Indian Journal of Agricultural Sciences **79** (12): 976–9, December 2009

Integrated weed management practices in dry direct-seeded summer rice (*Oryza sativa*)

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Received: 12 September 2008; Accepted: 22 September 2009

ABSTRACT

A field experiment was carried out during summer of 2007 and 2008 to work out integrated weed management practices with its economics in dry direct-seeded summer rice (*Oryza sativa* L.). Among the weed flora, grasses, like Bermudagrass [*Cynodon dactylon* (L.) Pers.], Jungle rice [*Echinochloa colona* (L.) Link], Large crabgrass [*Digitaria sanguinalis* (L.) Scop.], Signalgrass [*Brachiaria ramosa* (L.) Stapf]; sedges, like *Cyperus pilosus* L., Flatsedge (*Cyperus iria* L.) and broad-leaved weeds, like Spiny amaranth (*Amaranthus spinosus* L.), Black nightshade (*Solanum nigrum* L.), Garden spurge (*Euphorbia hirta* L.), *Commelina diffusa* Burmp., Gripe weed (*Phyllanthus niruri* Hook.f.), Common lambsquarters (*Chenopodium album* L.), *Alternanthera* sp., Ground cherry/Hogweed (*Physalis minima* L.) and several species of *Polygonum* was noticed during experimentation. The concept of brown manuring in which seeding of *dhaincha* (*Sesbania rostrata* Brem) with rice seeds, followed by 2,4–D application @ 0.50 kg/ha at 25 days after sowing and subsequent incorporation of dried *dhaincha* with rotary weeder at 35 days after sowing, has been used in integrated weed management. Among the integrated weed management practices, butachlor @ 1.25 kg/ha as pre-plant surface application + brown manuring + 2,4–D @ 0.50 kg/ha at 40 days after sowing recorded highest grain yield (4.36 and 4.18 tonnes/ha) and it was significantly at par with the grain yield (4.53 and 4.31 tonnes/ha) obtained from season-long weed-free situation. Highest net returns (Rs 21 954 and 20 494/ha) and benefit:cost ratio (1.30 and 1.22) was also recorded in this treatment during both the years.

Key words: Direct-seeded summer rice, Integrated weed management, Weed flora in rice

Rice (*Oryza sativa* L.) is cultivated as irrigated crop under transplanted ecosystem during summer season in terai agro-ecological region of West Bengal. Intermittent rain occurring during winter and summer seasons led to create an opportunity to grow summer rice in lowland situation. High cost involved in irrigation water and engagement of manual labour for seedbed preparation, puddling and transplanting operation reduce profit margin of summer rice cultivation. Moreover, most of the farmers in these areas are marginal in nature and unable to bear the cost in carrying out these operations. Direct seeding with pre-germinated rice seed in unpuddled condition could be an effective option to curtail several operations of transplanted rice cultivation, reduce engagement of manual labour and irrigation water. Weeds are considered as a major constraint in dry direct-seeded rice ecosystem. When weed control is optimum and crop establishment is good, yields of direct-seeded rice can equal those of transplanted crops (Sipaseuth *et al*. 2000). In this context the present investigation was conducted to find out economically viable integrated weed management practice in dry direct-seeded summer rice.

Based on complete information of Ph D thesis of the first author submitted to UBKV during 2008

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MATERIALS AND METHODS

Field experiment was conducted on sandy loam soil at the research farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar (25°57′ N–27° N latitude and 88°25′ E–89°54′E longitude), West Bengal during summer season of 2007 and 2008. The soil had *p*H 5.05, organic carbon 0.72%, available N 127.92 kg/ha, available P 21.59 kg/ha, and available K 122.46 kg/ha. The experiment was laid out in randomized block design replicated thrice with 12 treatment combinations, viz butachlor @ 1.25 kg/ha as pre-plant surface application + brown manuring + 2,4–D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_1); pretilachlor @ 0.6 kg/ha as pre-plant surface application + brown manuring + 2,4–D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_2); pendimethalin @ 0.6 kg/ha as pre-plant surface application + brown manuring + 2,4–D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_3);

benthiocarb @ 1.5 kg/ha as pre-plant surface application + brown manuring + 2,4–D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_4); butachlor @ 1.25 kg/ha as pre-plant surface application + hoeing at 30 days after sowing + 2,4–D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_5); pretilachlor @ 0.6 kg/ha as pre-plant surface application + hoeing at 30 days after sowing + 2,4–D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_6); pendimethalin @ 0.6 kg/ha as pre-plant surface application + hoeing at 30 days after sowing + 2,4–D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_7); benthiocarb @ 1.5 kg/ha as pre-plant surface application + hoeing at 30 days after sowing + 2,4–D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_8); PIIH 2023 (bispyribac sodium) @ 25 g/ha as post-emergence at 20 days after sowing + hoeing at 30 days after sowing + 2,4-D @ 0.5 kg/ha as post-emergence at 40 days after sowing (T_9); weedy check (T_{10}); season-long weed-free (T_{11}) and, farmers' practice comprising three hand weedings at 15, 30 and 50 days after sowing (T_{12}). In moisture stress sandy loam soil of this region, pre-plant surface application of herbicides increases selectivity than that of pre-emergence application.

Dhaincha (*Sesbania rostrata* Brem) @ 50 kg/ha was grown for brown manuring in inter-row spaces of 30 cm between paired row rice having the spacing of 15 cm. *S. rostrata* was then killed by the application of 2,4–D @ 0.5 kg/ha at 25 days after sowing followed by its mulching with the help of paddy weeder at 35 days after sowing. Pre-germinated seed (40 kg/ha) of 'GS 2' (Gotra selection 2) rice was sown in rows 15 cm apart in paired row system on 15 March 2007 and 29 March 2008 with the plot size of 8 m×4.5 m. The fertilizer dose was 100 kg N, 40 kg P_2O_5 and 60 kg K_2O/ha. Nitrogenous fertilizer was applied in 4 splits, ie ¼ at basal, ¼ at 25 days after sowing, ¼ at 45 days after sowing and ¼ at 60 days after sowing in all the treatments except under farmer's practice where application was made in 3 splits, ie 1/3 at 15 days after sowing, 1/3 at 30 days after sowing and 1/3 at 60 days after sowing after hand weeding. Potassic fertilizer was applied in 2 splits, ie ½ as basal and ½ at 70 days after sowing in all the treatments. The crop was irrigated twice during active tillering and grain-filling stage. Data pertaining to dry weight of weeds was recorded using 50 cm × 50 cm quadrate from all the plots at 30, 60 days after sowing and at harvest. Data on weed dry weight (g/m^2) were subjected to square-root ($\sqrt{X + 0.5}$) transformation before statistical analysis. The weed control efficiency (WCE) and weed index (WI) were calculated by using the following formulae.

$$WCE = \frac{\text{Dry weight of weed in control plot} - \text{dry weight of weed in treated plot}}{\text{Dry weight of weed in control plot}} \times 100$$

$$WI = \frac{\text{Grain yield in complete weed-free plot} - \text{grain yield in treated plot}}{\text{Grain yield in complete weed-free plot}} \times 100$$

Economic analysis was done on the basis of prevailing market price of inputs used and the output obtained from each treatment (sale price of out put:rice grain Rs 7 500/tonne; rice straw Rs 1 000/tonne; input price: rice seed Rs 10/kg; seed of *S. rostrata* Rs 10/kg; Urea, Rs 4.78/kg; SSP, Rs 3.22/kg; MOP, Rs 4.45/kg; herbicides: butachlor (machete), Rs 180/litre; pretilachlor (sofit), Rs 1 550/litre; pendimethalin (stomp), Rs 444/litre; benthiocarb (saturn), Rs 384/litre; PIIH 2023 (bispyribac sodium), Rs 4 500/litre; 2,4–D sodium salt, Rs 220/kg; labour wage, Rs 75.10/man-day).

RESULTS AND DISCUSSION

Weed flora, weed control efficiency and weed index

The common weeds infesting the experimental field included grasses, like Bermudagrass [*Cynodon dactylon* (L.) Pers.], Junglerice [*Echinochloa colona* (L.) Link], Large crabgrass [*Digitaria sanguinalis* (L.) Scop.], Signalgrass [*Brachiaria ramosa* (L.) Stapf]; sedges, like *Cyperus pilosus* L., Flatsedge (*Cyperus iria* L.) and broadleaved weeds, like Spiny amaranth (*Amaranthus spinosus* L.), Black nightshade (*Solanum nigrum* L.), Garden spurge (*Euphorbia hirta* L.), *Commelina diffusa* Burmp., Gripe weed (*Phyllanthus niruri* Hook.f.), Common lambsquarters (*Chenopodium album* L.), *Alternanthera sp*., Ground cherry/Hogweed (*Physalis minima* L.), Pennsylvania smartweed (*Polygonum pensylvanicum* L.), *P. orientale* L. and Ladysthumb (*P. persicarea* L.). Grasses and sedges, especially Flatsedge (*C. iria* L.) appeared during initial growth stages, whereas broadleaved weeds and other sedges, especially *C. pilosus* L. emerged after initial growth stage. Emergence of these weeds was observed during 20–30 days after sowing and there after it continuously emerged throughout the growth stages.

Experimental results revealed that among the integrated management practices, butachlor + brown manuring with sequential application of 2,4–D at 40 days after sowing registered lowest weed dry weight at all the growth stages leading to highest weed control efficiency of 84.65 and 88.89% in 2007 and 81.10 and 87.98% in 2008 at 30 and 60 days after sowing, respectively (Table 1). These values were closely followed by the values obtained from pretilachlor + brown manuring + 2,4–D, butachlor + hoeing + 2,4–D and PIIH–2023 + hoeing + 2,4–D. Among the integrated weed management practices, butachlor + brown manuring + 2,4-D recorded lowest weed index value of 3.75% and 3.02% in 2007 and 2008, respectively (Table 1). Highest value of weed control efficiency and lowest value of weed index of butachlor + brown manuring + 2,4-D treatment reflected its selectivity and high bio-efficacy in controlling weeds without causing phytotoxicity on rice plant. Butachlor + brown manuring + 2,4–D was able to reduce weed pressure as brown manuring acted as a cover crop in suppressing weed growth effectively at the initial growth stage. The similar results have also been reported by Ravisankar *et al.* (2008), Joseph *et al.*

Table 1 Effect of treatments on dry weight of weeds, weed control efficiency at different days after sowing and weed index at harvest in dry direct-seeded summer rice

Treatment	Weed dry weight (g/m^2)						Weed control efficiency (%)						Weed index (%)	
	30 DAS		60 DAS		At harvest		30 DAS		60 DAS		At harvest			
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Butachlor + BM + 2,4–D	1.82 (2.82)	2.23 (4.53)	3.06 (8.90)	3.31 (10.52)	4.37 (18.67)	4.42 (19.16)	84.65	81.10	88.89	87.98	90.24	90.82	3.75	3.02
Pretilachlor + BM + 2,4–D	1.97 (3.40)	2.37 (5.15)	3.14 (9.44)	3.45 (11.42)	4.43 (19.15)	4.52 (20.00)	81.49	78.51	88.21	86.95	89.99	90.42	5.52	4.18
Pendimethalin + BM + 2,4–D	2.22 (4.44)	2.85 (7.80)	3.47 (11.57)	3.82 (14.19)	5.25 (27.08)	5.28 (27.50)	75.83	67.46	85.55	83.78	85.85	86.82	9.05	6.96
Benthiocarb + BM + 2,4–D	2.49 (5.73)	3.06 (8.97)	3.72 (13.46)	4.05 (15.95)	5.43 (29.02)	5.50 (29.99)	68.81	62.58	83.19	81.77	84.83	85.63	10.38	8.12
Butachlor + hoeing + 2,4–D	2.04 (3.68)	2.62 (6.42)	3.36 (10.77)	3.62 (12.65)	4.91 (23.58)	4.95 (24.16)	79.97	73.22	86.55	85.54	87.68	88.42	13.02	12.06
Pretilachlor + hoeing + 2,4–D	2.31 (4.86)	2.79 (7.36)	3.43 (11.33)	3.68 (13.18)	5.03 (24.78)	5.04 (25.26)	73.54	69.29	85.85	84.94	87.05	87.89	15.67	13.22
Pendimethalin + hoeing + 2,4–D	2.43 (5.43)	3.03 (8.67)	3.82 (14.13)	4.13 (16.63)	5.98 (35.37)	6.02 (35.94)	70.44	63.83	82.36	81.00	81.51	82.78	18.54	16.94
Benthiocarb + hoeing + 2,4–D	2.71 (6.84)	3.20 (9.80)	4.07 (16.14)	4.35 (18.46)	6.31 (39.28)	6.32 (39.61)	62.77	59.12	79.85	78.91	79.47	81.02	19.65	18.33
PIIH–2023 + hoeing + 2,4–D	2.07 (3.77)	2.64 (6.62)	3.08 (8.97)	3.42 (11.26)	4.70 (21.66)	4.75 (22.15)	79.48	72.38	88.80	87.13	88.68	89.38	7.28	5.80
Weedy check	4.34 (18.37)	4.94 (23.97)	8.97 (80.08)	9.36 (87.51)	13.85 (192.34)	14.46 (208.66)	0.00	0.00	0.00	0.00	0.00	0.00	76.16	80.51
Season long weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	100	100	100	100	100	100	0.00	0.00
Farmer's practice	1.62 (2.13)	1.88 (3.04)	2.05 (3.74)	2.09 (3.89)	4.10 (16.30)	4.19 (17.12)	88.41	87.32	95.33	95.55	91.48	91.80	1.99	2.09
S Em (±)	0.10	0.23	0.19	0.24	0.18	0.39								
CD (*P*=0.05)	0.21	0.48	0.39	0.49	0.37	0.80								

Data subjected to square-root (√X+ 0.5) transformation; Figures in parentheses are original values; BM, brown manuring; DAS, days after sowing

(2008), Singh *et al.* (2006), Bhambri and Kolhe (2006) and Duary *et al.* (2005).

Effect on crop

Yield attributes: Highest yield attributes, viz panicle length (27.11 and 26.26 cm), test weight (22.30 and 21.29 g) and effective spikelets/panicle (158.66 and 150.68) were recorded in season long weed-free plots during both the years mainly due to minimum crop-weed competition for growth factors. Among the integrated weed management practices, the highest yield attributes were recorded with butachlor + brown manuring + 2,4–D treatment resulted from lowest weed-crop competition during the crop growth period which was followed by pretilachlor + brown manuring + 2,4–D and butachlor + hoeing + 2,4–D (Table 2).

Yield: Results obtained from the experiment revealed that among the integrated weed management practices, highest grain (4.36 and 4.18 tonnes/ha) and straw (6.11 and 6.00 tonnes/ha) yield were recorded with butachlor + brown manuring + 2,4–D treatment, which were statistically at par with the grain (4.53 and 4.31 tonnes/ha) and straw (6.37 and 6.17 tonnes/ha) yield estimated under season long weed-free situation and was closely followed by pretilachlor + brown manuring + 2,4–D and PIIH-2023 + hoeing + 2,4–D treatments during both the years of experimentation. This was due to selectivity and high weed control efficiency of the treatment (butachlor + brown manuring + 2,4–D) throughout the crop season. Among the treatments of herbicides integrated with hoeing, PIIH 2023 + hoeing + 2,4–D recorded highest grain (4.20 and 4.06 tonnes/ha) and straw yield (5.99 and 5.86 tonnes/ha), followed by butachlor + hoeing + 2,4-D, pretilachlor + hoeing + 2,4–D, pendimethalin + hoeing + 2,4-D and benthiocarb + hoeing + 2,4–D during both the years (Table 2). Lowest grain yield (1.08 and 0.84 tonnes/ha) was recorded in weedy check treatment. The grain yield during first year was higher than second year because of early sowing in the first year.

Table 2 Effect of treatments on yield-attributing characters, yield and economics of dry direct-seeded summer rice

Treatment	Length of panicle (cm)		Test weight (g)		Effective spikelets/ panicle		Grain yield (tonnes/ha)		Straw yield (tonnes/ha)		Net return (Rs/ha)		Benefit: cost ratio	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Butachlor + BM + 2,4–D	26.74	25.98	22.12	21.12	154.67	144.70	4.36	4.18	6.11	6.00	21 954	20 494	1.30	1.22
Pretilachlor + BM + 2,4–D	26.35	25.34	21.63	20.63	151.32	141.33	4.28	4.13	6.06	5.96	18 654	17 429	0.96	0.89
Pendimethalin + BM + 2,4–D	25.76	24.61	21.30	20.11	137.33	128.66	4.12	4.01	5.87	5.84	19 476	18 621	1.13	1.08
Benthiocarb + BM + 2,4–D	25.02	24.22	20.86	19.86	136.00	128.00	4.06	3.96	5.80	5.79	18 692	17 932	1.06	1.02
Butachlor + hoeing + 2,4–D	25.66	25.14	21.59	20.59	135.68	127.35	3.94	3.79	5.57	5.54	19 272	18 117	1.22	1.14
Pretilachlor + hoeing + 2,4–D	24.88	24.32	21.22	20.22	128.32	125.00	3.82	3.74	5.44	5.51	15 592	15 062	0.84	0.81
Pendimethalin + hoeing + 2,4–D	24.12	23.47	21.01	20.01	124.65	121.32	3.69	3.58	5.25	5.33	16 639	15 894	1.02	0.98
Benthiocarb + hoeing + 2,4–D	23.52	22.77	20.67	19.67	120.00	112.34	3.64	3.52	5.21	5.30	15 960	15 150	0.96	0.92
PIIH–2023 + hoeing + 2,4–D	26.02	25.22	21.71	20.71	137.67	133.65	4.20	4.06	5.99	5.86	20 967	19 787	1.27	1.20
Weedy check	21.02	20.55	20.25	19.25	94.70	86.33	1.08	0.84	2.14	1.33	–3 149	–5 759	–0.24	–0.43
Season long weed free	27.11	26.26	22.30	21.29	158.66	150.68	4.53	4.31	6.37	6.17				
Farmer's practice	26.74	26.05	22.22	21.22	154.70	146.00	4.44	4.22	6.22	6.03	15 993	14 153	0.68	0.60
S Em (±)	1.73	1.54	0.58	0.55	9.80	8.69	0.39	0.30	0.44	0.57				
CD (*P*=0.05)	3.59	3.20	1.20	1.14	20.32	18.01	0.81	0.61	0.91	1.17				

Economics

Maximum net returns (Rs 21 954 and 20 494/ha) as well as benefit:cost ratio (1.30 and 1.22) among the integrated weed management practices were obtained in butachlor + brown manuring + 2, 4–D treatment during both the years. This was due to high weed control efficiency (90.24 and 90.82% at harvest) with least man-days engagement and higher grain yield. The lower net returns (Rs 15 993 and 14 153) and benefit:cost ratio (0.68 and 0.60) obtained in farmers' practice were because of more man days that was required for hand weeding at 15, 30 and 50 days after sowing resulting in considerable increased of cost of cultivation (Table 2). Negative values of both net returns and benefit:cost ration were obtained in weedy check treatment because of poor grain yield.

Thus integrated weed management practice comprising butachlor @ 1.25 kg/ha as pre-plant surface application + brown manuring + 2,4–D @ 0.50 kg/ha at 40 days after sowing can be recommended for effective control over weeds as well as getting higher yield during summer season in dry direct-seeded rice ecosystem under terai agro-ecological region of West Bengal.

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