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Research Paper

Effect of double no-till and permanent raised beds on productivity, profitability and physical properties of soil in maize (*Zea mays*)–wheat (*Triticum aestivum*) cropping system under Indo-Gangetic plains of India

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ABSTRACT

A field experiment was conducted at Indian Agricultural Research Institute, New Delhi on sandy loam soil during 2010 to 2012 to study the effect of tillage and crop establishment techniques, and residue management on maize (*Zea mays* L.)–wheat [*Triticum aestivum* (L.) emend. Fiori & Paol] cropping system. Results indicated that permanent beds with residue retention (PB+R) and fresh beds with crop residue incorporation (FB+R) were found comparable with respect to yield and yield attributes both in maize and wheat. FB+R recorded 25.0 and 8.3 % higher grain yield of maize and wheat, respectively compared to conventional till–flat (CT–F). Likewise, PB+R gave 25.0 and 28.6% higher grain yield of maize and wheat, respectively over CT– F. Further, PB+R gave 3.5% higher system productivity compared to FB+R. PB+R gave the highest net returns of maize (39.2×10^3₹/ha), wheat (50.5×10^3₹/ha) and the cropping system (89.7×10^3₹/ha) followed by FB+R and zero till– flat with residue retention (ZT–F+R). At upper soil surface (0–10 cm), lowest bulk density and soil penetration resistance was observed in FB+R followed by PB+R. Among all the tillage, crop establishment, and residue management techniques, ZT–F+R gave lowest yield and yield attributes, and recorded highest bulk density in upper soil surface.

Key words : Conventional–till, Crop residue management, Flat bed, Maize–wheat system, Raised bed, Residue, System productivity, Zero–till

Maize–wheat is the 5th dominant cropping system of India covering 1.8 mha with 2.3% contribution in food basket (Jat *et al*., 2011). Recently, the growth rate of area and production of maize has increased by 2.2 and 8.9%, respectively, mainly due to adoption of single cross hybrids and various industrial uses. Further, it is projected that by 2020, the demand for maize in developing countries will surpass the demand for wheat and rice (GOI, 2012-13). Besides this, in Indo-Gangetic Plains (IGP) of India, continuous cultivation of rice–wheat system over the years has resulted in drastic decline of groundwater, deterioration of soil health and yield stagnation. These factors forced to pursue diversified crops and cropping systems, which are not only environmental friendly, but also efficient in conserving natural resource pool (Aulakh and Grant, 2008). Thus, maize–wheat cropping system can be a possible alternative of rice–wheat under IGP tracts of India mainly due to lower water requirement, higher productivity of wheat crop by its timely sowing and better soil health as compared to rice–based cropping system. This rotation does not have any adverse impact on physical environment of soil. Generally, maize and wheat are grown after 6–7 intensive tillage operations, which resulted into extra cost and energy for cultivation, accelerated rate of organic matter decomposition and degradation of soil health, which raised a question mark on the conventional practices of farming (Govaerts *et al*., 2006). In this perspective, conservation agriculture (CA) has drawn considerable attention of researchers as it has potential to improve resource use efficiency, productivity (Nyborg *et al*., 1995) and soil health, besides many environmental benefits (Limon-Ortega *et al*., 2000). Globally, CA occupies 124.79 mha, but in India, area under zero tillage is approximately 2.2 mha and mostly confined to rice–wheat only (FAO, 2013). Minimum mechanical soil disturbance, organic mulch cover and crop diversification constitute the major practices under CA. A number of studies reported that maize yield were similar with zero tillage as that of traditional tillage system (Sharma *et al.,* 2009), but the

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impact of various tillage and residue management methods on system productivity, profitability and soil properties as related to maize–wheat system in sandy loam soil of IGP has not been studied in detail. Therefore, an attempt was made to find out the effect of tillage and crop establishment, and residue management in terms of productivity and profitability under maize–wheat system.

MATERIALS AND METHODS

A fixed plot field experiment was conducted for 2 years during 2010–11 and 2011–12 at the research farm of Indian Agricultural Research Institute, New Delhi (28°37'N, 77°09'E, 228.7 m above mean sea-level). The climate of the experimental site is semi-arid and temperature is usually warm in most of the period in a year; summer is hot and long and winter is severe and short with average temperatures of 42°C and 15°C, respectively. The mean annual rainfall during the experiment was 986 and 671 mm during 2010–11 and 2011–12, respectively. The soil of the experimental site was sandy loam (15.6% clay, 18.2% silt, 66.2% sand) in texture having pH 7.9 (1:2.5 soil to water). The soil contained 0.36 % organic C (low), 164 kg/ha available N (low), 10.2 kg/ha 0.5 *M* $NaHCO_3$ extractable available P (low) and 270 kg/ha NH_4OAc extractable available K (medium) (Prasad *et al*., 2006). The treatments comprised of combinations of 4 tillage and crop establishment techniques, and residue management, viz. Conventional tillage–flat (CT–F); fresh beds with crop residue incorporation (FB+R); zero tillage–flat with residue retention (ZT–F+R) and permanents beds with residue retention (PB+R) were allocated randomly in a randomized block design with four replications. Under conventional tillage, the plots were ploughed 5 times (2 disc harrowing + 2 cultivators + 1 planking) followed by sowing, while in zero – tillage the crop was sown by "Turbo seed drill" without any tillage operations. The raised bed (70 cm centre to centre width of beds) was formed with a tractor mounted bed planter and basal dose of NPK was applied at sowing to both the crops. Under conventional tillage, raised beds were dismantled after harvesting of maize and again prepared before sowing of wheat. In zero tillage conditions, raised beds were prepared before sowing of first crop of maize and in every season reshaped by bed planter with minimum soil disturbance. Maize residues @ 3 t/ha were applied to the wheat crop, while wheat stubbles @ 2.5 t /ha were applied in maize. Maize "PEHM 3" was sown in rows at 70 cm apart so as to get one row in the centre of each bed (70 cm centre to centre spacing), while three rows of wheat "HD 2894" were accommodated on the respective beds. Fertilizer dose of 120, 26 and 33 kg N, P and K/ha was applied as to maize (50% of N and full P and K as basal and rest 50% N at knee high stage), while a dose of 120, 26 and 33 kg N, P and K/ha was applied to wheat (50% of N and full P and K as basal and rest 50% N at first irrigation). Maize was sown during first week of July and manually harvested about 10 cm above the ground level during third week of October. Wheat was sown in first week of November and harvested in third week of April across the years. Irrigation was given to both the crops as per recommendations after making adjustment to rainfall received.

All the necessary observations including yield attributes and grain yield of maize and wheat (14% moisture) were recorded. To compute the productivity of the system maize equivalent yield of wheat (M EY) was calculated by using the following formula.

MEY = {Yield of wheat (t/ha) × Price of wheat (₹/t)}/ Price of maize (₹/t).

Productivity of the system was worked out by adding maize yield and maize equivalent yield of wheat for respective years. Bulk density and soil penetration resistance were measured and for this, soil samples from 0–10, 10–20, 20–30 and 30–45 cm soil depths were collected. A two-factor analysis of variance (ANOVA) was carried out to test the significance of treatments. Critical difference (CD at P=0.05) was used to determine whether means differed significantly or not. For statistical analysis of data, Microsoft Excel (Microsoft corporation, USA) was used.

RESULTS AND DISCUSSION

Yield attributes of maize and wheat

The yield and yield attributes varied significantly ($P < 0.05$) among the different tillage and crop establishment, and residue management treatments in both the crops (Table 1). Permanent beds with residue retention (PB+R), conventional till–flat (CT–F) and fresh beds with residue incorporation (FB+R) were found comparable to each other with respect to cobs/plant and spikes/m^2 in maize and wheat, respectively. Zero till–flat with residue retention (ZT–F+R) had lowest cobs/plant and spikes/m^2 in maize and wheat, respectively, while in case of grains/cob in maize, ZT–F+R was found at par with FB+R and CT–F. The highest grains/cob and grains/spike in maize and wheat, respectively was observed in PB+R over the rest of treatment, but remained comparable to FB+R. Further, PB+R and CT–F were found at par in case of grains/cob and grains/spike in maize and wheat, respectively. PB+R, CT–F, ZT–F+R and FB+R were statistically non-significant with respect to 1000-grain weight in maize and wheat. Overall, PB+R and FB+R were found comparable among the varied tillage, crop establishment techniques and residue management practices. Inclusion of crop residues under conventional tillage and zero tillage may be one of the main reasons for higher yield attributes over conventional and zero tillage practices (Hodds *et al.*, 2008). Crop residue application reduces water evaporation losses and also moderates soil temperature, which reduces fluctuations in water availability to crop (Gosai *et al.*, 2009).

Component crop yield and system productivity

Tillage, crop establishment techniques and residue management significantly influenced yield, maize equivalent yield (MEY) and productivity of the maize–wheat cropping system (Table 1 and 2). On an average, crop residue retention and crop establishment techniques in zero tillage gave 25.0 and 21.4% higher grain and stover yield of maize, respectively over zero tillage. Similarly, fresh beds with residue incorporation (FB+R) recorded 25.0 and 3.4% higher grain and stover yield of maize, respectively compared to conventional till–flat (CT-F). The permanents beds with residue retention (PB+R) gave statistically highest grain and stover yield of maize over zero till flat with residue retention (ZT–F+R) and CT–F, but remained comparable to FB+R. Further, FB+R was found at par with ZT–F+R and CT–F in terms of grain and stover yield of maize. In case of wheat, PB+R recorded 28.6 and 22.0% higher values of grain and straw yield, respectively over ZT–F+R (Table 1). Likewise, PB+R gave 8.3 and 16.4% higher grain and straw yield of wheat, respectively than CT–F. At par grain yield and straw yield of wheat was obtained with FB+R and PB+R, which remained significantly higher over ZT–F+R. PB+R and FB+R were found comparable to each other in terms of MEY and system productivity, but remained statistically significantly higher over ZT–F+R. Further, PB+R gave 4.5 and 3.5% higher MEY and system productivity, respectively compared to FB+R. Yield enhancement in zero tillage with residue retention may be linked to subsequent lesser oxidation of organic C over the years. Restriction of tillage under zero tillage improves the structure of soil, especially micro-aggregates, which is active site of holding the labile C for longer periods (Jha *et al.,* 2012). This led to higher labile C formation in soil, which improves acquisition of nutrients to the plant and finally reflected in higher yield (Girma *et al.,* 2012).

Economics

Net returns and benefit: cost (B:C) ratio of maize, wheat and the system was significantly influenced by tillage and crop establishment techniques and residue management (Table 2). Permanent beds with residue retention (PB+R) gave highest net returns of maize, wheat and system followed by fresh beds with residue incorporation

Table 1. Yield and yield attributes of maize and wheat as influenced by tillage and crop establishment and residue management practices (mean value of data over 2 years)

Treatment	Maize					Wheat				
	Cobs/ plant	Grains/ cob	1000-grain weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Effective tillers/m^2	Grains/ spike	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
CT– F	1.33	253.3	231.6	4.4	5.9	388.9	37.3	40.0	4.8	6.1
FB+R	1.67	277.0	234.7	5.4	6.1	434.7	48.5	42.0	5.2	7.1
ZT–F+R	1.00	236.7	219.3	4.4	5.6	361.8	33.4	38.7	4.2	5.9
PB+R	2.00	296.7	236.3	5.5	6.8	460.8	50.5	43.0	5.4	7.2
SEm±	0.27	11.9	17.6	0.3	0.3	18.5	1.8	1.5	0.2	0.3
CD (P=0.05)	0.94	41.4	NS	1.0	0.9	63.9	6.4	NS	0.6	1.0

CT–F: Conventional till–flat bed; CT–B+R: Conventional till–raised bed with residue incorporation; ZT–F: Zero tillage–flat bed; ZT–B+R: Zero tillage–raised bed with crop residue retention; Test weight: 1,000-grain weight; NS: Non-significant

Table 2. System productivity and net returns of maize and wheat as influenced by tillage and crop establishment, and residue management practices (mean value of data over 2 years)

Treatment	MEY of wheat (t/ha)	MEY of system (t/ha)	Maize			Wheat			Maize-wheat		
			Economics (× 10^3 ₹/ha)	Net returns (× 10^3₹/ha)	B:C ratio	Economics (× 10^3₹/ha)	Net return (×10^3₹/ha)	B:C ratio	Economics (× 10^3₹/ha)	Net returns (× 10^3₹/ha)	B:C ratio
CT– F	5.69	10.10	18.0	27.8	1.55	17.0	42.6	2.50	35.0	70.4	2.01
FB+R	6.19	11.59	20.0	35.1	1.75	18.5	46.8	2.53	38.5	81.9	2.13
ZT–F+R	5.02	9.40	16.0	29.2	1.82	15.5	37.7	2.43	31.5	66.9	2.12
PB+R	6.47	11.98	17.5	39.2	2.24	17.5	50.6	2.89	35.0	89.8	2.56
SEm±	0.22	0.47	-	2.5	0.14	-	2.1	0.13	-	4.2	0.12
CD (P=0.05)	0.76	1.62	-	8.7	0.49	-	7.4	0.44	-	1.5	0.43

(FB+R) and zero till – flat with residue retention (ZT–F+R). The lowest net returns and B:C ratio were obtained with conventional till-flat (CT–F). Furthermore, PB+R increased 27.6 and 27.4% system net returns and B:C ratio, respectively over CT–F.

Soil physical properties

In general, soil bulk density (ρ_b) incresed with depth, highest values was recoreded at 10–20 cm and than started to decrese up to 30–45 cm soil layer (Fig. 1). Tillage and crop establishment tequniques significantly ($P < 0.05$) influenced ρ_b in uppar (0–10 cm) soil layer, but with incresed soil depth, differences were non-significant. The ρ_b in the 0–10 cm layer was significantly lower in fresh beds with residue incorporation (FB+R) than the rest of treatments. Conventional till–flat (CT–F) and permanent beds with residue retention (PB+R) was found comparable, while zero till – flat with residue retention (ZT–F+R) recoreded highest ρ_b. The lowest ρ_b in 10–20 cm soil layer was found with PB+R, which was found comparable to FB+R and CT–F. ZT–F+R recoreded highest ρ_b in 10–20 cm soil layer. Likewise, soil penetration resistance also followed a similar trend (Fig. 2). The soil water content in all of the treatments was same (0.20-0.22 l/m^3). So, the variation in soil penetration resistance was a result of ρ_b only. Penetration resistance was significantly higher in ZT–F+R and PB+R treatmets than CT–F and FB+R in

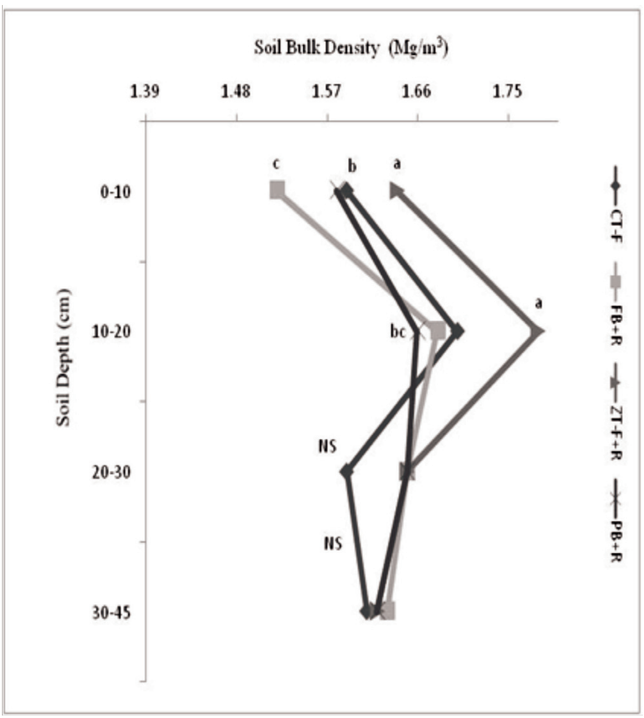

Fig. 1. Effect of tillage and crop establishment practices, and residue management practices on soil bulk density after two years of maize-wheat cropping system.

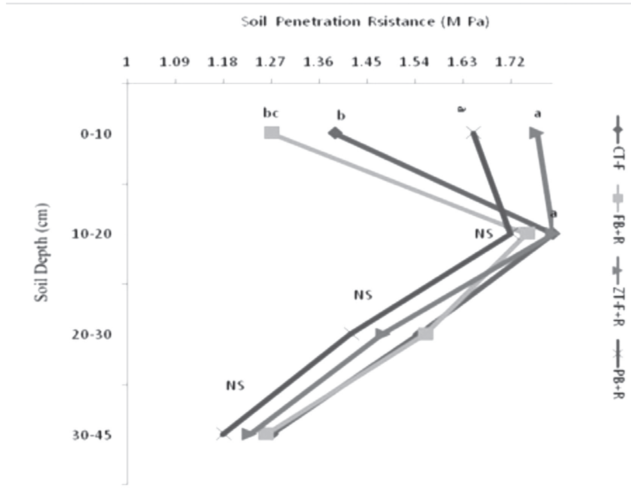

Fig. 2. Effect of tillage and crop establishment practices, and residue management practices on soil penetration resistance after two years of maize-wheat cropping system.

uppar 0–10 cm soil layer. All tillage and crop establishment techniques below this soil layer was found comaparble with respect to penetration resistance. In FB+R, where crop residues were incorporated with each machanical manipulation and this practice may led to significantly lower surface ρ_b and penetration resistance. This could be ascribed to inverse relationship between soil air voulme and ρ_b. However, decreased ρ_b in PB+R at lower soil surface may be linked to restricated traffic movement (Derpsch and Friedrich, 2009).

On the basis of study, it may be concluded that zero tillage flat without crop residue retention in light textured alluvial soil was noticed the poorest method of tillage and crop establishment. Conventional tillage resulted in intermediate yield. Crop residue retention or incorporation under zero tillage and conventional tillage resulted into higher yield. Overall, zero tillage with crop residue retention found to be a promising technology in maize–wheat cropping system with respect to productivity and profitability.

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