



Developing efficient weed management practices for higher productivity and profitability in aerobic rice (*Oryza sativa*) cultivation

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ABSTRACT

A field experiment was conducted on weed management in aerobic rice (*Oryza sativa* L.) cultivation during dry season in 2013, 2014 and 2015. Efficacy of different weed management tools was compared for their weed suppression ability in the cultivation of an improved rice variety, Sahbhagi Dhan at aerobic soil situations. The study showed highest (around 60%) weed control efficiency (WCE) and lowest (around 15%) weed index (WI) with intensive weed management (IWM), which was, however, found an uneconomical option on account of higher cost of weed management. The most economically viable weed management tool was the combined practice of the application of pre-emergence weedicide, Butachlor @ 2.5 l/ha after three days of sowing followed by manual weeding at 4th week stage of crop growth accounting around 35% WCE and 22.12% WI. Grain yield was recorded significantly higher (3.70 - 3.89 t/ha) with IWM followed by 3.61 – 3.62 t/ha with twice manual weeding. However, combined practice of pre-emergence weedicide application followed by manual weeding, although produced comparatively less grain yield of 3.47 – 3.50 t/ha, resulted in higher net return of ₹ 15250.0 and B:C ratio of 1.48 for the lowest cost of weed management (₹ 6075.0). Thus, the study could suggest the application of pre-emergence weedicide supplemented with one manual weeding as the efficient weed management tool that could effectively control weed population in aerobic rice cultivation.

Key words: Aerobic rice, Manual weeding, Productivity and profitability, Weedicide application, Weed management

Looming water crisis is becoming a great challenge for sustainable rice (*Oryza sativa* L.) cultivation in the tropics. Rice is ostensibly a water-guzzling crop, thus balancing a trade-off between crop and water productivity developed the concept of aerobic rice (Belder *et al.* 2005). Unlike temperate region, yield potentiality of tropical aerobic rice is moderately high; although, actual yields happen to be much lower, largely due to lack of proper weed management. Aerobic environment experiences a transitional soil water regime of dry and wet spell alternately that creates a congenial micro-environment prompting emergence and growth of highly competitive complex weed flora in different flushes (Mishra and Singh 2008). Thus, weed appears to be the main impediment in aerobic rice cultivation causing even 80 - 100% loss in grain yield (Rao *et al.* 2007). Germination of both rice and weed occurs concurrently in this environment; however, weed pressure becomes severe due to the lack of a 'head start' of rice seedling over weeds. Therefore, fast growing

weed population quickly smothers rice crops. This implies the prospect of this aerobic rice is largely governed by an effective weed management technology.

Taking account the varying nature of weed and different flushes in their growth, no single method could suppress weed population effectively. Farmers are mostly reluctant opting cost intensive manual/mechanical weeding alone (Rodder 2001); while, though economic, weedicide application is another concern with far reaching consequences (Singh *et al.* 2006). Thus, socio-economic inhibition for cost intensive manual weeding *vis-à-vis* environmental degradation with weedicides application alone emerged as the paradoxical issue to be resolved for developing a viable weed management technology in aerobic rice cultivation.

Understanding above situation insisted us conducting the present study to generate information on a comprehensive manner against weed control in aerobic rice taking account contribution of both cultural management and weedicide application, the information of which was not adequately available across the country in aerobic rice cultivation.

MATERIALS AND METHODS

The study was conducted under the aerobic environment at the research farm in the ICAR-National Rice Research

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Institute, Cuttack during three dry seasons in 2012, 2013 and 2014 successively. Geographic location of the experimental site was at 20° 30' North and 86° East, and at an altitude of 22 m above mean sea level where ground water table remained within 5075 cm throughout the cropping season. The soil was *aeric, heplaquept* analyzing 0.83% organic C, 0.09% total Kjeldahl N, 12 mg/kg soil available phosphorus, 65 mg/kg soil available potash and pH of 6.8. The texture of the soil was sandy clay loam with bulk density 1.3-1.6 g/ cc and field capacity 2.8 mm/cm depth of soil estimating 45 mm water holding capacity at root zone (30 cm) depth.

A medium duration (100-110 days), photo sensitive, medium stature (80-100 cm) rice genotype, Sahbhagi Dhan was grown during dry season across the year at the aerobic soil environment where soil water potential was maintained at 40 kPa throughout entire growth period.

In the first year, considering weedy (T_1) and weed free (T_2) plots as checks, six weed management methods namely manual weeding once at the stage of 3rd week of crop growth (T_3), manual weeding twice at the stage of 2nd and 4th week of crop growth (T_4), application of pre-emergence weedicide, Butachlor (2,Chloro-2,6,Diethyl-N-Butoxymethyl Acetanilide @ 2.5 l/ ha after three days of sowing (T_5), application of post emergence herbicide, Na salt of 2,4-D (2, 4-Dichlorophenoxy acetic acid sodium salt) at 2.0 l/ha after two weeks of sowing (T_6), T_5 + manual weeding once at the stage of 4th week of crop growth (T_7) and T_6 + manual weeding at the stage of 4th week of crop growth (T_8) were compared for their efficacy in suppressing weed population. Stages of different weed management practices were decided in principle of keeping weed pressure at minimum level during first 30-35 days, which is considered as the most critical stage of crop growth for medium duration rice genotype.

In the 2nd and 3rd year, two weed management methods emerged better out of 1st year study were compared with another weed management method, i.e. intensive weed management constituted with the application of pre-emergence weedicide, Butachlor @ 2.5 l/ha after three days of sowing supplemented with manual weeding twice at the stage of 2nd and 4th week of crop growth. Thus, treatments in the 2nd and 3rd year were weedy (T_1) and weed free (T_2) plots as checks, and three other weed management namely, application of pre-emergence herbicide, Butachlor @ 2.5 l/ ha after three days of sowing along with manual weeding at the stage of 3rd week of crop growth (T_3), manual weeding twice at the stage of 2nd and 4th week of crop growth (T_4), and intensive weed management (T_5).

In all the years of study, seeds @ 40 kg/ha were direct sown in dry soil during 1st -2nd week of December at 15 × 15 cm spacing and with recommended dose of N, P₂O₅ and K₂O @ 120, 60 and 60 kg/ha respectively within the plot size of 45 m². A flush irrigation was applied soon after sowing facilitating uniform germination. Further irrigation was scheduled to maintain 40 kPa soil moisture potential at 30 cm root zone depth.

Weed was collected at 35 days of crop growth (tillering stage) from per sq m area in each treatment plot determining weed population density, fresh and dry weed biomass, and weed control efficiency (WCE), which was determined as; $WCE (\%) = \{ \text{dry biomass of weeds in (weedy plot-treated plot)} / \text{dry biomass of weed in weedy plot} \} \times 100$. Grain yield was estimated at 14% moisture content taking a sample harvest from 5 m² areas in each plot; subsequently, benefits of superior management methods in terms of different production economic parameters along with weed index (WI) were determined. WI could derive the relative yield advantages on account of weed management comparing with the crops under weed free condition, it could be determined as, $WI (\%) = \{ \text{Grain yield in (weed free plots- treated plot)} / \text{Grain yield in weed free plot} \} \times 100$.

All the treatments were arranged in a randomized complete block design with three replications. The data were subjected to standard analysis of variance using standard statistical procedure as suggested by Gomez and Gomez (1984). The treatment differences were tested following least significant difference (LSD) tests and compared at $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

Composite nature of weeds

Different types of weed prevailing during the crop growth periods showed dominance of grassy weeds in the field accounting for 70-75% population density at the beginning of the season; while sedges and broadleaf weeds prevailed vigorously on the later stages of crop growth. Predominant grassy weeds were *Echinochloa colona*, *Echinochloa crus-galli*, *Dactyloctenium aegypticum*, *Eleusine indica*; sedges were *Cyperus iria*, *Cyperus rotundus*, *Fimbristylis milliacea*, *Amaranthus spinosus*, *Alternanthera sessilis* and broad leaf weeds were *Eclipta alba*, *Eclipta prostrata*, *Commelina benghalensis*, *Portulaca oleracea*, and *Euphorbia hirta*.

Results obtained from the 1st year showed higher WCE (40.6%) with manual weeding twice at the stage of 2nd and 4th week of crop growth; next higher WCE (37.0%) was recorded with the application of pre-emergence weedicide, Butachlor followed by manual weeding at the stage of 4th week of crop growth (Table 1). This was attributed to low weed pressure (22-30 weed/m²) with less fresh (205-220 g/m²) and dry weed (84-89 g/m²) biomass (Bahar and Singh 2004).

In the 2nd and 3rd year also, two weed management practices found better in 1st year study namely, manual weeding twice at the stage of 2nd and 4th week of crop growth and application of pre-emergence weedicide, Butachlor followed by manual weeding at the stage of 4th week of crop growth showed consistently better performances with higher WCE (34-38%), which was attributed to low weed pressure (25-32 weed plants/m²) with less fresh (165-220 g/m²) and dry weed (85 - 95 g/m²) biomass as compared with weedy/ weed free checks (Table 2). Although, maximum WCE

Table 1 Influence of improved management on different weed parameters and grain yield of aerobic rice, variety Sahbhagi Dhan in 2013

Treatment	Weed density (weeds/m ²)	Fresh weed biomass (g/m ²)	Dry weed Biomass (g/m ²)	WCE (%)	Weed Index (%)	Grain yield (t/ha)
Weedy check(T ₁)	80.5	260.5	140.7			1.50
Weed free check(T ₂)	20.4	170.3	55.6	60.48		4.64
Manual weeding once at 3 rd weeks' stage (T ₃)	25.8	212.8	92.8	30	26.70	3.40
Manual weeding twice at 2 nd & 4 th weeks' stage (T ₄)	22.5	205.4	83.6	40.6	11.64	4.10
Pre-emergence weedicide, Butachlor @ 2.5 l/ha (T ₅)	35.5	235.7	105.5	25.0	29.96	3.25
Post emergence weedicide, 2,4 D @ 2.0 l/ha (T ₆)	50.0	245.0	110.0	21.8	33.18	3.10
T ₅ + Manual weeding once at 4 th weeks' stage (T ₇)	30.8	220.0	88.6	37.0	15.95	3.90
T ₆ + manual weeding once at 2 nd weeks' stage (T ₈)	28.7	230.5	100.0	28.9	27.80	3.35
SEm±	0.40	0.80	0.70	1.20		0.02
CD (P= 0.05)	1.10	2.30	2.20	3.50		0.07

Table 2 Influence of improved management on different weed parameters and grain yield of aerobic rice, variety Sahbhagi Dhan during 2014 and 2015

Treatment	Weed density (weed/m ²)		Fresh weed biomass (g/m ²)		Dry weed biomass (g/m ²)		WCE (%)		Grain yield (t/ha)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Weedy check(T ₁)	85	82	270.2	268.5	145.5	138.06			1.65	1.58
Weed free (T ₂)	20	18	182.3	103.38	53.4	50.41	63.30	63.49	4.55	4.37
Pre-emergence weedicide/b Manual weeding once at 4 th weeks' stage (T ₃)	32	28	225.0	178.85	95.4	90.51	34.43	34.44	3.47	3.50
Manual weeding twice at 2 nd & 4 th weeks' stage (T ₄)	28	25	200.0	165.92	90.6	86.78	37.7	37.14	3.61	3.65
Intensive weed management (T ₅)*	19.6	22	200.0	210.03	54.6	57.28	62.5	58.50	3.89	3.70
SEm±	0.65	0.70	0.68	3.80	0.50	3.65	1.80	1.10	0.02	0.01
CD (P= 0.05)	2.01	2.20	2.00	11.00	1.40	10.20	5.05	3.41	0.07	0.04

* T₅: Pre-emergence weedicide application + T₄.

(58-62%) was recorded with intensive weed management (T₅) due to lower weed pressure (19-22 weed plants/m²) and lesser fresh (200-210 g/m²) and dry weed (54-57 g/m²) biomass (Zhao *et al.* 2007).

Grain yield

Results of the 1st year study showed significant variation in grain yields among different weed management treatment. Manual weeding twice at the stage of 2nd and 4th week of crop growth was attributed with significantly higher grain yield (4.10 t/ha) accounting for more than double yield advantages as compared with that in weedy check and around 12% less than that at weed free check (Table 1). While, the second best weed management tool was the application of pre-emergence weedicide followed by manual weeding

once at the stage of 4th week of crop growth stage, which was attributed with the grain yield of 3.90 t/ha, around 15% than that of weed free check (Zhao *et al.* 2007).

Results of 2nd and 3rd year of the study showed consistently higher grain yield with these two weed management tools namely, manual weeding twice at the stage of 2nd and 4th week of crop growth and application of pre-emergence weedicide, 'Butachlor' followed by manual weeding at the stage of 4th week of crop growth. Although, grain yield (3.61-3.65 t/ha) produced in the crops stands with manual weeding twice was significantly higher than that with pre-emergence weedicide application followed by manual weeding once at 4th week of crop growth. However, the highest grain yield of 3.70-3.89 t/ha was pronounced with intensive weed management, which was around 15%

less than that at weed free check (Singh *et al.* (2008)).

Thus, single application of either pre- or post emergence herbicide alone did not hold promise as it contributed only 21-25% WCE; thus, implying the necessity of one supplementary manual weeding for higher WCE. These observations were in conformity with some earlier reports by Mishra and Singh (2008). Accordingly, application of pre-emergence herbicide, Butachlor followed by manual weeding once at 4th week of crop growth stage was found as effective as manual weeding twice at the stage of 2nd and 4th week of crop growth. However, taking account the dearth of man power, manual weeding could be advocated to be substituted with pre-emergence weedicide application. Although, contradicting this observation, a different opinion was also reported in a study with higher dose (4 l/ha) of Butachlor application in an irrigated rice-wheat system as a sole weed control tool (Sharma *et al.* 2006) .

Production economics

Weed index (WI) derived across the year of the study implied the relative yield advantages among different treatments (Ghosh *et al.* 2016). The highest WI (33.18%) resulting lower grain yield was found with post emergence weedicide application in the 1st year and the lowest WI (11.64%) resulting higher grain yield was found with manual weeding twice at 2nd and 4th week of crop growth (Table 1). While, during 2nd and 3rd year, highest WI (23.74 and 19.91%) resulting lower grain yield and lowest WI (14.50 and 15.33%) resulting higher grain yield were found with pre-emergence weedicide application followed by manual weeding at 4th week of crop growth and intensive weed management respectively (Table 3). These observations were in conformity with some earlier report also (Pradhan *et al.* 2016).

Cost of weed management taking account the nature of operations and input investment in different treatments ranged from ₹ 6650.0 to 10750.0/ha and ₹ 5440.0 to 9540.00/ha during 2nd and 3rd year respectively, compared that of ₹ 24875.0 and 23680.00 for maintaining a weed free condition during respective year. Pooled data of 2nd and 3rd year results showed lower cost of weed management (₹ 6075.00 /ha) with the application of pre-emergence weedicide followed by manual weeding, which incurred around 20% of the total cost of cultivation. While, higher costs of weed management were recorded with manual weeding twice and intensive weed management contributing around 24 and 27% of the total cost of cultivation, respectively. Rodder (2001) also showed combined practice of weedicide application supplemented with manual weed management very much cost effective, instead of manual weeding alone.

As a result, net return (₹ 12042.00 and 18310.00 /ha) and B:C ratios (1.34 and 1.59) were estimated maximum with the application of pre-emergence herbicide followed by manual weeding during 2nd and 3rd year’s of study, closely followed by manual weeding twice with net return (₹ 11846.0 and 17865.0/ha) and B:C ratio (1.31 and 1.53). Singh *et al.* (2008) also derived similar results in their study showing

Table 3 Production economics of different weed management tools in cultivation of aerobic rice, variety Sahbhagi Dhan, during 2014 and 2015

Treatment	Weed Index (%)		Cost of weed management (₹/ha)		Cost of production* (₹/ha)		Gross return (₹/ha)		Net return (₹/ha)		B:C ratio			
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015		
Weedy check(T ₁)														
Weed free (T ₂)			0.0	0.0	26825.0	25600.0	26250.5	22440.0	22278.0	22425.0	3400.0	3322.0	0.84	0.87
Pre-emerg. weedicide fb weeding at 4 th week stage (T ₃)	23.74	19.91	6650.0	5440.0	35150.0	31040.0	33150.0	47192.0	49350.0	48330.0	12042.0	18310.0	1.34	1.59
Weeding twice at 2 nd and 4 th week stage (T ₄)	20.66	16.47	9300.0	8000.0	37800.0	33600.0	35825.0	49096.0	51465.0	50325.0	11296.0	17865.0	1.30	1.53
IWM(T ₅)	14.50	15.33	10750.0	9540.0	10185.0	39250.0	35140.0	37250.0	52904.0	52170.0	13654.0	17030.0	1.35	1.48

*Cost of weed management + cost of other management practices (₹ 28500.00 in 2014 and 25600.0/ha in 2015). MSP of rice – ₹ 13600/tonne in 2014 and ₹ 14100.0 /tonne in 2015

economic advantages with combined management practice of weedicide application along with manual weeding.

Conclusions

Field studies during 2013 to 2015 showed that prevailing alternate wet and dry soil water condition accelerated vigorous weed growth at different flushes in aerobic rice cultivation. As a result, rice productivity often comprised with higher weed pressure unless efficient weed management practices would be followed. Therefore, comparing different weed management tools, the study showed that application of pre-emergence herbicide, Butachlor @ 2.5 l/ha after three days of sowing followed by manual weeding once at 4th week of crop growth stage was better than other management practices. Accordingly, this management tool resulted in higher profitability with net return of ₹ 15250.0 and B:C ratio of 1.48. Thus, the study could suggest the application of pre-emergence weedicide followed by a single manual weeding as an efficient and economically viable weed management tool in aerobic rice cultivation.

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