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Integrated weed management in dry direct-seeded rainy season rice (*Oryza sativa*)

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ABSTRACT

A field experiment was carried out during rainy season (*kharif*) of 2006 and 2007 at Pundibari, West Bengal to work out integrated weed management practices and their economics in dry direct-seeded rice. The weed flora emerged during experimentation were: grasses like *Cynodon dactylon* and *Echinochloa colonum*; sedges like *Cyperus rotundus, C. iria,* and *Fimbristylis miliacea*; and broad-leaved weeds like *Ludwigia parviflora, Ageratum conyzoides, Spilanthes paniculata, Eclipta alba* and *Enhydra fluctuans.* In integrated weed-management practices, butachlor @ 1.5 kg/ha as pre-plant surface application + brown manuring with *Sesbania rostrata* + 2,4-D @ 0.50 kg/ha recorded the highest grain yield (3.00-3.88 t/ha), which was significantly on a par with that obtained from season-long weed-free situation (3.14-3.98 t/ha). The highest net returns (Rs11,889 and 19,029/ha) and benefit : cost ratio (0.74 and 1.19) were also recorded in this treatment. Therefore, this integrated weed management practice could become effective in dry-direct seeded *kharif* rice under foothill (*terai*) agro-climatic region of West Bengal.

Key words: Direct-seeded rice, Grain yield, Integrated weed management, Weed flora

Rice (*Oryza sativa* L.) is cultivated as rainfed crop under transplanted ecosystem during rainy (*kharif*) season in Terai agro-climatic region of West Bengal. Huge labour cost is incurred in the seed-bed preparation, puddling and transplanting operations. Most of the farmers are marginal, unable to bear the cost in carrying out these operations. In addition, long turn-around time and unpredictable monsoon delays the sowing of the succeeding crop. Direct seeding with pre-germinated rice seed in unpuddled condition could be an effective option to overcome these problems if the weeds are controlled effectively, because they become a major constraint in direct-seeded rice ecosystem. Without weeding the transplanted crop significantly outyields the direct-sown crop; but when the weeds were controlled through repeated weeding or with herbicide + hand weeding, the direct-sown crop (broadcast or drilled) gives yields similar to that of the transplanted crop (Singh *et al.,* 1985). A weed-free period for the first 30-45 days after sowing is required to avoid any loss in yield because the dry weight of weeds increases greatly from 30 days after sowing in dry direct-seeded rice (Huh *et al.*, 1995). Uncontrolled weeds reduce the yield by 96% in dry direct-seeded rice, 61% in wet direct-seeded rice and 40% in transplanted rice (Kim and Pyon, 1998). In view of the great loss in yield of dry direct-seeded rice, the present study was conducted to work out integrated weed management practices and their economics.

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MATERIALS AND METHODS

A field experiment weas conducted during 2006 and 2007 at the research farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar (25° 57' N latitude and 88° 25' E longitude), West Bengal. The soil was sandy to sandy-loam, having 0.57% organic C, low in available N (97.3 kg/ha), medium in available P (15.6 kg/ha) and very low in available K (77.2 kg/ha). There were 11 treatment combinations, viz. butachlor @ 1.5 kg/ha used as pre-plant surface application + hoeing at 30 days after sowing (DAS) + 2,4-D @ 0.5 kg/ha used as post-emergence at 40 DAS; pretilachlor @ 0.75 kg/ha as pre-plant surface application + hoeing at 30 DAS + 2,4-D @ 0.5 kg/ha as post-emergence at 40 DAS; pendimethalin @ 0.6 kg/ha as pre-plant surface application + hoeing at 30 DAS + 2,4-D @ 0.5 kg/ha as post-emergence at 40 DAS; benthiocarb @ 1.5 kg/ha as pre-plant surface application + hoeing at 30 DAS + 2,4-D @ 0.5 kg/ha as post-emergence at 40 DAS; butachlor @ 1.5 kg/ha as pre-plant surface application + brown manuring + 2,4-D @ 0.5 kg/ha as post-emergence at 40 DAS; pretilachlor @ 0.75 kg/ha as pre-plant surface application + brown manuring + 2,4-

D @ 0.5 kg/ha as post-emergence at 40 DAS; pendimethalin @ 0.6 kg/ha as pre-plant surface application + brown manuring + 2,4-D @ 0.5 kg/ha as post-emergence at 40 DAS; benthiocarb @ 1.5 kg/ha as pre-plant surface application + brown manuring + 2,4-D @ 0.5 kg/ha as post-emergence at 40 DAS; season long weedy; season long weed free and, farmer's practice comprising three hand weeding at 15, 30 and 50 DAS.

The treatments were laid out in randomized block design with three replications. *Sesbania rostrata* (50 kg/ha) was grown for brown manuring in inter-row spaces of 30 cm between paired row rice at 15 cm row spacing. *Sesbania rostrata* was then killed with the application of 2,4-D @ 0.5 kg/ha at 25 DAS followed by its mulching with the help of paddy weeder. Pre-germinated seed (40 kg/ha) of rice 'Swarnamasuri (MTU 7029)' was sown in rows 15 cm apart on 12 July 2006 and 26 June 2007 in plots of 8 x 4 m. The fertilizer dose was 60 kg N + 30 kg P + 40 kg K/ha. Nitrogenous fertilizer was applied in four splits i.e. one-fourtheach at basal, 25, 45 and 60 DAS in all the treatments, except under farmer's practice where application was made in three splits i.e. one-third each at 15, 30 and 60 DAS. Data on dry weight of weeds were recorded using 50 x 50 cm quadrate.

Rainfall was very much erratic during the monsoon period of 2006 leading to occurrence of drought, but it was well distributed in 2007. Economic analysis was done on the basis of prevailing market price of inputs used and the output obtained from each treatment. Sale price of output per t was: rice grain, Rs 7,500; rice straw, Rs 1,000; input price (kg): rice seed, Rs 10; seed of *Sesbania rostrata*, Rs 10; urea, Rs 4.78; single superphosphate, Rs 3.22; muriate of potash, Rs 4.45; herbicides (litre): butachlor, Rs 180; pretilachlor, Rs 480; pendimethalin, Rs 584; benthiocarb, Rs 384; 2,4-D sodium salt, Rs 220/kg ; labour wage, Rs 75.1/man day).

RESULTS AND DISCUSSION

Effect on weeds

The weed flora emerged during the period of experimentation were: grasses like *Cynodon dactylon* and *Echinochloa colonum;* sedges like *Cyperus rotundus, C. iria* and *Fimbristylis miliacea* and broad-leaved weeds like *Ludwigia parviflora, Ageratum conyzoides, Spilanthes paniculata, Enhydra fluctuans* and *Eclipta alba.* Choubey *et al.* (1998) also reported similar finding. Grasses and sedges especially *Cyperus rotundus* appeared during the initial growth stages, whereas broad-leaved weeds specially *Ludwigia parviflora,* and sedges *Cyperus iria* and *Fimbristylis miliacea* emerged after that. These weeds emerged during 15 to 20 DAS and thereafter continuously throughout the growth stages. Other broad-leaved weeds like *Ageratum conyzoides, Spilanthes paniculata* and *Eclipta alba* appeared during the later stages of crop growth. Among the broad-leaved weeds, *Spilanthes paniculata* appeared during the first year and *Enhydra fluctuans* during the second year of experimentation.

The results revealed that among the herbicides + cultural methods of weed control, combination of butachlor + brown manuring followed by 2,4-D application at 40 DAS recorded the lowest dry weight of weeds at all the growth stages, leading to highest weed control efficiency of 80.8 and 86.0% in 2006, and 84.7 and 88.1% in 2007 at 30 and 60 DAS respectively (Table 1). It was closely followed by pretilachlor + brown manuring + 2,4-D at 40 DAS and butachlor + hoeing + 2,4-D at 40 DAS. Among different treatments, butachlor + brown manuring + 2,4-D recorded the lowest weed index of 4.5 and 2.5% in 2006 and 2007, respectively. The highest weed control efficiency and the lowest weed index of butachlor + brown manuring + 2,4-D reflected its selective nature and higher efficacy. Butachlor + brown manuring + 2,4-D was able to reduce the weed pressure because brown manuring acted as a cover crop in suppressing the weed growth effectively at the initial growth stage. Angadi *et al.* (1993), Sharma and Ghosh (2000), and Yadav (2004) also reported similar results.

Effect on crop

The highest yield attributes, viz. panicle length (25.3 and 28.1 cm), 1,000-grain weight (20.9 and 21.0 g) and effective spikelets/panicle (176.7 and 186.0), were recorded in season-long weed-free plots during both the years, mainly due to the lowest dry weight of weeds and highest weed-control efficiency. Among the integrated weed-management practices, the highest yield attributes were recorded with butachlor + brown manuring + 2,4-D due to the lowest weed-crop competition during the crop growth, which was followed by pretilachlor + brown manuring + 2,4-D and butachlor + hoeing + 2,4-D (Table 2).

The highest grain (3.14 and 3.98 t/ha) and straw (5.33 and 6.04 t/ha) yields were recorded with season-long weed-free situation which was statistically on a par with the grain (3.0 and 3.88 t/ha) and straw (5.42 and 5.96 t/ha) yields obtained from butachlor + brown manuring + 2,4-D during both the years of experimentation. This might be due to high weed control efficiency of the latter treatment throughout the crop season without causing any crop phytotoxicity. It was closely followed by pretilachlor + brown manuring + 2,4-D (2.57 and 3.70 t/ha) during 2006, and these were equal during second year. Among the treatments of herbicides integrated with hoeing, butachlor + hoeing + 2,4-D recorded the highest grain (2.10 and 3.23

Table 1. Effect of treatments on dry weight of weeds, weed control efficiency and weed index at harvest in dry direct-seeded *kharif* rice

Treatment	Dry weight of weeds (g/m^2)						Weed control efficiency (%)						Weed index (%)	
	30 DAS		60 DAS		At harvest		30 DAS		60 DAS		At harvest		2006	2007
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007		
Butachlor + hoeing + 2,4-D	2.79	2.64	4.62	4.38	6.38	6.17	72.2	77.4	77.6	80.0	83.2	84.5	33.1	18.8
	(7.39)	(6.52)	(21.16)	(18.98)	(40.55)	(37.76)								
Pretilachlor + hoeing + 2,4-D	3.16	3.00	5.19	5.01	7.11	6.88	64.0	70.5	71.8	73.9	79.1	80.7	35.7	20.8
	(9.59)	(8.51)	(26.62)	(24.79)	(50.36)	(46.96)								
Pendimethalin + hoeing + 2,4-D	3.58	3.43	5.82	5.65	8.25	7.89	53.3	60.6	64.6	66.8	71.9	74.6	39.2	27.6
	(12.44)	(11.36)	(33.44)	(31.56)	(67.83)	(61.92)								
Benthiocarb + hoeing + 2,4-D	3.81	3.66	6.08	5.92	8.68	8.24	47.1	54.9	61.3	63.5	68.9	72.2	39.8	29.9
	(14.08)	(12.99)	(36.60)	(34.68)	(75.04)	(67.60)								
Butachlor + BM + 2,4-D	2.35	2.20	3.70	3.41	5.13	4.96	80.8	84.7	86.0	88.1	89.2	90.0	4.5	2.5
	(5.10)	(4.40)	(13.24)	(11.27)	(26.00)	(24.40)								
Pretilachlor + BM + 2,4-D	2.75	2.61	4.32	4.06	5.99	5.78	73.1	77.7	80.7	83.0	85.2	86.3	18.1	7.0
	(7.15)	(6.41)	(18.21)	(16.12)	(35.62)	(33.28)								
Pendimethalin + BM + 2,4-D	3.20	3.04	4.89	4.66	6.92	6.72	63.1	69.6	75.2	77.5	80.3	81.6	20.1	19.8
	(9.83)	(8.76)	(23.49)	(21.38)	(47.61)	(44.75)								
Benthiocarb + BM + 2,4-D	3.39	3.21	5.27	5.09	7.47	7.27	58.4	65.4	70.9	73.1	77.0	78.4	31.5	21.9
	(11.06)	(9.98)	(27.52)	(25.56)	(55.42)	(52.46)								
Season-long weedy	5.21	5.41	9.75	9.77	15.54	15.61	0.0	0.0	0.0	0.0	0.0	0.0	83.7	71.1
	(26.62)	(28.81)	(94.56)	(95.10)	(241.13)	(243.45)								
Season-long weed-free	0.71	0.71	0.71	0.71	0.71	0.71	100	100	100	100	100	100	0.0	0.0
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)								
Farmer's practice	1.62	1.60	1.81	1.78	2.69	2.75	91.8	92.7	97.0	97.1	97.2	97.0	3.5	2.0
	(2.17)	(2.10)	(2.84)	(2.71)	(6.82)	(7.24)								
SEm±	0.13	0.13	0.30	0.19	0.42	0.40								
CD (P=0.05)	0.28	0.27	0.62	0.40	0.89	0.84								

Data subjected to square-root ($\sqrt{X + 0.5}$) transformation; figures in parentheses are original values; BM = brown manuring; DAS = days after sowing

Table 2. Effect of treatments on yield-attributing characters and yield of dry direct-seeded *kharif* rice

Treatment	Panicle length (cm)		Test weight (g)		Effective spikelets/ panicle		Grain yield (t/ha)		Straw yield (t/ha)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
Butachlor + hoeing + 2,4-D	23.8	27.2	19.9	20.2	165.0	174.7	2.10	3.23	4.67	5.52
Pretilachlor + hoeing + 2,4-D	22.9	26.2	19.4	19.8	156.3	169.0	2.02	3.15	4.59	5.48
Pendimethalin + hoeing + 2,4-D	22.8	26.1	18.9	19.8	149.7	162.0	1.91	2.88	4.58	5.43
Benthiocarb + hoeing +2,4-D	22.5	25.1	18.9	19.7	146.0	159.0	1.89	2.79	4.55	5.36
Butachlor + BM + 2,4-D	24.7	27.9	20.3	20.3	170.7	179.0	3.00	3.88	5.42	5.96
Pretilachlor + BM + 2,4-D	24.0	27.1	19.6	20.2	164.0	176.0	2.57	3.70	5.31	5.89
Pendimethalin + BM + 2,4-D	23.6	26.5	19.3	20.1	158.3	168.3	2.51	3.19	5.22	5.71
Benthiocarb + BM + 2,4-D	23.0	25.8	19.1	19.8	155.3	166.3	2.15	3.11	5.01	5.67
Season-long weedy	18.0	21.0	18.9	19.2	113.7	121.0	0.51	1.15	2.41	3.84
Season-long weed-free	25.3	28.1	20.9	21.0	176.7	186.0	3.14	3.98	5.33	6.04
Farmer's practice	25.1	27.9	20.4	20.6	172.7	180.7	3.03	3.90	5.25	5.97
SEm±	0.8	1.1	0.5	0.6	2.9	2.6	0.2	0.4	0.6	0.5
CD (P=0.05)	1.7	2.4	1.1	1.1	6.0	5.5	0.4	0.9	1.2	1.0

BM = Brown manuring

Table 3. Economics of dry direct-seeded *kharif* rice as influenced by different weed control treatments

Treatment	Total cost (x 10^3 Rs/ha)		Net returns (x 10^3 Rs/ha)		Benefit : cost ratio	
	2006	2007	2006	2007	2006	2007
Butachlor + hoeing + 2,4-D	15.02	15.02	5.40	14.72	0.36	0.98
Pretilachlor + hoeing + 2,4-D	15.20	15.20	4.54	13.90	0.30	0.91
Pendimethalin + hoeing + 2,4-D	15.65	15.65	3.25	11.38	0.21	0.73
Benthiocarb + hoeing + 2,4-D	15.64	15.64	3.09	10.65	0.20	0.68
Butachlor + BM + 2,4-D	16.03	16.03	11.89	19.03	0.74	1.19
Pretilachlor + BM + 2,4-D	16.21	16.21	8.37	17.43	0.52	1.08
Pendimethalin + BM + 2,4-D	16.66	16.66	7.39	12.98	0.44	0.78
Benthiocarb + BM + 2,4-D	16.64	16.64	4.49	12.35	0.27	0.74
Season-long weedy	12.47	12.47	- 6.24	- 9.00	- 0.50	0.00
Season-long weed-free	25.99	25.99	2.89	9.89	0.11	0.38
Farmer's practice	22.24	22.24	5.74	12.98	0.26	0.58

t/ha) and straw (4.67 and 5.52 t/ha) yields, followed by pretilachlor + hoeing + 2,4-D, pendimethalin + hoeing + 2,4-D and benthiocarb + hoeing + 2,4-D during both the years. The grain yield during the first year was lower than that during the second year because of erratic rainfall pattern of the monsoon in 2006, especially because drought prevailed in these areas in August, leading to moisture stress during the active growth stage of rice. However, rainfall pattern of monsoon in 2007 was well distributed during growth stages of rice, resulting in better crop performance.

Economics

Among the integrated weed management practices, butachlor + brown manuring + 2, 4-D registered highest net returns (Rs 11,889 and 19,029/ha) as well as benefit : cost ratio (0.74 and 1.19), during both the years. This might be owing to high weed control efficiency (89.2 and 90.0% at harvest) with least engagement period (mandays) and higher grain yield. The lower net return (Rs 5,738 and 12,983) and benefit : cost ratio (0.26 and 0.58) in farmer's practice might be owing to more period (mandays) in hand weeding at 15, 30 and 50 DAS, which in turn considerably increased cost of cultivation (Table 3).

It was concluded that integrated weed management practices that encompass butachlor @ 1.5 kg/ha as preplant surface application + brown manuring + 2,4-D @ 0.50 kg/ha at 40 DAS could become effective in controlling the weeds as well as for getting higher yield during *kharif* season in dry direct-seeded rice ecosystem under *terai* agro-climatic region of West Bengal.

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