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Influence of integrated weed-management practices on productivity and profitability of wet-seeded rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted at Coimbatore during 2000–2001 and 2001-2002 to study the effect of seeding methods (surface and anaerobic), *in-situ* incorporation of *dhaincha* (*Sesbania aculeata*) and time of pretilachlor-plus application on productivity and profitability of wet-seeded rice (*Oryza sativa* L.). Treatments included two seeding methods, viz. surface wet seeding and anaerobic seeding, with two intercropping levels, viz. sole rice and rice + *dhaincha*; and four weed-control treatments, viz. pretilachlor-plus @ 0.30 kg/ha 2 days after sowing (DAS) followed by (fb) 1 hand-weeding (HW) at 45 DAS, pretilachlor-plus @ 0.30 kg/ha 5 DAS fb 1 hand-weeding at 45 DAS, hand-weeding twice at 20 and 45 DAS, and unweeded check. Surface and anaerobic drill seeding were comparable in terms of weed density, growth and productivity of rice. Conjoint cropping of rice + *dhaincha* and incorporation of the latter at 37 DAS using cono weeder proved better in terms of reducing the total weed density, increasing the crop growth, productivity (5.1 t/ha) and weed-smothering efficiency (25.5%) of wet-seeded rice. Pre-emergence application of pretilachlor-plus @ 0.30 kg/ha on 2 DAS + hand-weeding at 45 DAS registered lower total weed density (53.6/m^2) and higher weed-control efficiency, as well as markedly improved the growth and yield parameters and grain yield (5.6 t/ha). Anaerobic seeding, rice + *dhaincha* and pretilachlor-plus at 2 DAS gave better profit (Rs 13,892/ha). It was concluded that anaerobic seeding, dual cultivation of rice + *dhaincha* and pretilachlor plus @ 0.30 kg /ha on 2 DAS + hand-weeding at 45 DAS is an efficient method for improving weed control, productivity and profitability of wet-seeded rice.

Key words: Productivity, Profitability, Weed management, Wet-seeded rice

Transplanting of rice (*Oryza sativa* L.) is the traditional system of crop establishment; accounting for 21% of the operational cost, critically taking energy of 30 persons/ha/day. As the rice-production system in Asia undergoes major adjustments in response to the rising scarcity of land, labour, capital and water, major adjustment is to be made in the method of establishment. Wet seeding can be practised as an alternative to transplanting in irrigated and rainfed lowlands, as it holds promise for saving labour, time and energy, minimizes drudgery, and ensures efficient water use and increased benefit: cost ratio. Rice farmers in the tropics practise wet seeding by broadcasting or line seeding of germinated seeds on the puddled soil surface. As the seeds are sown on the soil surface, they are often splashed by heavy rain, destroyed by birds and rodents, and are likely to dry-up due to water scarcity and direct exposure to sunlight, resulting in poor seedling establishment. In addition, the plants are prone to lodging due to poor anchorage. To circumvent these deterrents inherent in surface seeding, anaerobic seeding which consists of seeding pre-germinated seeds under the surface of puddled soils merits investigation. Weeds in direct-seeded rice cause 73% loss in yield, and the farmers may end-up using most of the labour saved by wet seeding to control weeds (Milberg and Hallgren, 2004). There is a possibility of intercropping green manures during early stage of rice crop with less interference on the crop growth. This situation can effectively be capitalized upon by raising *dhaincha* (*Sesbania aculeata*) as a green-manure crop conjointly with wet-seeded rice, and incorporating it at 35-40 days of growth using cono weeder. As the crop and weed seeds germinate concurrently in wet-seeded rice and the growth rate of weeds is faster, information on integrated weed management with dual cropping of *dhaincha* and time of pre-emergence herbicide application is essential. Hence, the present study was planned to elicit information on the influence of seeding, intercropping and weed-management practices on productivity and profitability of wet-seeded rice.

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MATERIALS AND METHODS

The field experiment was conducted during 2000-2001 and 2001-2002 at wetland farm of Tamil Nadu Agricultural University, Coimbatore (11° N, 77° E, 427 m mean sea-level). In general, weather during the crop growth period was normal with mean rainfall 292.6 mm, and maximum and minimum temperature 30.6 and 20.3°C (+0.9°C and 0.7°C respectively). The bright sunshine was 6.7 hr/day (+0.6). The soil was clay-loam (*Typic haplustalf*). It was low in available N (280 and 210 kg/ha), medium in available P (15 and 16 kg/ha) and high in available K (694 and 571 kg/ha) during 2000-01 and 2001-02 respectively. The medium-duration rice cv 'Co 43' was grown. *Dhaincha* was grown as the intercrop as per treatment. The experiment was laid out in split-plot design with four replications. The method of seeding and *dhaincha* intercropping were assigned to main plots, and weed management to subplots. The treatments included two seeding methods, viz. surface wet seeding and anaerobic seeding, with two intercropping levels, viz. sole rice and rice + *dhaincha* in main plots, and four weed-control treatments in subplots, viz. pretilachlor-plus @ 0.30 kg/ha 2 DAS followed by (fb) 1 hand-weeding (HW) at 45 DAS; pretilachlor-plus @ 0.30 kg/ha 5 DAS fb 1 hand-weeding at 45 DAS; hand-weeding twice at 20 and 45 DAS; and unweeded check.

Manually operated single-wheel rice-cum-green manure seeder developed by the Tamil Nadu Agricultural University, Coimbatore and anaerobic seeder developed by Borlagdan *et al.* (1993), International Rice Research Institute, Philippines, were used in the study. Sole rice treatment was imposed by closing the *dhaincha* holes. As per treatment schedule, pre-emergence herbicide pretilachlor-plus (pretilachlor prepacked with fenclorim safener - Sofit 30% EC) @ 0.30 kg/ha was applied at 2 and 5 DAS. One hand-weeding at 45 DAS was carried out in herbicide-applied treatments, whereas two hand-weedings were carried out at 20 and 45 DAS in hand-weeding treatment. Intercropped *dhaincha* was incorporated *in-situ* at 37 DAS using IRRI cono weeder. Rice and *dhaincha* were sown simultaneously during the standard week 44 in 2000-01 and standard week 38 in 2001-02, with gross plot size of 6 x 4 m. Pre-germinated rice seeds (seeds soaked in water overnight and incubated for 24 hr) were used @ 75-80 kg/ha (wet weight basis) for both surface and anaerobic drill seeding. For the intercrop *Sesbania aculeata*, the seed rate adopted was 25 kg/ha. The row-to-row spacing was 25 cm between rice with one row of *dhaincha* in the middle. Recommended doses of 150:22:42 kg/ha of N:P:K in the form of urea, single super phosphate and muriate of potash were applied. Nitrogen was applied in four equal splits at 21 DAS, active tillering, panicle initiation and heading, whereas the entire dose of P was applied basal before sowing. Potassium was applied in two equal splits as basal and at heading. A very thin film of water was maintained at the time of drum seeding. For the next 8-10 days, irrigation and drainage were alternated to enable germination of seeds and establishment of seedlings. Thereafter, the crop was irrigated to 5 cm depth at required intervals when the water was completely drained, and irrigation was withheld 10 days before the harvest. Need-based plant-protection measures for rice were followed. Weed-smothering efficiency of *dhaincha* at 20 and 35 DAS was calculated as given by Bhandari (1981). The sampling techniques for all the growth and yield characters including estimation of yield were followed as per standard procedures. Weed density and N removal at 20, 35 and 45 DAS, N uptake by the crop at 20 DAS, tillering and flowering, number of panicles/m^2, and the grain and straw yields at harvest were recorded. The total cost of cultivation was Rs 12,106/ha excluding the treatment cost. The treatment cost for surface and anaerobic seeding was Rs 435 and 485/ha respectively; besides Rs 1,051/ha was additional cost for rice + *dhaincha* compared with sole rice. Returns were worked out using rice-grain price Rs 4,750/t and rice-straw price Rs. 600/t.

RESULTS AND DISCUSSION

Weed growth

Emergence count of rice in anaerobic and surface wet seeding was 381 and 355 /m^2. Population of rice remained almost the same in sole rice (372/m^2) and rice + *dhaincha* (368/m^2). *Dhaincha* population in rice + *dhaincha* was 70.3/m^2. Weather parameters that prevailed during the crop-growth period were more favourable and played a crucial role in *dhaincha* growth, which is essential for smothering of weeds and accumulation of more N. The quantum of dry- matter production from *dhaincha* ranged from 2.18 to 2.52 t/ha (Table 1). The intercropped *dhaincha* led to addition of 50.9 kg N/ha. The variation in biomass and N accumulation by *dhaincha* might be due to inherent differences in growth pattern, which is vulnerable to seasonal variations.

The wet-seeded rice was infested with composite weed flora, comprising grasses (51.5% of total weeds), sedges (30.9%) and broad-leaf weeds (BLW) (17.5%). Among grasses, *Echinochloa colona* (L.) Link was dominant, followed by *E. crusgalli* (L.) P. Beauv and *Leptochloa chinensis* (L.) Ness. Among sedges, *Cyperus* spp. such as *Cyperus difformis* (L.) and *C. irria* (L.) were prevalent. Among broad-leaf weeds, *Eclipta alba* (L.) Hassk outnumbered others, followed by *Ammania baccifera* (L.) and *Ludwigia parviflora* Roxb. *Dhaincha* incorporation effectively reduced the total weed density (Table 2). The total weed density decreased sharply at 45 DAS, and rice + *dhaincha* recorded 62% less density than sole rice. This might have resulted due to the use of mechanical weeder, which besides incorporation of the green-manure also destroyed the weeds (Ravisankar *et al.*, 2007a).

Pretilachlor-plus at 2 DAS effectively controlled the germinating weeds at the plumule-initiation stage itself. It reduced the weed density more compared with pretilachlor-plus at 5 DAS. The presence of crop safener fenclorim in pretilachlor-plus protects the crop from phytotoxicity and hence it can be applied early (on 2 DAS). Suganthi *et al.* (2005) reported that early application of pretilachlor-plus gave commendable control of grasses, followed by BLW and sedges.

Intercropping of *dhaincha* led to higher weed-smothering efficiency. At 20 and 35 DAS, overall weed-smothering efficiency was 13.3 and 26.8 % respectively (Table 1). The lower weed smothering efficiency at 20 DAS was due to slow-growth of *dhaincha* in its earlier stage. However, at later stages (20-35 DAS) due to faster growth and canopy spread by *dhaincha*, the germination and growth of weeds were effectively repressed, with a concomitant increase in weed-smothering efficiency.

Growth and yield of rice

The seeding method had no significant influence on crop-growth rate (CGR) but rice + *dhaincha* intercropping proved significantly superior for CGR than sole rice (Table 2). Among weed-control methods, pretilachlor-plus at 2 DAS gave higher CGR value. Surface and anaerobic seeding were comparable in terms of number of panicles/m^2. This lack of difference was due to the absence of rainfall at the time of sowing, which led to uniform seedling establishment and growth characters, which in turn resulted in similar value of yield attributes (Ravisankar *et al.*, 2007b). Growing of *dhaincha* as intercrop and its mechanical incorporation at the early stage (37 DAS) of wet-seeded rice increased the number of panicles/m^2 by 7.8% in comparison with sole rice. Pretilachlor-plus at 2 DAS proved better than at 5 DAS, which was 7.2% better than with hand-weeding. Decrease in weed competition decreased the nutrient removal by weeds, which provided a competition-free environment for rice.

Grain and straw yield behaved similar to the growth rate and number of panicles/m^2, with both surface and anaerobic seeding (Table 2). Rice + *dhaincha* increased the grain yield substantially due to the effective suppression of weeds, restriction of nutrient drain by weeds and increase in nutrient uptake by the crop. Grain yield had a strong negative correlation (0.88** to - 0.94**) with weed parameters such as total weed population/m^2, total dry matter production (DMP) of weeds and N removal by the weeds, as well as positive correlation with rice DMP and N uptake (0.92** to 0.99**) (Table 4). Straw yield also showed a similar trend. Pretilachlor-plus at 2 DAS recorded 5.6 t/ha grain yield, which was 6.7 and 8.8% more than that of pretilachlor-plus applied at 5 DAS and hand-weeding respectively. This might be due to weed-free environment created from the day after sowing till harvest, which led to less competition by the weeds. Further, the association between weeds, yield parameters and grain yield was confirmed through correlation and regression studies. Grain yield was negatively associated with total weed population, weed DMP and N removal by the weeds, and positively associated with rice DMP and N uptake by the crop (0.96**). Lower yield (2.0 t/ha) in the

Table 1. Dry-matter production, N accumulation and weed-smothering efficiency of *dhaincha* in wet-seeded rice

Treatment	Dry-matter production (t/ha)		N accumulation (kg/ha)		Weed-smothering efficiency (%)			
	2000-01	2001-02	2000-01	2001-02	AT 20 DAS		AT 35 DAS	
					2000-01	2001-02	2000-01	2001-02
Surface (rice+ dhaincha)								
Pretilachlor-plus at 2 DAS fb HW at 45 DAS	2.72	2.22	54.40	51.06	14.5	10.1	24.3	29.1
Pretilachlor-plus at 5 DAS fb HW at 45 DAS	2.36	2.24	49.56	53.25	14.0	9.8	17.6	28.7
HW twice at 20 and 45 DAS	2.42	2.01	47.80	51.75	16.6	14.4	11.5	28.1
Unweeded check	2.04	1.97	44.88	52.56	16.2	13.8	17.9	24.8
SEm±	0.21	0.18	0.76	0.81	0.38	0.39	0.57	0.67
CD (P=0.05)	0.75	0.65	2.67	2.87	1.08	1.10	1.98	1.89
Anaerobic (rice + dhaincha)								
Pretilachlor- plus at 2 DAS fb HW at 45 DAS	2.50	2.27	52.50	54.85	12.4	10.7	32.1	30.8
Pretilachlor- plus at 5 DAS fb HW at 45 DAS	2.76	2.26	50.75	53.75	14.3	9.5	33.6	31.4
HW twice at 20 and 45 DAS	2.94	2.16	48.56	52.25	13.8	14.0	37.0	32.0
Unweeded check	2.40	2.28	46.71	50.26	14.7	14.5	25.7	24.7
SEm ±	0.21	0.20	1.03	0.93	0.37	0.28	0.50	0.52
CD (P=0.05)	0.73	0.70	3.62	3.30	1.04	1.01	1.76	1.85

Table 2. Influence of seeding method, intercropping and weed-management practice on total weed density, crop-growth rate and yield of wet-seeded rice

Treatments	Weed density at 45 DAS (no./m^2)		Crop-growth rate (g/m^2 /day) (tillering – flowering)		No of panicles/ m^2		Grain yield (t/ha)		Straw yield (t/ha)	
	2000–01	2001–02	2000–01	2001–02	2000-01	2001–02	2000–01	2001–02	2000–01	2001–02
Seeding methods										
Surface	1.93 (105.5)	1.85 (90.4)	9.16	9.55	326	365	4.2	4.6	6.3	6.5
Anaerobic	1.90 (98.7)	1.83 (87.1)	9.64	9.82	344	373	4.4	4.7	6.6	6.8
SEm±	0.02	0.01	0.16	0.29	6	3	0.1	0.1	0.1	0.1
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Intercropping										
Sole rice	2.12 (146.9)	2.07 (129.7)	8.99	9.20	321	356	3.7	4.1	6.3	6.4
Rice + *dhaincha*	1.71 (57.3)	1.61 (47.8)	9.81	11.73	349	381	4.9	5.2	6.7	6.8
SEm±	0.02	0.01	0.16	0.29	6	3	0.1	0.1	0.1	0.1
CD (P=0.05)	0.07	0.02	0.50	0.93	18	9	0.2	0.3	0.4	0.3
Weed management										
Pretilachlor -plus 2 DAS fb HW 45 DAS	1.72 (57.6)	1.63 (49.6)	12.09	12.52	404	413	5.4	5.7	7.7	7.8
Pretilachlor- plus 5 DAS fb HW 45 DAS	1.87 (80.4)	1.79 (68.3)	11.85	12.11	384	391	5.0	5.4	7.4	7.3
HW twice 20 and 45 DAS	1.80 (67.2)	1.73 (58.9)	11.74	11.72	381	381	4.9	5.3	7.3	7.4
Unweeded check	2.27 (203.2)	2.22 (178.1)	1.92	2.37	173	291	1.8	2.2	3.4	4.0
SEm±	0.04	0.02	0.25	0.37	6	5	0.1	0.1	0.1	0.1
CD (P=0.05)	0.10	0.06	0.73	1.05	18	13	0.4	0.3	0.4	0.4

*Figures in parentheses are original values

Table 3. Influence of seeding method, intercropping and weed-management practice on N uptake by weeds, crop and economics of wet-seeded rice

Treatment	N removal by weeds at 45 DAS (kg/ha)		N uptake by crop at tillering (kg/ha)		Available soil N at maturity (kg/ha)		Net returns (x 10^3 Rs/ha)		B : C ratio	
	2000–01	2001–02	2000–01	2001–02	2000–01	2001–02	2000–01	2001–02	2000–01	2001–02
Seeding method										
Surface	2.15	3.03	35.43	37.58	212.5	212.9	9.49	11.32	1.64	1.77
Anaerobic	2.40	3.46	38.23	41.68	214.8	215.1	10.71	12.35	1.73	1.84
SEm±	0.08	0.05	0.97	1.34	3.5	3.4				
CD (P=0.05)	NS	0.15	NS	NS	NS	NS				
Intercropping										
Sole rice	3.35	4.58	32.80	35.47	202.8	207.5	7.64	9.38	1.53	1.65
Rice + *dhaincha*	1.20	1.92	40.86	43.80	224.5	220.5	12.56	14.29	1.84	1.97
SEm±	0.08	0.05	0.97	1.34	3.5	3.4				
CD (P=0.05)	0.27	0.15	3.10	4.30	11.0	10.9				
Weed management										
Pretilachlor-plus 2 DAS fb HW 45 DAS	1.07	1.91	42.67	48.49	224.8	226.8	15.95	17.48	2.11	2.21
Pretilachlor-plus 5 DAS fb HW 45 DAS	1.61	2.76	38.00	40.78	221.3	223.3	13.94	15.50	1.97	2.08
HW twice 20 and 45 DAS	1.37	1.92	35.79	37.89	221.3	221.5	12.84	14.61	1.85	1.97
Unweeded check	5.04	6.40	30.85	31.37	187.3	184.5	- 2.33	- 0.99	0.82	0.98
SEm±	0.14	0.08	1.50	1.96	10.4	10.4				
CD (P=0.05)	0.40	0.22	4.30	5.62	29.8	29.8				

Table 4. Correlation and regression between grain yield and weed parameters

Y	X	Correlation coefficient (r) (n=64)		Regression equation	
		2000–01	2001–02	2000–01	2001–02
Grain yield (kg/ha)	Total weed population/m^2	- 0.92**	- 0.92**	Y = 6009 - 3.82 X	Y = 6312 - 4.39 X
Grain yield (kg/ha)	Total weed DMP (kg/ha)	- 0.93**	- 0.92**	Y = 6014 - 3.82 X	Y = 6306 - 4.36 X
Grain yield (kg/ha)	N removal by weeds (kg/ha)	- 0.89**	- 0.88**	Y = 5815 - 125.50 X	Y = 6120 - 142.75 X
Grain yield (kg/ha)	Rice DMP (kg/ha)	0.99**	0.98**	Y = -743 + 0.47 X	Y = - 837 + 0.48 X
Grain yield (kg/ha)	N uptake by rice (kg/ha)	0.98**	0.92**	Y = - 229.60 + 48.98 X	Y = 420 + 43.60 X

**Significant at P=0.01

unweeded check was due to the severe competition between crop and weed for resource pool (Balakrishnan *et al.,* 2007).

Nutrient uptake by weeds and crop

The seeding method had no effect on N removal by weeds (Table 3). Intercropping significantly reduced the N removal at 45 DAS, which was 60.5% in rice + *dhaincha* compared with sole rice. At 20 DAS pretilachlor-plus applied at 2 DAS recorded 67% lesser N removal than at 5 DAS. Similar results were observed at 35 and 45 DAS.

The seeding method had no influence on N uptake, whereas rice + *dhaincha* intercropping registered significantly higher N uptake because of restricted weed DMP, reduced nutrient uptake by weeds and additional nutrients supplied by the incorporated intercrop. Significantly higher N uptake by rice at tillering was observed under pretilachlor-plus at 2 DAS, perhaps due to less weed competition, which ultimately led to greater uptake of nutrients in the rice plants. The seeding method did not influence the available soil N at maturity, but rice + *dhaincha* intercropping led to 8.5% improvement. This indicates that incorporation of *dhaincha*, while reducing N removal by weeds, assisted in the build up of soil-available N status, resulting in improved soil fertility and crop yield.

Economics

Anaerobic seeding gave higher net returns (Rs 11,532/ha) and benefit : cost ratio (1.79). This was because the cost of cultivation did not differ much between the seeding methods and there was numerically increased grain and straw yields in anaerobic seeding. Rice + *dhaincha* intercropping recorded higher net returns (Rs 13,430/ha) and B : C ratio (1.91), perhaps due to significant improvement in grain (29.4%) and straw yields. Pretilachlor-plus at 2 DAS gave better net returns (Rs 16,716/ha) and B: C ratio (2.16) than at 5 DAS and hand-weeding (Table 3). Unweeded check recorded a loss of Rs 1,658/ha due to severe decrease yield (64%). Awan *et al*. (2007) reported similar findings.

It was concluded that direct wet seeding with dual cultivation of rice + *dhaincha* and pretilachlor-plus @ 0.30 kg/ha at 2 DAS with one hand-weeding at 45 DAS is better for improving productivity and profitability of wet-seeded rice.

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