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Productivity and economics of rice *(Oryza sativa)*– wheat *(Triticum aestivum)* cropping system as affected by establishment methods and tillage practices

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ABSTRACT

A field experiment was conducted during 2001–02 and 2002–03 on clay loam soil at Rice Research Station, Kaul, Haryana, to evaluate 4 methods of crop establishment and tillage practices in rice (*Oryza sativa* L.), viz. transplanting, direct seeding in puddled soil by drum seeder, direct seeding in friable soil by seed drill and direct seeding by zero-till drill; and 3 methods in succeeding wheat (*Triticum aestivum* L. emend. Fiori & Paol.) crop, *viz.* sowing with zero-till drill, sowing with rotavator drill and conventional sowing, for getting higher productivity and profitability of irrigated rice–wheat system. Manual transplanting of rice gave significantly higher grain yield of rice (70.8 q/ha), followed by direct seeding of rice in puddled soil (58.0 q/ha), whereas the lowest yield was obtained with dry seeding by seed drill or zero-till drill. The wheat sown after dry seeding of rice yielded significantly higher (48.4-49.6 q/ha) than when sown after transplanted (46.3 q/ha) or direct-seeded puddled rice (45.3 q/ha). In wheat, sowing by rotavator drill (reduced tillage) or by zero-till drill (zero tillage) gave significantly higher grain yield (47.4 and 49.6 q/ha respectively) than by conventional method (45.2 q/ha). Transplanting in rice and sowing by rotavator in succeeding wheat resulted in the highest total productivity and profitability of the rice–wheat system.

Key words : Bulk density, Crop establishment, Direct seeding, Dry seeding, Rice–wheat system, Rotavator, Zero tillage

Rice–wheat is a dominant cropping system on fertile and irrigated alluvial soils of North-West India, particularly in Punjab and Haryana. In this region, conventional crop-establishment practice in rice involves manual transplanting of rice in puddled soil, whereas wheat is seeded in well-prepared fine seedbed. These practices involve excessive tillage and hence, result not only in high-energy consumption but also in deterioration of soil structure. Puddling, a pre-requisite for rice transplanting, decreases the soil aggregates and pore size, thereby restricting germination and rooting of the succeeding crops (Giri *et al.*, 1993). Manual transplanting of rice, done usually by hired labour, is increasingly becoming a difficult proposition due to shortage of labour during the peak season, escalating labour wages and inadequate plant population obtained with the hired labour. Moreover, there is lack of suitable transplanting equipment. Direct seeding of rice is another method of crop establishment, which may ensure better plant population, especially if it involves the use of improved equipment like seed drill, drum seeder. Sowing of wheat, which requires excessive tillage by traditional method, can also be accomplished efficiently with the use of the improved devices to save the energy and time (Sharma *et al.*, 2002). Moreover, there may be complementary and supplementary relationship among various methods of crop establishment in rice and wheat, which may affect the crop stand and ultimately the productivity of rice–wheat system. Keeping these facts in view, the present investigation was undertaken.

MATERIALS AND METHODS

A field experiment was conducted during 2001–02 and 2002–03 at the Rice Research Station, Kaul, Haryana, on a clay loam soil having organic C 0.37%, electrical conductivity 0.27 dS/m. The soil was low in available N (198 kg N/ha), medium in available P (18 kg P/ha) and high in available K (335 kg K/ha), with pH 8.1. The experiment was laid out in split-plot design. The treatments consisted of 4 methods of rice crop establishment, viz. transplanting (conventional), direct seeding in puddled soil by drum seeder, direct seeding in friable soil by seed drill, and direct seeding by zero-till drill in main plots; and 3 methods of wheat establishment, viz. sowing with zero-till drill (zero tillage), sowing with rotavator drill (reduced tillage) and conventional method in sub-plots in split-plot design, replicated thrice. Direct

seeding of rice cv. 'IR 64' by seed drill, zero till drill or drum seeder was done on 19 June 2001 and 22 June 2002, whereas transplanting of 30 days old seedlings was done 1 month later. The seed rate was 75 kg/ha for direct seeding in dry soil and 60 kg/ha for direct seeding in puddled soil, whereas for transplanting, it was only 25 kg/ha. Tillage operations in transplanting and direct sowing (in puddled soil) consisted of 2 dry harrowings, 2 puddlings and 1 planking, whereas the plots dry seeded with seed drill were ploughed thrice with harrow and once with cultivator, followed by planking. For efficient weed control, Glyphosate @ 2% was applied 6 days before sowing in plots where dry seeding of rice was to be done by zero till drill to control pre-germinated weeds, followed by application of Pendimethalin @ 1.0 kg a.i/ha (pre-emergence) 4 days after sowing (DAS). In plots seeded dry by seed drill, only Pendimethalin was applied, whereas Butachlor @ 1.5 kg a.i./ha (pre-emergence) was applied for weed control in plots where rice was transplanted or seeded directly under puddled condition. This was supplemented by hand-weeding twice at 20 and 40 days in dry-seeded plots and at 40 days in plots seeded in puddled conditions. The direct-seeded (by seed drill or zero-till drill) plots received a pre-sowing irrigation and irrigated soon after sowing for seed germination. In direct seeding under puddled conditions, irrigation for puddling was given. All the direct-seeded plots received frequent irrigations to keep the soil wet. For transplanted crop, irrigation was applied for puddling, thereafter, uniform irrigations were applied to all the treatments.

After harvesting of rice, a pre-sowing irrigation was given to all the main plots to ensure optimum moisture for sowing of wheat. Sowing of wheat cv. 'PBW 343' by conventional and rotavator drill methods was done on 6 and 18 November in 2001 and 2002, respectively, whereas sowing by zero-till drill was done 3 days earlier. The conventional sowing in wheat involved 2 harrows, 2 cultivators, 1 shallow harrow before seeding and planking. The field was harrowed once before using rotavator drill. For weed control in wheat, Sulfosulfuron @ 32.5 g/ha was sprayed after the first irrigation. A fertilizer dose of 150 kg N and 60 kg P_2O_5/ha was applied to each of the crops. Rice crop was also supplied with zinc sulphate @ 25 kg/ha. All the other cultivation practices recommended for both the crops were followed. The second year rice (2002) and wheat (2002–03) were grown in the same layout as of the first year to consider the effect of tillage or crop-establishment treatments given to wheat. Data on plant height, yield attributes and grain yield of rice and wheat crops were recorded at maturity. Bulk density of the soil was also worked out from the soil samples taken from 0–15 cm and 15–30 cm soil depths by core sampler 40 days after sowing of wheat in 2002–03.

RESULTS AND DISCUSSION

Bulk density

Crop establishment or tillage practices in rice did not differ markedly in respect of bulk density of upper (0–15 cm) as well as of lower (15–30 cm) soil layers (Table 1), except the seed drill method, which showed the lowest bulk density (1.58 g/cc) of the upper layer. Irrespective of the various practices in rice, the bulk density of both the layers increased markedly with the rotavator and zero tillage over the conventional practice in wheat. However, between the latter 2 methods, zero tillage resulted in relatively higher density of upper layer (1.66 g/cc) than the rotavator method (1.61 g/cc). The effect of all the methods on the bulk density of the lower soil layer were less pronounced. The higher bulk density under zero or reduced tillage might be due to more compactness of the soil, while the soil became more porous with increased intensity of tillage in conventional practice. The results confirm are the findings of Dhiman *et al.* (1998).

Rice performance

Yield attributes and grain yield of unhusked rice were affected significantly by various crop-establishment methods in rice (Table 2). The highest grain yield was obtained with transplanting which was significantly better than with the other methods. Direct seeding or rice under puddled

Table 1. Bulk density of soil (g/cc) at 40 days after sowing of wheat (2002–03) as affected by methods of crop establishment

Treatment to rice	Treatment to wheat							
	Soil depth (0 – 15 cm)				Soil depth (15 – 30 cm)			
	ZTD	RD	CT	Mean	ZTD	RT	CT	Mean
Transplanting	1.68	1.62	1.60	1.63	1.69	1.70	1.66	1.68
Direct seeding in puddled soil	1.65	1.63	1.60	1.63	1.70	1.70	1.67	1.69
Dry seeding by seed drill	1.64	1.56	1.54	1.58	1.70	1.70	1.67	1.69
Dry seeding by zero till drill	1.66	1.64	1.58	1.63	1.71	1.71	1.68	1.70
Mean	1.66	1.61	1.58		1.70	1.70	1.67	

ZTD, Zero-till drill; RD, rotavator drill; CT, conventional tillage

condition proved significantly superior to both the dry seeding methods. The effect on growth, viz. plant height, and yield attributes, viz. number of panicles, grains/panicle and 1,000-grain weight was also similar, except for 1,000-grain weight under transplanting and direct seeding under puddled condition which were at par. Dry seeding of rice by seed drill or zero till drill, both at par, gave the lowest yield. The poor productivity of rice under dry sowing was attributed to less favourable conditions for germination and growth of the crop as well as growth of weeds (Sharma *et al.*, 2002). Performance of the crop in 2002 was poor due to lower rainfall at critical stages.

Wheat performance

Yield attributes and grain yield of wheat were influenced significantly due to different methods of establishment in preceding rice (Table 3). Ears/m^2, grains/ear and grain yield were found to be significantly higher when the wheat was grown after dry-seeded rice than after transplanted or direct-seeded puddled rice. This could be owing to better seed-bed for wheat sowing available after dry-seeded rice which resulted in better growth and yield of wheat (Sharma *et al.*, 2002). Irrespective of the various crop-establishment methods in rice, sowing of wheat either by zero-till drill or rotavator drill increased the ears/m^2, grains/ear and grain yield significantly over the conventional method. However, the rotavator method proved significantly better than the zero tillage. Ahmad *et al.* (1992) reported beneficial effects of reduced tillage over conventional tillage in wheat. Interactions between the crop-establishment methods in rice and wheat were not significant for yield or yield attributes of wheat.

Total productivity of rice – wheat system

Transplanting of rice gave the highest total productivity of the rice – wheat system and proved significantly better than the other methods of establishment (Table 4). The next best treatment was direct seeding under puddled condition, being significantly superior to dry-seeding methods. The latter two, though at par with each other, resulted in the lowest total productivity despite giving higher wheat yield than the former two, indicating that the reduction in the rice yield under the dry seeding methods was much greater than the corresponding increase in wheat yield. Dhiman *et al.* (1998) also reported higher productivity of rice – wheat system with transplanting in rice than dry seeding method. Sowing of wheat by rotavator method gave the highest total productivity, followed by zero-till drill, whereas the productivity was the lowest with the conventional method. Interaction between the various

Table 2. Effect of crop-establishment methods on yield attributes and grain yield of rice

Treatment	Plant height at maturity (cm)		Panicles/ m^2		Grains/ panicle		1,000-grain weight (g)		Grain yield (q/ha)		
	2001	2002	2001	2002	2001	2002	2001	2002	2001	2002	Mean
Transplanting	98.6	96.8	318	261	115.4	124.3	23.4	26.3	71.8	69.8	70.8
Direct seeding in puddled soil	90.5	92.4	294	250	106.9	107.0	23.2	26.3	57.5	58.6	58.0
Dry seeding by seed drill	84.3	74.1	280	196	91.2	95.1	22.8	23.2	50.8	32.0	41.4
Dry seeding by zero till drill	82.0	75.6	282	199	88.9	89.6	22.5	24.2	49.9	34.6	42.2
CD (P=0.05)	6.0	4.2	12	10	4.1	10.5	0.4	1.2	3.0	3.6	3.2

Table 3. Effect of crop-establishment methods in rice and in wheat on yield attributes and grain yield of wheat

Treatment	Plant height at maturity (cm)		Ears/ m^2		Grains/ ear		1,000-grain weight (g)		Grain yield (q/ha)		
	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	Mean
Methods in rice											
Transplanting	79.7	78.0	280	249	53.8	49.5	38.2	42.7	46.5	46.2	46.3
Direct seeding in puddled soil	79.3	78.1	277	240	53.7	49.4	38.2	43.4	45.5	45.2	45.3
Dry seeding by seed drill	80.8	77.5	289	277	58.5	51.5	37.8	44.5	50.9	48.4	49.6
Dry seeding by zero till drill	81.9	78.0	288	275	58.6	50.4	37.1	44.1	49.2	47.7	48.4
CD (P=0.05)	0.7	NS	6	11	2.7	NS	NS	NS	1.8	1.4	1.6
Methods in wheat											
Zero till drill	81.5	78.5	283	269	57.4	50.9	38.0	42.8	47.8	47.1	47.4
Rotavator drill	79.8	78.0	298	265	57.6	50.6	38.3	44.7	50.4	48.8	49.6
Conventional tillage	80.0	77.9	269	247	53.5	49.2	37.2	43.5	45.8	44.7	45.2
CD (P=0.05)	NS	NS	10	14	2.1	1.2	NS	NS	1.7	1.2	1.4

Table 4. Effect of crop-establishment methods on total productivity and economics of rice–wheat system average of 2 years

Treatment	Total productivity (q/ha)			Total net returns	Benefit: cost
	2001–02	2002–03	Mean	(Rs/ha)	ratio
Treatments to rice					
Transplanting	118.3	116.0	117.1	26,959	1.76
Direct seeding in puddled soil	103.0	103.8	103.4	20,968	1.63
Dry seeding by seed drill	101.7	80.4	91.0	11,210	1.31
Dry seeding by zero till drill	99.1	82.3	90.7	11,721	1.32
CD (P=0.05)	2.3	2.9	2.5		
Treatments to wheat					
Zero till drill	105.3	95.8	100.5	17,889	1.51
Rotavator drill	107.9	97.6	102.7	19,407	1.55
Conventional tillage	103.3	93.5	98.4	15,839	1.44
CD (P=0.05)	2.0	1.8	1.8		

crop-establishment methods in rice and wheat were not found significant.

Economics

In rice–wheat system, transplanting of rice gave maximum benefit : cost ratio and net income, and hence proved more remunerative than the other methods of establishment (Table 4). The next best treatment was direct seeding in puddled soil. This was ascribed to higher grain yield under these treatments. Sharma *et al.* (2002) reported greater output : input ratio with transplanted than with dry-seeded rice. Sowing of wheat with rotavator resulted in higher benefit : cost ratio and net returns, followed by zero tillage, whereas the conventional method was found to be the least remunerative. This was owing to higher wheat productivity and lower cost of cultivation under reduced or no tillage treatments. Sharma *et al.* (1995) also reported that reduced tillage was more remunerative than conventional one.

It can be concluded that the rice crop may be grown by transplanting, whereas the succeeding wheat crop may be sown by rotavator for getting higher productivity and profitability of the rice–wheat system under irrigated conditions.

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