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Integrated weed management in zero-till direct-seeded rice (*Oryza sativa*) - wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted during 2004-05 and 2005-06 on clay-loam soil at Jabalpur in Madhya Pradesh to find out the effect of integrated weed-management practices on weeds and yield of zero-till direct-seeded rice (*Oryza sativa* L.). Different methods of crop establishment were evaluated for getting higher productivity and profitability of irrigated rice-wheat cropping system. For rice there were four methods, viz. direct seeding by zero-till drill, direct drilling in friable soil by seed drill, direct seeding of sprouted seeds in puddled soil, and transplanting; and for the succeeding wheat (*Triticum aestivum* L. emend. Fiori & Paol.) there were two methods, viz. sowing with zero-till drill and conventional sowing. *Echinochloa colona* and *Commelina* spp. were the major weeds in zero-till, direct-seeded rice, which reduced the grain yield by 27.4%. Pre-emergence application of pretilachlor at 750 g/ha or pendimethalin at 1.0 kg/ha each, followed by one hand-weeding at 30 days after sowing was on a par with hand-weeding twice, giving significantly higher grain yield (5.20 and 3.50 t/ha) compared with the weedy check (3.98 and 2.25 t/ha). Zero-till, direct-seeded rice with proper weed management resulted in significantly higher yield than transplanted rice. In the succeeding wheat crop, population of dominant weeds, viz. *Chenopodium album* and *Medicago hispida*, was found to be reduced when wheat was grown after zero-till, direct-seeded rice compared with other methods of rice establishment. The wheat sown after zero-till, direct-seeded rice yielded significantly higher (3.76 and 3.61 t/ha) than when sown after other methods of rice establishment. Zero tillage in direct-seeded rice-wheat system reduced the weed problem and increased the system productivity as well as profitability.

Key words: Crop establishment, Direct-seeded rice, Rice-wheat system, Weed control, Zero tillage

Rice-wheat system is one of the most important cropping systems for food security in south Asia. In this system rice crop is grown by transplanting the seedlings manually in puddled fields and the subsequent wheat crop is grown by repeated tillage operations. Puddling results in poor soil-physical conditions for establishment and raising the succeeding crops (Tripathi *et al.*, 2003). Due to rising costs of labour and excessive water use in puddling for transplanting rice in the irrigated eco-systems, direct seeding of rice is gaining popularity in south-east Asia (Balasubramanian and Hill, 2002). Direct-seeded rice needs only 34% of the total labour requirement and saves 29% of the total cost of the transplanted crop (Ho and Romli, 2000). Weed management is, however, a major concern in direct-seeded rice. With the availability of broad-spectrum herbicides to conrol weeds and the associated technology, it is possible to raise the productivity of direct-seeded rice crop with low production cost. The cost of weed control could partially or completely be compensated with saving in tillage operations in zero tillage (ZT). Minimum and ZT techniques have resulted in considerable saving in time, labour, water, power and capital without loss in rice yield under widely varying ecological conditions (Tripathi *et al.*, 1999). Sharma *et al.* (2003) reported that direct drilling of rice using zero or rotary tillage could be followed for growing a good crop of rice in soils with low infiltration rate. Direct seeding of rice also allows early establishment of the succeeding wheat crop, reduced methane emissions and higher profit in areas with assured water supply (Balasubramanian and Hill, 2002). As the zero-till, direct-seeded rice facilitates timely sowing of wheat, even a slight loss in rice productivity is compensated by increased wheat yield, implying no loss in the system productivity. Moreover, there may be many complementary and supplementary relationships among various methods of crop establishment in rice and wheat that might affect the weed problem, crop stand and ultimately the productivity of rice-wheat system. Keeping these points in view, the present investigation was undertaken.

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MATERIALS AND METHODS

The field experiment was conducted during 2004-05 and 2005-06 at National Research Centre for Weed Science, Jabalpur. The soil was clay loam (Typic Haplustert), low in available N (235 kg/ha) and medium in organic C (0.66%), available P (17.5 kg/ha) and K (290 kg/ha), with neutral pH (7.2) and electrical conductivity (EC) (0.37 dS/m). Treatments in rice consisted of integration of pre-emergence application of pretilachlor @ 0.75 kg/ha or pendimethalin @ 1.0 kg/ha with post-emergence application of fenoxaprop @ 70 g/ha, mixed cropping of *Sesbania* followed by 2,4-D at 30 days after sowing, hand-weeding, mechanical weeding and weedy check (Table 1). These were replicated thrice in randomized block design. Due to non-availability of pretilachlor in the second year, pendimethalin was used. Weed-free checks of conventional direct-seeded rice, puddle broadcast and transplanted rice were also kept for comparison. However, in the second year the conventional direct-seeded rice check could not be sown due to continuous rains. Tillage operations in transplanting and puddle broadcasting consisted of 1 disc ploughing, 2 harrowings and 1 puddling, followed by planking, whereas in conventionally tilled direct-seeded rice the plots were dry seeded with seed drill after 1 disc ploughing, 2 harrowings and 1 rotavtor. The zero-till, direct-seeded rice was sown directly using zero-till seed-drill. Pre-germinated weeds in zero-till, direct-seeded rice were killed with the application of glyphosate (0.5%) before sowing. Rice variety 'Kranti' was sown on 29 June 2004 and 23 July 2005 with 80 kg seed/ha. Direct-seeded rice was sown in rows with zero-till seed-cum-fertilizer drill and normal seed-cum-fertilizer drill as per the treatment. On the next day the seeds of same variety soaked for 24 hr were broadcast in the puddled field. Nursery of rice for taking transplanted rice was sown on the same day and transplanted 25 days later at 20 × 20 cm spacing. One-third of the recommended dose of N (40 kg/ha) and full dose of P (26.2 kg/ha) and K (33.2 kg/ha) were applied at sowing, and the remaining N was top-dressed in two equal splits, half at active tillering and half at panicle-initiation stage. Direct-seeded and puddle-broadcast rice matured a week earlier than transplanted rice, but the subsequent wheat was sown at the same time.

During winter (*rabi*) season, four rice cultures, viz. zero-till direct-seeded rice, conventionally tilled direct-seeded rice, puddle broadcasting and transplanting, were taken as main plots, and wheat cv 'WH 147' was sown as subplot treatment under two tillage conditions, viz. zero tillage (direct sown by zero-till seed-drill) and conventional tillage (1 disc ploughing, 2 discing, 2 cultivator and 1 rotavator) in a plot size of 20 x 4 m on 17 November 2004 and 30 November 2005. Spinkler irrigation was given immediately after sowing to ensure proper germination. Fertilizer was applied @ 120 kg N, 26.2 kg P and 33.2 kg K/ha. Half the N and full dose of P and K were applied basal; and the remaining N was top-dressed in two equal splits, half at crown-root initiation stage and half at spike-initiation stage. Herbicides as per treatment in rice and 2,4-D @ 0.50 kg/ha in wheat were applied using 500 litres /ha water with the help of knapsack sprayer, fitted with flat-fan nozzle. The crop was raised under irrigated condition with recommended package of practices. Population and dry matter of weeds were recorded at 60 days after sowing (DAS) with the help of random quadrate (0.5 x 0.5 m) at four places in a plot. These were subjected to square-root transformation before analysis. Data on grain yield, total productivity, net monetary returns and benefit : cost ratio obtained from the cropping sequence during the 2 years were pooled. Economics was calculated by considering the prevailing sale prices of rice and wheat and the cost of cultivation.

RESULTS AND DISCUSSION

Effect on weeds in rice

The major weeds observed in weedy check plots at 60 DAS during both the years were *Echinochloa colona* (L.) Link and *Commelina* sp. (Table 1). A few weeds, viz. *Cyperus difformis*, *Ammania baccifera* L. and *Eriocaulon* spp were also recorded in 2005 due to water submergence. Different weed-control treatments significantly influenced the population and dry matter of weeds. Pre-emergence application of pretilachlor 750 g/ha or pendimethalin 1.0 kg/ha followed by 1 hand-weeding or harrowing at 30 DAS significantly reduced the population of *E. colona* compared with the weedy check. These treatments, however, did not affect the population of *Commelina* spp. Broadcasting of *Sesbania* and its subsequent killing by 2,4-D followed by 1 hand-weeding completely controlled the *Commelina* spp., *Ammania baccifera* and *Eriocaulon* spp. Application of pre-emergence herbicides + 1 hand-weeding at 30 days, being on a par with broadcasting of *Sesbania*, and its subsequent killing by 2,4-D followed by 1 hand-weeding significantly reduced the total dry matter of weeds compared with other treatments. Singh *et al.* (2003) also reported that growing of *Sesbania* as an intercrop with direct-seeded rice up to 30 DAS reduced the weed infestation by 30%.

Grain yield of rice

In ZT direct-seeded rice, different weed-control treatments did not influence the number of panicles/m^2 during 2004, but during 2005 the pre-emergence application of

Table 1. Effect of weed-control treatments on poulation and dry matter of weeds in rice

Treatment	Dose (g/ha)	Time of applic-action	Weed population (no./m²)							Dry weight of weeds (g/m²)	
			E. colona		*Commelina* spp.		*Cyperus difformis*	*Ammania baccifera*	*Eriocaulon* spp.		
			2004	2005	2004	2005	2005	2005	2005	2004	2005
Pretilachlor/ pendimethalin + 1 HW	750/ 1,000	Pre-em. 30 DAS	1.1 (0.6)	2.4 (5.4)	1.2 (0.9)	1.9 (3.0)	0.9 (0.3)	0.7 (0.0)	1.3 (1.3)	4.8 (22.7)	1.6 (2.0)
Pretilachlor/ pendimethalin + 1 harrowing	750/ 1,000	Pre-em. 30 DAS	1.9 (3.2)	3.4 (10.9)	1.2 (0.9)	2.4 (5.3)	1.5 (1.6)	0.9 (0.3)	1.1 (0.6)	8.0 (62.7)	3.1 (8.9)
Pretilachlor/ pendimethalin fb fenoxaprop	750/ 1,000 70	Pre-em. 30 DAS	3.0 (8.7)	3.7 (12.9)	1.2 (0.9)	2.7 (6.6)	2.4 (5.3)	2.8 (7.2)	1.3 (1.3)	8.0 (63.0)	6.7 (44.3)
Broadcasting of *Sesbania* fb 2,4-D fb 1HW	500	35 DAS 45 DAS	1.2 (0.9)	2.3 (5.0)	0.7 (0.0)	0.7 (0.0)	0.9 (0.3)	0.7 (0.0)	0.7 (0.0)	5.4 (28.8)	1.2 (1.0)
2 HW		30 and 45 DAS	1.6 (1.9)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	2.0 (3.7)	1.6 (1.9)	3.0 (8.6)	0.7 (0.0)	3.0 (8.2)
Weedy check			4.4 (19.2)	4.9 (23.6)	2.4 (5.3)	1.9 (3.0)	1.8 (2.6)	2.7 (7.0)	4.1 (16.3)	14.9 (222.7)	7.2 (51.8)
SEm±			0.3	0.4	0.2	0.1	0.2	0.2	0.2	1.1	0.4
CD (P=0.05)			0.8	1.3	0.5	0.4	0.5	0.6	0.7	2.9	1.3

Values in parentheses are original; HW = hand weeding

pendimethalin @ 1.0 kg/ha + 1 hand-weeding at 30 DAS, being on a par with broadcasting of *Sesbania*, and its subsequent killing by 2,4-D followed by 1 hand-weeding (HW) and herbicide followed by 1 harrowing produced significantly higher panicles/m² than other treatments (Table 2). Significantly higher number of grains/panicle in ZT direct-seeded rice was recorded in 2 hand-weedings treatment compared with the weedy check. Different weed-control treatments did not affect 1,000-grain weight significantly during 2004; however, in 2005 hand-weeding twice significantly increased the grain weight compared with the weedy check. Higher grain yield of rice was obtained in 2004 than in 2005 due to timely sowing. On an average, weed competition reduced the yield of zero-tilled direct-seeded rice by 27.5%. Pre-emergence application of herbicide + 1 HW at 30 DAS, being on a par with hand-weeding twice, produced significantly higher grain yield than the weedy check. Grain yield of rice was negatively correlated (r = –0.85*) with dry matter of weeds. A positive correlation between yield attributes [panicles/m² (r =0.39), grains/panicle (r = 0.83*) and 1,000-grain weight (r = 0.57)] and grain yield was also recorded.

When compared with other rice cultures, ZT direct-seeded rice with proper weed management gave higher yield than conventionally tilled, direct-seeded rice, puddle broadcast and transplanted rice in 2004. However, in 2005 transplanted rice, being on a par with puddle-broadcast seeding, yielded significantly better than ZT. Lower yield of ZT direct-seeded rice during 2005 might be due to delayed sowing.

Effect on weeds in wheat

Wheat field was dominated with broad-leaved weeds, viz. *Chenopodium album* and *Medicago hispida*. Different methods of rice establishment significantly influenced the population of weeds in wheat (Table 3). The population of *C. album* was found to be significantly reduced when wheat was grown after ZT direct-seeded rice compared wih other methods of rice establishment. The population of *Medicago hispida* was lower in CT direct-seeded rice during 2004-05; however, in 2005-06 it was significantly reduced after ZT direct-seeded rice compared with puddle-broadcast rice. Except after transplanted rice, dry matter of weeds in wheat did not vary significantly due to rice-establishment techniques. Irrespective of the various crop-establishment methods in rice, sowing of wheat by zero-till drill significantly reduced the population and dry matter production of weeds. Less exposure of weed seeds to light and presence of crop residue on soil surface might have inhibited the emergence of weed seed in zero tillage. Singh *et al.* (2004) also reported significant reduction in the population of *Chenopodium album* in zero tillage.

Table 2. Effect of weed-control treatments on yield attributes, yield and economics of rice

Treatment*	Panicles/m²		Grains/ panicle		1,000-grain weight (g)		Grain yield (t/ha)		Gross returns	B : C ratio
	2004	2005	2004	2005	2004	2005	2004	2005	(Rs/ha)	
Pretilachlor / pendimethalin + 1 HW	341	302	122	119	25.3	29.5	5.20	3.50	21,750	1.97
Pretilachlor / pendimethalin + 1 harrowing	348	275	132	106	24.7	25.8	5.23	2.75	19,950	1.91
Pretilachlor/pendimethalin fb fenoxaprop	354	239	114	131	26.7	30.4	4.58	3.33	19,750	1.83
Broadcasting of *Sesbania* fb 2,4-D fb 1HW	341	295	113	113	25.7	24.7	4.46	2.90	18,400	1.62
2 HW	338	241	136	136	26.3	34.0	5.36	3.25	21,500	1.58
Weedy check	334	236	108	106	25.7	26.3	3.98	2.25	15,800	1.74
Conventional till, direct - seeded rice*	224		122		26.0		4.87		24,350	2.15
Puddle-broadcast rice	250	284	160	146	26.3	29.0	4.84	4.67	23,800	1.93
Transplanted rice	219	269	137	150	27.7		4.38	5.00	23,450	1.45
SEm±	22	16	9	8	1.5	2.8	0.24	0.19		
CD (P=0.05)	61	15	24	23	NS	7.9	0.68	0.56		

*Herbicide dose and time of application details as in Table 1

Table 3. Effect of crop-establishment methods in rice and wheat on population and dry matter of weeds in wheat

Treatment	Weed population (no./m²)						Dry matter of weeds (g/m²)	
	Chenopodium album		*Medicago hispida*		Total			
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Rice culture								
Transplanted	5.1	0.90	2.6	6.7	5.7	6.7	6.9	6.4
	(25.7)	(0.3)	(6.1)	(44.4)	(32.0)	(44.4)	(47.1)	(40.5)
Puddled broadcast	3.3	1.2	2.4	9.5	4.1	9.7	5.8	6.9
	(10.7)	(0.9)	(5.2)	(89.8)	(16.3)	(93.6)	(33.1)	(47.1)
Conventional till, direct-seeded rice	3.7		2.1		4.2		5.8	
	(13.3)		(3.8)		(17.1)		(33.1)	
Zero-till, direct-seeded rice	2.7	0.71	2.5	6.3	4.0	6.3	6.6	6.2
	(7.0)	(0.0)	(6.0)	(39.2)	(15.5)	(39.4)	(43.1)	(37.9)
SEm±	0.2	0.2	0.1	0.4	0.2	0.5	0.3	0.4
CD (P=0.05)	0.6	0.5	0.3	1.3	0.6	1.5	1.0	NS
Tillage								
Conventional tillage	4.2	0.80	2.7	7.7	5.0	7.7	7.0	7.0
	(16.9)	(0.1)	(7.0)	(58.8)	(24.5)	(58.8)	(48.5)	(48.7)
Zero tillage	3.5	1.1	2.1	7.4	4.0	7.5	5.5	6.1
	(11.7)	(0.71)	(3.7)	(54.3)	(15.5)	(55.8)	(29.8)	(36.7)
SEm±	0.1	0.1	0.1	0.4	0.1	0.1	0.2	0.3
CD (P=0.05)	0.4	0.3	0.2	1.1	0.4	NS	0.7	NS

Values in parentheses are original

Grain yield of wheat

Plant population, plant height, number of spikes/m row length and grain yield of wheat were significantly influenced due to different methods of establishment in preceding rice (Table 4). Zero-till, direct-seeded rice being on a par with conventionally tilled direct-seeded rice, produced significantly higher number of plants/m row length than puddle broadcast and transplanted rice. The number of spikes/m row length was also significantly higher when wheat was grown after ZT direct-seeded rice compared with other methods of rice establishment. This could be owing to better soil-seed contact, resulting in higher number of plants/unit area. Irrespective of the various crop-establishment methods in rice, sowing of wheat by zero-till seed drill increased the plant population, plant height and yield attributes over conventional method. The wheat sown after zero-till direct-seeded rice yielded significantly higher than when sown after other methods of

rice establishment. Zero tillage significantly increased the grain yield of wheat. Ram *et al.* (2006) also reported similar findings. Interactions between crop-establishment methods in rice and wheat were not significant for yield and yield attributes of wheat. Yield parameters of wheat were positively correlated with grain yield. Among different parameters, plant population (r = 0.84*) and number of spikes/m row length (r = 0.94**) were highly correlated.

Total productivity of rice-wheat system

Zero-till, direct-seeded rice-wheat system gave the highest total productivity, followed by conventional tillage and puddle broadcast systems (Fig. 1). Transplanted rice-wheat system resulted in the lowest total productivity despite giving higher rice yield than ZT direct-seeded rice, indicating that reduction in wheat yield after transplanted rice was much greater than the corresponding increase in rice yield. Sowing of wheat by zero-till seed drill gave higher total productivity compared with that by conventional tillage. Singh *et al.* (2002) also reported similar yields of transplanted and direct-seeded rice and higher grain yield of wheat crop following it.

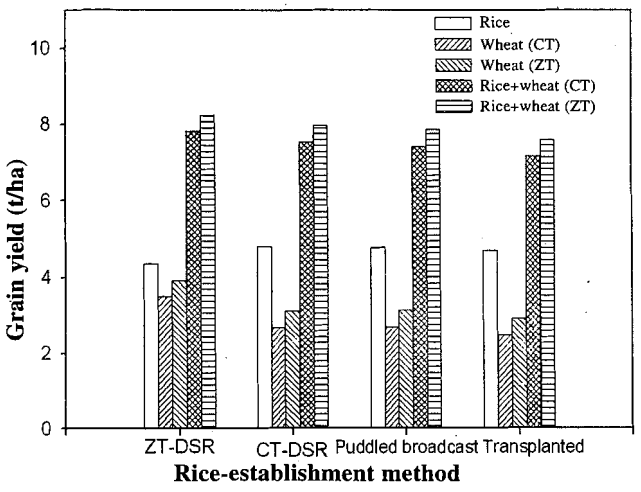

Fig. 1. Effect of rice-establishment method on productivity of rice and wheat under various tillage conditios

Table 4. Effect of crop-establishment methods in rice and wheat on plant population, plant height, yield attributes and yield of wheat

Treatment	Plant population/m row length		Plant height (cm)		No. of spikes/m row length		Grains/spike		1,000-grain weight (g)		Grain yield (t/ha)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Rice culture												
Transplanted	55.8	59.6	89.9	87.4	48.4	53.6	43.0	52.0	48.2	52.1	2.35	3.02
Puddled broadcast	57.4	64.0	93.4	89.0	48.2	54.5	45.4	52.5	51.0	51.1	2.48	3.26
Conventional till, direct seeded rice	59.3		92.2		49.7		45.9		49.3		2.83	
Zero-till, direct-seeded rice	63.7	66.0	96.4	92.0	61.1	60.4	43.4	47.8	49.6	52.3	3.76	3.61
SEm±	1.9	2.6	1.1	2.1	2.8	2.5	1.6	1.8	1.6	0.7	0.11	0.15
CD (P=0.05)	5.5	NS	3.1	NS	8.2	NS	NS	NS	NS	NS	0.31	0.48
Tillage												
Conventional tillage	53.4	61.8	89.2	88.0	50.0	52.5	44.0	49.3	48.3	51.8	2.57	3.16
Zero tillage	64.7	64.6	96.7	91.0	54.0	59.8	44.8	51.0	50.7	51.9	3.17	3.44
SEm±	1.6	1.3	0.8	1.7	1.2	1.9	0.4	0.5	0.8	0.1	0.11	0.10
CD (P=0.05)	4.6	NS	2.2	NS	NS	5.4	NS	NS	2.3	NS	0.26	0.21

Table 5. Effect of methods of rice establishment on economics of rice-wheat system (average of 2 years)

Treatment	Cost of cultivation (Rs/ha)		Net returns (Rs/ha)		B : C ratio	
	R+WCT	R+WZT	R+WCT	R+WZT	R+WCT	R+WZT
Zero-till, direct-seeded rice	25,684	23,885	22,166	27,115	1.86	2.13
Conventional till, direct-seeded rice*	25,985	24,185	18,390	23,415	1.71	1.97
Puddled broadcast	26,985	25,185	16,615	21,940	1.62	1.87
Transplanted	30,785	28,985	11,205	16,290	1.36	1.56

*2004-05 only

ZT = Zero tillage, CT = conventional tillage; R = rice; W, wheat

Selling price: Rice Rs 5,000/t; wheat, Rs 7,500/t

Economics

In zero-till, direct-seeded rice, pre-emergence application of herbicide followed by 1 hand-weeding at 30 DAS gave maximum benefit : cost ratio (1.97), and hence proved more remunerative than the other weed-control treatments (Table 2). The lower B:C ratio (1.45) in transplanted rice was ascribed to higher cost of production due to additional cost involved in puddling and transplanting of rice. The total net returns (Rs 27,115/ha) and B:C ratio (2.13) obtained from zero-till, direct-seeded rice and zero-till wheat system were higher than those from other systems (Table 5). This was owing to higher wheat productivity and lower cost of cultivation in zero-tillage treatment. The minimum net return (Rs 11,205/ha) and B:C ratio (1.36) were obtained in transplanted rice and conventional tillage wheat system due to lower wheat yield and higher cost of production.

It was concluded that both direct-seeded rice and wheat may be grown in zero tillage for getting higher weed control, and productivity and profitability of the rice-wheat system under irrigated conditions.

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