Mechanization Practices in Rice-Wheat Cropping Systems in Upper Gangetic Plains of India

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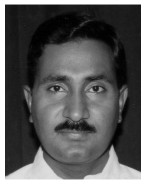

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Abstract

A three year field study was conducted on crop establishment and tillage options in rice-wheat cropping systems in sub-tropical India at Project Directorate for Cropping Systems Research, Modipuram, Meerut, U.P., (India) from 1999 to 2002. The treatment included three crop establishment practices (direct seeding, manual transplanting and mechanical transplanting by self-propelled rice transplanter) as the main plot in rice and three tillage levels (conventional, zero and strip) as the sub plot in wheat; replicated thrice. The highest mean grain yield of rice (6.11 Mg/ha) was obtained in mechanically transplanting that was, respectively, 27.3 and 50 percent higher than manual transplanting and direct seeding. In wheat, the highest mean yield (5.90 Mg/ha) was recorded under conventional sowing that was, respectively, 11.3 and 6.3 percent higher than zero and strip till drilling. The lowest mean weed dry weight (0.24 Mg/ha) was recorded under mechanical transplanting in rice and conventional tillage (0.19 Mg/ ha) in wheat. The greater root density in terms of root dry weight (7.5 gm /20 cm row length) was recorded in conventional tillage and the lowest root dry weight (5.8 gm / 20 cm row length) was obtained in zero tillage during 2000-01.The specific energy (392 kcal/ha) and benefit cost ratio maximum (3.25) in mechanical transplanting followed by manual translating and direct seeding of rice. In wheat, the zero till drilling required minimum specific energy (471 kcal/kg) followed by strip- till drilling (694 kcal/kg) and conventional sowing (501 kcal/kg). Soil physical parameters showed that infiltration rate and moisture content were significantly affected by both crop establishment and tillage practices, whereas bulk density was influenced by tillage practices during the three years. Significantly higher infiltration rate (1.50 cm/h) and moisture content (13.10 %) were recorded in direct seeding (puddled) adopted in the preceding rice crop, whereas lowest values of infiltration rate (0.69 cm/h) and moisture content (9.50 %) were obtained in zero tillage. The results show that mechanical transplanting by a self propelled rice transplanter in rice followed by strip till drilling (reduced tillage) in wheat resulted in higher productivity, profitability and energy saving in rice-wheat systems in India.

Introduction

Rice (Oryza sativa L.) —wheat (Triticum aestivum L) is one the major cropping systems of the Indian sub-continent (Majid *et al.*, 1988). This system covers about 12 million ha in India and is the backbone of food security with a yield potential of 8 Mg /ha /year (Singh *et al.*, 1986 and Bhandari *et al.*, 1992). Transplanting paddy is a labour intensive and arduous operation requiring 200-250 man-hours per hectare (about 25 % of the total labour requirement for the crop production) and results in low and non-uniform plant population and reduced crop yields. Moreover, the productivity is decreased due to want of proper equipment and labour. It calls for evaluation and popularization of the translating machine to cater to the needs of farmers (Singh and Gangwar, 1999).

Rice is normally transplanted in June-July in wet puddled soil. Puddling is essential for destruction of macropores (Jamison, 1953) and reduction in permeability (Bodman and Rubin, 1948). The reduction in permeability is highly desirable because it reduces the need for irrigation water. However, puddling results in poor physical conditions for the succeeding wheat crop. Under such conditions, 2-3 operations of primary tillage followed 2-3 operations of secondary tillage (in heavy soils even 8-12 operations) are commonly performed by farmers for seedbed preparation before sowing of wheat in November-December. Due to shortage of time after rice harvesting and wheat sowing, direct drilling of wheat is recommended.

Strip-till and zero-till drilling are partial conservation tillage systems because, whatever type of tillage is performed, it is not the same over the whole field (Anon, 1987 and Wiese, 1985). Conservation tillage systems reduce the production costs by requiring less labour, fuel, machinery and other inputs. However, highly reduced systems may require more pesticides and a higher management level to maintain or increase yield (Brown *et al.*, 1989). The present study was, therefore, conducted to compare different tillage treatments in wheat after suitable crop establishment practices followed in rice under rice-wheat cropping systems.

Material and Methods

A field experiment was conducted for three years (1999-2000 to 2000-2002) at the experimental farm of Project Directorate for Cropping Systems Research Modipuram (29º4′ N latitude and 77º46′ E longitude), Meerut, U.P., India at an elevation of 237 m above mean sea level. The climate of Modipuram is broadly classified as semi-arid and sub-tropical. It is characterized by very hot summers and cold winters. The hottest months are May-June, when maximum temperatures may shoot up as high as 45-46 ºC, whereas, December and January are the coldest months of the year, when minimum temperature often goes below 5 ºC. The average annual rainfall is 862.7 mm, 75.80 percent of which is received through Northwest monsoon during July to September. The soil of the experimental field was sandy loam consisting of 642, 185 and 173 g/kg sand, silt and clay, respectively. According to FAO classification the soil was deep alluvial fine sandy mixed developed under hyperthermic regime (Typic Ustochrept). The soil pH, electrical conductivity, organic carbon, available P and available K as determined by procedures described by (Prasad 1998), respectively, were 8.02, 0.42 d s /m, 4 g/kg, 3.5 mg/kg and 36 mg/kg of soil.

Table 1 Puddled bed condition developed for rice transplanting

Parameters	Mean ± SD
Depth of puddled, mm	63.4 ± 4.3
Depth of water, mm	52.3 ± 2.6
Amount of dispersion, %	54.2 ± 6.2
Bulk density in 25-150 mm profile, Mg /m^3	1.37 ± 0.5
Water content in 25-150 mm profile, %	58.4 ± 5.8

Data represents average of 5 observations. SD = Standard deviation

Treatments

The field experiment was initiated during July 1998 with rice (Oryza sativa L.). The treatments consisted of three crop establishment practices, namely, direct seeding (puddled), manual transplanting and mechanical transplanting by self-propelled rice transplanter. Each method of puddled bed was prepared by dry tillage of two harrowing and two passes of the cultivator at 75-100 mm depth at a water content of about 20 %, followed by flooding for 24 hours and two passes of a rotary puddler. After 24 hours, the dispersed soil settled, the excess water drained to consolidate the soil and the soil was re-flooded with 25-50 mm of standing water just before start of the transplanting operation. The main plots were 50 m × 12 m while sub plots were 16 m × 4 m.

The puddled bed characteristics of soil prior to transplanting are given in **Table 1**. In direct seeding, pre-germinated seeds (soaked in water for 12 hours) were broadcast uniformly in the field at the rate of 50 kg/ha. For growing seedlings by the traditional method, pre-soaked seed (12 hours) were broadcast in the puddled bed at the rate of 35 kg/ha. Fertilizers were applied as per recommendation and water was applied as required. When the seedlings were 21 days old, they were uprooted and transplanted in the puddled field manually.

For mechanical transplanting, mat seedlings (50 m^2/ha of transplanting) were grown over 50 to 60 gauge polythene (10 % perforated) in the nursery bed (5 m × 1.2 m) with

side furrows. The soil was ground and sieved (2 mm) and mixed with farmyard manure (ratio of 3 : 1). The removing of the floating seeds, then disinfecting, soaking and sprouting the remainder prepared the seed at 25 kg/ha. Over the bed, 15 mm thick soil mixture was spread followed by uniformly spreading of sprouted seed and covered by 5 mm thick soil mixture. Then the jute bags or dry hay was placed over beds, if required, and water was sprinkled by the watering cane for 3-4 days. After that the jute bags/dry hay were removed and water was applied by flooding through side furrows. The seedlings became ready to transplant in 21 to 22 days when the highest reached 125-150 mm. The seedling mats were trimmed on sides and loaded into the transplanter (400 mates/ha of transplanting).

A self-propelled single wheel driven rice transplanter, (Chinese make, model: 2ZT-238-8) with a 2.4 kW air-cooled diesel engine and a transplanting system of fixed fork and knock out lever type planting fingers, was used for transplanting the mat seedlings. The machine covered 8-rows with 238 mm row spacing per pass.

After harvest of the rice crop, each of the plots was subdivided into three sub plots. The sowing of the wheat in winter season was done in sub plots using conventional method, zero-till drill and strip-till drill. In conventional tilled plots, two harrowing, two cultivating and one planking operation were performed and the sowing (HD 2,329) was done with seed cum fertilizer drill at the rate of 100 kg/ha. Sowing with zero and strip trill drill was done directly on the field without any soil preparation after harvest of rice. Each treatment was replicated thrice. The same seed rate, as well as fertilizer rate, was applied in the three sowing methods.

Crop Management

Rice (Oryza sativa L.) received 120 kg N as urea, 26 kg P as single super phosphate, 33 kg K as murite of potash and 25 kg Zn as zinc sulphate per ha. Nitrogen was applied in two doses; half at transplanting and the other half at panicle initiation. Wheat (Triticum aestivum L) received 120 kg N as urea, 26 kg P as single super phosphate and 33 kg K as murite of potash per ha. Rice and wheat were supplied with recommended doses of NPK; i.e. 120 kg N, 26 kg P and 33 kg K per ha. Nitrogen was applied in two applications, first half at sowing and the other half at first irrigation (21 days after sowing). Wheat received 4-5 irrigations and rice was irrigated as needed. Glyphosate (N-Phosphonomethilglycine) at 2.5 liter in 500-600 liter water per hectare was sprayed to kill green vegetation 20 days before of wheat sowing. Wheat was sown, in the third week of November, with respective seed drills on the same day to keep the same date of sowing, and harvested in the second week of April.

Soil and Plant Analysis

Soil moisture was determined gravimetrically (Jalota *et al.*, 1998). After the third crop of wheat, the soil bulk density was measured in 0-15 cm depth by the core method (Blake and Hartge, 1996) and infiltration rate by infiltrometer (Bouwer, 1986). Root samples were collected from all plots with a core sampler of 5 cm inner diameter at 10 cm depth intervals from a single site (Garji *et al.*, 1994) by centering the auger 3 cm away from the base of the plant. The length of the clean root samples was estimated by a line intercept method (Newman, 1986). The root samples were dried at 65 ºC for determination of their dry matter at 90 days after sowing. Weed spices and weed dry matter were recorded at 45 days after planting in rice and wheat from an area enclosed in quadrant of 0.25 m^2 randomly selected at two places in each plot. The weed samples were dried at 65 ºC for their dry matter.

Economic Methodology and Statistical Procedures

The economic and energy requirement for all the treatments were measured for the growing period of the crops. Labour, machinery, fuel, fertilizer, seed, pesticides and irrigations were considered as inputs for the growth period of the crops. The yield was considered as output of the crop. The economic and energy equivalent of the each parameter were calculated as per

Table 2 Rice grain yield (Mg ha^{-1}) affected by methods of planting

Planting method	1998-1999	1999-2000	2000-2001	Mean
Direct seeding (puddled)	3.40	4.30	4.50	4.07
Manual transplanting	4.50	5.10	5.40	5.00
Mechanical transplanting	5.10	6.50	6.80	6.11
$LSD_{0.05}$	0.66	0.54	0.60	-

Table 3 Wheat grain yield (Mg ha^{-1}) influenced by crop establishment and tillage practices

Tillage (in wheat)	Crop establishment (rice)												
	1999-2000				2000-2001				2001-2002				Overall mean
	DS	MT	Me T	Mean	DS	MT	Me T	Mean	DS	MT	Me T	Mean	
Conventional tillage	5.02	3.70	3.81	4.17	5.92	5.28	5.33	5.61	6.32	5.68	5.71	5.90	5.23
Strip tillage	3.83	2.98	3.42	3.41	5.73	5.32	5.58	5.45	6.03	5.62	5.88	5.82	4.89
Zero tillage	3.20	2.87	3.06	3.04	5.80	5.13	5.25	5.39	5.70	5.33	5.45	5.40	4.61
Mean	4.02	3.18	3.43		5.82	5.24	5.39		6.02	5.54	5.68	-	-
$LSD_{0.05}$													
Crop establishment	0.40				0.36				0.42				
Tillage	0.56				0.16				0.61				
Tillage × Crop establishment	0.90				0.27				0.82				
Crop establishment × Tillage	0.89				0.42				0.70				

DS, Direct seeding; MT, manual transplanting; MeT, mechanical transplanting; CT, conventional tillage; ST, strip tillage; ZT, zero tillage the procedure given by Pimental (1980). The data were subjected to analysis of variance for a split plot design with the method of rice planting in main plots and wheat planting in sub plots as procedure given by Little and Hills (1978). The treatment effects were tested by the "F test". The significant differences between treatments were compared by standard error of differences at 5 percent levels of probability.

Results

Grain Yield

The rice yield was significantly affected by methods of planting. The greater mean grain yield of 6.11 Mg/ha was for mechanical transplanting (by self-propelled rice transplanter) followed by manual transplanting and direct seeding (**Table 2**). The growth and subsequent establishment of transplanting seedlings by self-propelled rice transplanter were faster with almost no loss of plants giving significantly higher number of yield attributes. Apart from this, the uniform growth of the crop was also observed due to uniform spacing and depth of placement of seedlings with equal number of seedlings per hill. These factors contributed to higher grain yield of rice under mechanical transplanting.

The wheat yield was significantly affected by different planting methods of both rice and wheat during all the three years of experimentation (**Table 3**). Direct seeding adopted in preceding rice crop produced significantly higher three-year mean wheat yield (5.29 Mg ha^{-1}) compared to mechanical (4.83 Mg ha^{-1}) and manual transplanting (4.65 Mg ha^{-1}) methods. Variation in wheat yield between manual and mechanical transplanting was not significant. Among tillage practices used for sowing wheat, significantly greater overall mean wheat yield (5.23 Mg ha^{-1}) was obtained under conventional tillage followed by reduced tillage (4.88 Mg ha^{-1}) and zero tillage (4.61 Mg ha^{-1}) treatments. Better germination and low weed infestation resulted in higher value of yield contributing characters; i.e. ear head/m^2 grain/ear head, length of ear head and 1,000 grain weight (**Table 4**) that ultimately contributed to higher yield of wheat.

Interaction effect between tillage levels with in crop establishment practice and also between crop establishments practices within a tillage level were significant. The highest mean grain yield (5.75 Mg ha^{-1}) was obtained in conventional tillage where direct seeding was done in the preceding rice crop while lowest mean grain yield (4.44 Mg ha^{-1}) was recorded under zero tillage and manual transplanting.

Weed Dynamics

In order to study the weed competition under different methods of planting, weed species and weed dry matter were recorded at 45 days after planting of rice and wheat. However, weed count were not taken in any of the crop. Among the major weeds, Enchinochloa crusgalli (barnyard grass) was the most predominant weed affecting the rice crop followed by Cyperus iria (nutgrass) while other species were of minor significance in rice. The direct seeding recorded highest weed dry weight (0.14 Mg ha^{-1})

Table 5 Weed dry weight Mg ha^{-1}) in rice at 45 days after planting as influenced by methods of planting

Planting method	Weed dry weight			
	1998-1999	1999-2000	2000-2001	Mean
Direct seeding	0.14	0.14	0.12	0.13
Manual transplanting	0.12	0.12	0.11	0.11
Mechanical transplanting	0.025	0.032	0.014	0.024
$LSD_{0.05}$	0.025	0.017	0.015	-

Table 4 Yield attributes of wheat as influenced by crop establishment and tillage practices

Treatment	1999-2000				2000-2001				2001-2002			
	Ear head m^{-2}	Grain ear $head^{-1}$	Length of ear head, cm	1000-grain weight, g	Ear head m^{-2}	Grain ear $head^{-1}$	Length of ear head, cm	1000-grain weight, g	Ear head m^{-2}	Grain ear $head^{-1}$	Length of ear head, cm	1000-grain weight, g
Crop establishment (in rice)												
Direct seeding	284	36.7	8.7	39.0	333	41.6	10.7	41.6	354	42.5	10.8	42.7
Manual transplanting	276	31.6	7.6	38.3	305	36.5	9.6	41.5	321	37.7	9.7	41.5
Mechanical transplanting	291	34.8	8.1	38.8	297	39.8	10.1	41.1	301	40.8	10.2	40.3
$LSD_{0.05}$	NS	2.3	0.45	0.54	18.5	3.1	0.40	0.89	20.6	2.9	0.3	1.8
Tillage (in wheat)												
Conventional tillage	322	34.5	8.5	39.0	308	39.5	10.5	41.4	312	41.1	10.6	42.7
Strip tillage	273	34.3	8.0	38.6	321	39.3	10.1	41.9	331	41.2	10.2	41.5
Zero tillage	256	34.3	8.0	38.5	306	39.3	10.0	41.0	310	41.1	9.9	41.1
$LSD_{0.05}$	0.9	NS*	NS	0.38	16.3	NS	0.43	0.57	15.2	NS	0.5	1.1

*NS = Non significant

during first two years and lowest in the third year (0.12 Mg ha^{-1}), compared to manual and mechanical transplanted. The lowest dry weight of weeds (0.025 Mg ha^{-1}) was noticed in mechanical transplanting (**Table 5**). In wheat, the majority of weeds were Phalaris minor (wild canary-grass), Angallis arvensis (blue pimpernel), Cyperus rotundus (nutsedge), Cornopus didimus (swinecress), Chenopodium album (common lambsquarters), Melilotus indica (sweet clover), Visia sativa(common vetch) and Lathyrus aphca (yellow vetch). Among these species, Phalaris minor was the most prominent weed infesting the wheat crop. Weed dry weight showed the perceptible influence of crop establishment and tillage practices. Significantly lower dry weight of weeds (0.19 Mg ha^{-1}) was recorded with mechanical transplanting. Similarly, conventional tillage also had lowest mean weed dry weight (0.19 Mg ha^{-1}) followed by reduced tillage and zero tillage (0.26 Mg ha^{-1}) because zero tillage practices avoid burial of weed seed and preserve them in the soil (**Table 6**).

Root Density

Root density in terms of root length and root dry weight was significantly affected due to tillage practices only (**Table 7**). Conventional tillage resulted in greater mean root length (22.2 cm) and higher root mean dry weight (7.4 g) as 20 cm row length compared to reduce and zero tillage due to more compaction of soil that, in turn, restricted root length. Crop establishment practices followed in rice did not bring significant variation in root length and root dry weight of wheat. However, numerically, more root length and dry weight was observed with direct seeding.

Energy Use

The operational energy, energy output, specific energy, energy output-input ratio, grain yield, cost of production, net income and benefit-cost ratio for direct seeding, manual and mechanical transplanting of rice are given in **Table 8**. The mechanical transplanting required minimum specific energy (392 kcal ha^{-1}) than manual transplanting of rice (487 kcal ha^{-1}) and direct seeding of rice (573 kcal ha^{-1}). The benefit-cost ratio of mechanical transplanting was maximum (3.25) followed by manual (2.44) and direct seeding (2.37). In wheat, strip-till drilling required minimum specific energy of 458 kcal kg^{-1} followed by zero-till drilling (471 kcal kg^{-1}) and conventional sowing (501 kcal kg^{-1}). However, the energy out put-input ratio of conventional sowing was maximum (4.88) followed by strip-till drill (4.32) and zero-till (3.91) drilling (**Table 9**). Thus, mechanical transplanting of rice followed by strip-till drilling of wheat in rice-wheat system was most energy efficient.

Changes in Soil Physical Properties

Crop establishment and tillage practices significantly affected infiltration rate, bulk density and mois-

Table 6 Weed dry weight (Mg ha^{-1}) in wheat at 45 days after planting as influenced by crop establishment and tillage practices

Planting method	Weed dry weight			Mean
	1998-1999	1999-2000	2000-2001	
Crop establish-ment (in rice)				
Direct seeding	0.22	0.25	0.26	0.24
Manual transplanting	0.20	0.23	0.25	0.23
Mechanical transplanting	0.19	0.21	0.22	0.21
$LSD_{0.05}$	0.047	0.043	0.056	
Tillage (in wheat)				
Conventional tillage	0.17	0.19	0.20	0.19
Strip tillage	0.21	0.23	0.25	0.23
Zero tillage	0.23	0.27	0.28	0.26
$LSD_{0.05}$	0.046	0.015	0.012	-

Table 7 Wheat root length and dry weight as influenced by crop establishment and tillage practices (at 90 days after planting)

	1999-2000		2000-2001		2001-2002		Mean	
	Root length, cm	Root dry weight (g 20 cm row^{-1})	Root length, cm	Root dry weight (g 20 cm row^{-1})	Root length, cm	Root dry weight (g 20 cm row^{-1})	Root length, cm	Root dry weight (g 20 cm row^{-1})
Crop establishment (in rice)								
Direct seeding	18.2	6.5	18.3	6.6	18.6	7.0	18.3	6.7
Manual transplanting	17.2	6.2	17.5	6.3	17.8	6.5	17.5	6.3
Mechanical transplanting	16.7	5.9	17.0	6.0	17.0	5.6	16.9	5.8
$LSD_{0.05}$	NS	NS	NS	NS	NS	NS		
Tillage (in wheat)								
Conventional tillage	22.3	7.3	22.3	7.5	22.0	7.5	22.2	7.4
Strip tillage	18.5	6.4	18.8	6.6	18.2	6.4	18.5	6.5
Zero tillage	15.7	5.9	16.0	6.0	14.9	5.8	15.5	5.9
$LSD_{0.05}$	1.8	0.7	1.8	0.7	1.7	0.6	-	-

ture content (**Table 10**). The higher mean infiltration rate (1.47 cm h^{-1}) and mean moisture content (12.90 %) were recorded in direct seeded and lower mean infiltration rate (1.36 cm/h) and mean moisture content (11.30 %) were noticed under mechanical transplanting adopted in preceding crop of rice. Bulk density was not affected significantly by crop establishment practices. However, a minimum mean value of bulk density (1.59 Mg m^{-3}) was registered in direct seeding followed by mechanical transplanting adopted in rice crop (1.62 Mg m^{-3}). The different tillage operations were found to make spectacular changes in soil physical properties and higher mean infiltration rate (1.35 cm h^{-1}) was observed in conventional tillage, which clearly revealed the quality of field preparation that allowed more water to penetrate in the field and in turn helped the wheat crop to grow vigorously. The lowest mean infiltration rate was recorded in zero tillage due to compaction of soil. The mean bulk density was lowest (1.59 Mg m^{-3}) in conventional tillage and minimum in zero tillage (1.68 Mg m^{-3}). The highest mean moisture content (12.91 %) was with conventional tillage followed by reduced (12.31 %) and zero tillage (9.73 %) treatments.

Table 8 Economics and energy use in direct seeded, manually and mechanically transplanting rice

Parameters	Direct seeding Mean + SD	Manual transplanting Mean + SD	Mechanical transplanting Mean + SD
Cost of production, US \$ ha^{-1}	217 +1.30	250 +1.10	239 +1.50
Net income, US \$ ha^{-1}	297 +1.95	262 +2.50	538 +2.30
Benefit: cost ratio	2.37 +0.22	2.05 +2.30	3.25 +0.28
Specific energy, Kcal kg^{-1}	573 +2.95	487 +2.50	392 +2.62
Energy output: input ratio	5.2 +0.26	6.2 +0.21	7.7 +0.18

Data represents average of 3 years

Table 9 Economics and energy use in strip and zero till drilling with conventional sowing of wheat after harvest of rice

Parameters	Conventional sowing	Strip till drilling	Zero till drilling
Cost of production, US \$ ha^{-1}	261	213	202
Net income, US \$ ha^{-1}	620	695	671
Benefit: cost ratio	3.38	4.26	4.32
Specific energy, Kcal kg^{-1}	501	458	471
Energy output: input ratio	4.88	4.32	3.91

Data represents average of 3 years

Table 10 Influence of different crop establishment and tillage practices on physical properties of soil after harvest of wheat crop

Treatment	Infiltration rate (cm h^{-1})				Bulk density (Mg m^{-3})				Moisture content (%)			
	1999-2000	2000-2001	2001-2002	Mean	1999-2000	2000-2001	2001-2002	Mean	1999-2000	2000-2001	2001-2002	Mean
Crop establishment (in rice)												
Direct seeding	1.50	1.48	1.42	1.47	1.58	1.60	1.60	1.59	12.7	12.9	13.1	12.9
Manual transplanting	1.44	1.40	1.37	1.40	1.60	1.61	1.62	1.61	12.2	12.3	12.6	12.4
Mechanical transplanting	1.39	1.36	1.32	1.36	1.61	1.62	1.63	1.62	11.5	11.2	11.2	11.3
$LSD_{0.05}$	0.10	0.09	0.07		NS	NS	NS		1.1	1.5	1.8	
Tillage (in wheat)												
Conventional tillage	1.40	1.35	1.30	1.35	1.54	1.60	1.62	1.59	12.3	13.2	13.3	12.9
Strip tillage	1.25	1.20	1.18	1.21	1.67	1.67	1.65	1.66	11.6	12.6	12.7	12.3
Zero tillage	0.90	0.80	0.69	0.80	1.69	1.69	1.66	1.68	9.5	9.7	10.0	9.7
$LSD_{0.05}$	0.40	0.35	0.70		0.70	0.12	0.12	0.03	2.4	2.8	3.1	-

Discussion

Consistently higher yield of rice was recorded in mechanical transplanting (by self propelled rice transplanter). This was significantly greater than manual transplanting and direct seeding (unpuddled) due to crop growth and subsequent establishment of transplanted seeding by self-propelled rice transplanter. This was, also, faster with almost no loss of plants giving a significantly higher number of yield attributes such as effective tiller m^{-2}, panicle length (cm), panicle weight (g), number of filled grains panicle-1 and 1,000 grain weight (g). Besides this, uniform growth of crop was also observed due to uniform spacing and depth of seed placement with an equal number seedlings per hill. These factors contributed to higher yield of rice under mechanical transplanting (Singh and Gangwar, 1999). The reduction in yield was on the order of 6.7 % and 11.9 % under reduced and zero tillage treatments, respectively. This higher yield under conventional tillage was probably due to better germination and adequately low weed infestation. Singh *et al.* (1998) also reported that wheat sown after conventional tillage resulted in taller plants, longer and bolder ears, more grains ear-1 and higher grain yield compared to wheat sown with zero and reduced tillage. Adoption of direct seeding in the rice crop proceeding wheat produced a higher overall mean wheat yield compared with manual and mechanical transplanting. This was mainly attributable to relatively greater compaction of puddled soil under mechanical transplanting and its carry-over effect of succeeding wheat. In direct seeded rice plots the subsequent wheat yield was highest and demonstrated the disadvantages of puddling and transplanting on succeeding wheat crops (Tripathi *et al.*, 1999). Among tillage levels, conventional tillage produced significantly greater yield of wheat and reduced tillage and zero tillage produced 5.9 and 13.4 % less, respectively. Taller plants, heavier ears and more grains per ear were observed in conventional tillage than with zero tillage. Similar result were reported by Oussible and Crookston (1987) and Singh and Brar (1994).

Growth parameters including root growth and dry matter accumulation were affected significantly by tillage under different methods of rice seeding. Wheat plants grown in conventional tillage had nearly 30 % higher root dry weights than plants grown in zero tillage, probably related to finer seed bed preparation. The lowest root dry weight was observed in zero tillage and probably related to compaction of the soil. Immediately after rice cropping, aerobic soil conditions, impaired soil structure and a hard pan are major impediments to the establishment and growth of wheat (Meelu *et al.*, 1979; Kirchhog and So, 1996).

The destruction of soil aggregates by puddling leads to the formation of surface crusts and cracks on drying, delaying preparation of the seedbed for the wheat crop. When broken by tillage, the resulting large clods provide poor contact with seed, thereby restricting germination. Subsurface compaction caused by puddling generally reduces root growth of wheat (Oussible *et al.*, 1992; Aggarwal *et al.*, 1995), although roots that penetrate the compacted layer before it hardens on drying may extend more deeply as soil drains (Sur *et al.*, 1981). Very little (Little *et al.*, 1978) is known of the root growth of wheat in rice-wheat systems on puddled soils of heavy texture. Tayer *et al.* (1966) observed that the rate of root elongation is inversely related to soil strength. Greater mechanical impedance encountered by axially elongating the root causes thickening of root tips (Russell and Goss, 1974) but sub soiling of sandy soil reduces root thickening as indicated by increases in root length to mass ratios (Prihar and Gajri, 1994).

Crop establishment methods in rice and tillage in wheat significantly influenced weed flora and their dry matter production of (**Tables 4** and **5**). Mechanical transplanting recorded lowest weed dry matter since almost weed-free seedlings were grown and planted by self propelled rice transplanter as compared to manual transplanting and direct seeding (Singh and Gangwar, 1999). Similarly, Reddy and Hukkari (1980a) reported an improvement in rice yield due to fewer weeds under puddled conditions. Significantly, lowest weed dry weight was obtained under mechanical transplanting adopted in previous rice crop due to good growth of wheat in this treatment that had a smothering effect on weed population. In the same way, conventional tillage recorded lowest dry weight followed by reduced and zero tillage because zero tillage avoided burying weed seeds and preserved them in the soil. Weed seed germinate in large numbers when they get a congenial environment and offer heavy weed competition in wheat crop (Pandey *et al.*, 2005). The specific energy in mechanical transplanting in rice and zero tillage in wheat was minimum as compared to the other treatments. It was due to a minimum requirement of input energy (Singh and Gangwar, 1999).

The higher infiltration rate and soil moisture content were recorded under direct seeding while low values were obtained in mechanical transplanting adopted in preceding rice crop because of puddling surface soil. Tillage operations resulted in higher infiltration rate and moisture content of the soil as compared to zero tillage. This might be attributed to pulverized soil conditions due to loosening of the soil mass under conventional tillage (Singh *et al.*, 1998). Tillage significantly decreased soil bulk density since settling of soil particles can increase bulk density under zero tillage systems (Cassel and Nelson, 1985).

Conclusions

Under rice-wheat sequence, in rice, the mechanical transplanting (by self-propelled transplanter) provided considerable savings in time, cost of production, energy use and increase in productivity and profitability compared to manual transplanting and direct seeding. In wheat, strip and zero till drilling were more cost and energy efficient compared to conventional tillage. Further, mechanical transplanting resulted in lower weed density and weed dry weight in comparison to direct seeding and manual transplanting due to churning of puddled soil. Similarly, mechanical transplanting adopted in rice resulted in lower weed density and weed dry weight in wheat. The zero till drilling decreased Phalaris minor population compared to conventional sowing in wheat. The conventional tillage improved the soil physical environment to favor root growth, increase infiltration rate and moisture content and decrease the bulk density. Therefore, mechanical transplanting in rice followed by conventional sowing or strip-till drilling in wheat recorded higher productivity and profitability in the rice-wheat system.

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ABSTRACTS

The ABSTRACTS pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

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Synergic Effect of Heat Treatment and Peening Intensity on Low Stress Abrasive Wear Behaviour of High Strength Low Alloy Agricultural Grade Medium Carbon Steel: Dushyant Singh, Central Institute of Agricultural Engineering, Bhopal-462038, INDIA; **D. P. Mondal**, Advanced Materials and Processes Research Institute, Bhopal-462026, same; **S. Rathod**, same; **N. V. Prasad**, Central Institute of Agricultural Engineering, Bhopal-462038, same.

The performance and efficiency of soil engaging agricultural machines like cultivator sweep, furrow opener of seed drills and planters depends on their mechanical properties and abrasive wear resistance. It is seen that in agricultural field more than 50 % of wear is abrasive in nature. To study the wear rate of low alloy medium carbon steel (commonly used in agriculture), three body abrasive wear (low stress abrasive wear) tests were conducted. In order to achieve different types of microstructures and mechanical properties, the medium carbon steel was heat-treated differently. Steels were further subjected to shot peening in the range of 0.17 to 0.47 mm ALMEN 'A' to improve their surface properties. It was noted that the intercritically annealed and quenched and tempered steels showed comparable wear rate. The wear rates of inter critical annealed and quenched and tempered steels are considerably less than that of as-received and annealed steels, irrespective of peening intensity. It could be further noted that the steels exhibit the minimum wear rate at a critical peening intensity of 0.17 mm ALMEN'A' irrespective of heat treatment schedules.

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