimuron ethyl 10% and metsulfuron methyl 10% + chlorimuron ethyl 10% + working with star weeder. The tallest plants were noticed in weed-free check at flowering. Significant disparity was noticed for total and productive tillers/clump due to weed-control treatments. Maximum number of total and productive tillers/clump was recorded in weed-free check, which was however on a par with working with star weeder at 20 and 40 DAS and oxadiargyl + working with star weeder. The lowest tiller number (total and productive) was observed in weedy check, which was on a par with sole application of metsulfuron methyl 10% + chlorimuron ethyl 10%.

Significantly smaller panicles were produced in weedy check, which was however in parity with that of pretilachlor, butachlor, metsulfuron methyl 10% + chlorimuron ethyl 10% and metsulfuron methyl 10% + chlorimuron ethyl 10% + working with star weeder. For percentage of filled grains/panicle, weed-free check registered significantly higher percentage of sound grains, whereas weedy check gave the lowest grain-filling percentage. Among the herbicide treatments, oxadiargyl, working with star weeder at 20 and 40 DAS, pretilachlor + working with star weeder, butachlor + working with star weeder, oxadiargyl + working with star weeder and mixing horsegram seed with rice seed were found on a par with each other and significantly superior to the rest of the herbicide treatments. The lowest test weight was recorded with metsulfuron methyl 10% + chlorimuron ethyl 10%, which was, however, on a par with weedy check. Pre-emergence application of oxadiargyl, working with star weeder at 20 and 40 DAS, oxadiargyl + working with star weeder and mixing horsegram seed with rice seed produced significantly heavier grains and were on a par with weed-free check. Significantly higher number of grains/panicle was recorded with weed-free check. The next best treatments were working with star weeder at 20 and 40 DAS, butachlor, pretilachlor + working with star weeder and butachlor + working with star weeder, which were comparable with each other but superior to the rest of the treatments. The lowest number of filled grains/panicle was recorded with weedy check. Effective suppression of weed growth throughout the critical period of crop-weed competition might have enabled the rice crop to bear

Table 2. *Effect of weed-control treatments on crop parameters, net returns and benefit : cost ratio in rainfed upland rice (pooled data of 2005-2006)*

Treatment	Plant height (cm)			Tillers/clump		Panicle length (cm)	Filled grain panicle	Grain filling (%)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Weed index (%)	Net returns (Rs/ha)	B : C ratio
	20 DAS	40 DAS	Flowering	Maximum tillering	Flowering									
T_1	23.6	44.1	89.0	12.4	11.0	20.5	66.6	75.7	21.2	2.43	4.47		2,703	1.17
T_2	21.3	39.0	75.2	4.5	3.7	16.6	41.3	45.2	18.6	0.91	3.11	62.6	-4,212	0.62
T_3	23.3	43.1	83.0	7.4	5.8	18.8	57.1	64.8	20.2	1.92	3.85	26.7	2,800	1.24
T_4	22.9	42.1	85.0	7.6	5.8	18.4	56.9	65.5	20.0	1.98	3.83	18.5	3,345	1.29
T_5	19.0	36.9	80.5	5.4	4.1	17.0	49.3	54.7	19.2	1.58	3.23	34.9	505	1.04
T_6	23.7	43.3	85.3	8.9	7.5	19.9	59.4	65.2	20.8	2.09	4.11	13.5	4,210	1.37
T_7	23.2	43.6	85.8	10.9	9.8	20.1	61.1	68.5	20.9	2.11	4.19	13.0	2,433	1.18
T_8	23.6	43.6	84.8	8.8	7.7	20.0	60.1	69.1	20.4	2.17	4.08	10.5	3,445	1.27
T_9	23.5	43.1	85.7	8.9	7.4	19.5	59.8	69.5	20.5	2.10	4.10	11.6	3,055	1.24
T_{10}	19.1	37.6	83.6	6.4	6.0	17.8	52.7	59.6	20.1	1.92	3.73	20.4	1,840	1.15
T_{11}	23.6	43.8	86.6	10.7	9.2	20.2	62.3	66.9	20.5	2.21	4.31	8.9	3,880	1.31
T_{12}	23.7	44.1	86.6	9.4	8.1	19.7	59.5	63.5	20.6	1.99	3.77	18.1	2,268	1.18
SEm±	0.1	0.3	0.4	0.6	0.5	0.7	1.3	2.7	0.2	0.07	0.12			
CD (P=0.05)	0.4	0.9	1.3	1.8	1.6	2.2	4.1	8.2	0.7	0.23	0.37			

*Treatment details given in Table 1

promising architecture of yield attributes and higher grain filling percentage in weed-free check and in integrated weed-management practices compared with the weedy check.

All the weed-control treatments resulted in significantly higher grain yield over the weedy check. The reduction in grain yield due to uncontrolled weed growth was 62.6% (Table 2). Significantly higher grain yield was recorded with weed-free check, which was however on a par with that under oxadiargyl 80 g/ha + working with star weeder at 40 DAS. Among the herbicide treatments, metsulfuron methyl 10% + chlorimuron ethyl 10% registered significantly lower grain yield.

Significantly higher straw yield was recorded with weed-free check, which was however in parity with that under oxadiargyl + star weeding, working with star weeder at 20 and 40 DAS and butachlor + working with star weeder. The lowest straw yield was recorded with weedy check, which was however on par with that under metsulfuron methyl 10% + chlorimuron ethyl 10%. The lowest weed index (8.9%) was observed with oxadiargyl + star weeding, and the highest (62.6%) with weedy check. The superior performance of the integrated treatments over their respective sole application of herbicides might be due to effective suppression of weeds in early stages by pre-emergence herbicides and at later stages by star weeding, as reflected in reduced weed growth, which in turn enabled the rice crop to produce better yield. However, the efficacy of metsulfuron methyl 10% + chlorimuron ethyl 10% in terms of better weed control could not be translated into increased grain and straw yields due to its strong phytotoxic effect on crop, as seen from the drastic 19, 16 and 9.6% reduction in plant height at 20 and 40 DAS and at flowering respectively (Table 2). The results are in close conformity with those reported by Saha (2006).

Economic analysis

The monetary advantage based on mean of 2 years of experimentation indicated that the maximum net returns were obtained with oxadiargyl @ 80 g/ha + working with star weeder at 40 DAS, whereas the benefit : cost ratio (1.37) was marginally higher with oxadiargyl @ 80 g /ha alone over oxadiargyl @ 80 g/ha + working with star weeder at 40 DAS (Table 2). The slight reduction in the benefit : cost ratio, despite higher net returns, could be attributed to the additional manual labour involved in star weeding operation, which escalated the cost and marginalized the benefit. Hand-weeding treatment improved the grain and straw yields, reduced the net returns and benefit : cost ratio owing to higher labour cost, indicating that it was less remunerative than other integrated weed-management practices. Mukherjee and Singh (2005) also reported similar results.

It was concluded that the integrated use of oxadiargyl @ 80 g/ha as pre-emergence spray, followed by star weeding at 40 DAS or oxadiargyl @ 80 g/ha alone was effective in checking the weed population and their growth, and proved remunerative and economical in rainfed upland rice ecosystem.

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