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Research Paper

INFLUENCE OF CONSERVATION AGRICULTURE,PERMANENT RAISED BED PLANTING AND RESIDUE MANAGEMENT ON SOIL QUALITY AND PRODUCTIVITY IN MAIZE-WHEAT SYSTEM IN WESTERN UTTAR PRADESH

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Conservation agriculture in its version of permanent raised bed planting with crop residue retention has been proposed as an alternative wheat production system of western Uttar Pradesh.Therefore the present work was undertaken during 2008-2011 to compare permanent and tilled raised beds with different residue management under irrigated conditions. Permanent beds with residue retention resulted in increased crop yield of 11-17% in maize and 12-15% in wheat over conventional practices. In permanent raised beds with retained plot over without residue plot the savings in water use were 11.2 % to 21.5 % in maize and 12.3% to 19.7 % in wheat as compared to conventional practices of seeding. Permanent raised beds with full residue retention increased soil organic matter content 1.6 times in the 0–5 cm layer and had significantly higher mean weight diameter and aggregate stability compared to conventionally tilled flat beds.

Keywords: Crop residue, Permanent raised beds, Soil quality, Productivity, Zero tillage

INTRODUCTION

Land quality and land degradation affect agricultural productivity, but quantifying these relationships has been difficult (Wiebe 2003). However,it is clear that the necessary increase in food production will have to come from increase in productivity of the existing land rather than agricultural expansion and the restoration of degraded soils and improvement in soil quality will be extremely important to achieve this goal.The effects of soil degradation or regeneration, and therefore increased or reduced soil quality,on agricultural productivity will vary with the type of soil,cropping system and initial soil conditions,and may not be linear (Scherr 1999). Connor *et al.* (2003) reported that permanent raised beds may offer farmers significant advantages, such as reduced tillage, increased

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opportunity for crop diversification, mechanical weeding and placement of fertilizers, opportunities for relay cropping and inter cropping, and water savings. There are also indications that crop yields from beds can be further increased with higher N doses and later irrigation because of the reduced risk of lodging (Sayre and Ramos 1997). Crop residues are important natural resource in the stability of agricultural ecosystems. About 25% of N and P, 50% of S and 75% of K uptake by cereal crops can be retained in crop residues,making them valuable nutrient sources (Singh 2003). Traditionally, in rice-wheat or other systems of South Asia, straw is fed to cattle, burnt for fuel,or used as building material leaving little for soil incorporation. As a result soil organic matter levels are declining in these cropping systems which can have serious implications for soil health. These factors must be considered to develop new farming practices that can increase system yields. Investigations were undertaken on permanent bed systems to evaluate yields of maize-wheat system and to study the profitability of the pattern, as affected by straw management. Conservation tillage is a widely-used terminology to denote soil management systems that result in at least 30% of the soil surface being covered with crop residues after seeding of the subsequent crop (Jarecki and Lal 2003). To achieve this level of ground cover, conservation tillage normally involves some degree of tillage reduction and the use of non-conversion tillage methods. Conser-vation agriculture removes the emphasis from the tillage component alone and addresses a more enhanced concept of the complete agricultural system.

MATERIALS AND METHODS

An experiment was conducted for maize-wheat system in farmers participatory mode in the jurisdiction area of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (Uttar Pradesh), India, during 2008-09 to 2010-11. The climate of the area is semiarid with an average annual rainfall of 805 mm (75-80% of which is received during July to September), minimum temperature of 4^0C in January, maximum temperature of 41 to 45^0C in June,and relative humidity of 67 to 83% throughout the year. In general the soils of the experimental sites were silty loam in texture with medium fertility status. The particle size distribution of 0-20 cm soil layer is 68.3 % sand, 17.4 % silt and 14.7 % clay. The soil samples were taken at 0-15 cm soil layer from top of the permanent beds and within the row of flat beds.The bulk density was 1.54 mg m^3, weighted mean diameter of soil aggregates 0.58 mm, infiltration rate 58.3 mm hr^{-1}, cone index 2.45 and total C 8.3 g kg^{-1}. The experiment comprised on maize-wheat cropping system, and was designed as a randomised complete block design with three replicates, commencing with *kharif* in 2008. The plots consisted of seven layout or crop establishment straw treatments. The sites, treatments and management are briefly summarised in Table 1 for convenience.

Soil samples were collected at the start of the experiment from 0 to 15-cm soil depth using an auger of 5-cm diameter. Each sample was a composite from three locations within a plot. The freshly collected soil samples were mixed thoroughly, air-dried,crushed to pass through a 2-mm sieve and stored in sealed plastic jars before analysis.Olsen P (0.5 M $NaHCO_3$ extractable) and NH_4OAc–extractable K were analyzed using the methods described by Page

Table 1: Treatments in the Replicated Experiment in Maize-Wheat Cropping System

Kharif Season		Rabi Season	
Layout	Abbrevations	Layout	Abbrevations
T_1 – No – Till Maize – Without Residue	NT – M – WR	T1 – No –Till direct seeded Wheat – Without residue	NT – DSW – WR
T_2 – No – Till Maize + 50% Residue retained	NT – M + 50% RR	T2 – No –Till direct seeded Wheat + 50% Residue retained	NT – DSW +50%RR
T_3 – No – Till Maize + 100% Residue retained	NT – M +100% RR	T3 – No –Till direct seeded Wheat + 100% Residue retained	NT – DSW +100%RR
T_4 – Maize on permanent beds – Without residue	PB – M – WR	T4 – Zero till wheat on Permanent beds – Without residue	PB – ZTW – WR
T_5 – Maize on permanent beds+50% Residue retained	PB – M + 50% RR	T5 – Zero till wheat on Permanent beds+50%Residue retained	PB – ZTW+50%RR
T_6 – Maize on permanent beds+100% Residue retained	PB – M +100% RR	T6 – Zero till wheat on Permanent beds+100% Residue retained	PB – ZTW+100%RR
T_7 – Conventional tillage practices maize	CTM	T7 – Conventional tillage practices broadcast wheat	CT – BCW

*et al., (*1982). Soil organic C was analyzed by the Walkley and Black method (Page *et al.*, 1982). The samples for determination of soil physical properties (soil aggregates, mean weight diameter of aggregates) were collected at the start of the experiment and after the harvest of each crop. The cumulative infiltration rate and penetration resistance were measured at the onset of the experiment and after the 3 years of study. Soil aggregation and mean weight diameters of aggregates were analyzed using the wet-sieving method (Yoder, method). Soil resistance was measured to a depth of 45-cm at intervals of 5-cm soil depth using a manual cone penitrometer (Eijkelkamp Agrisearch Equipment). Bulk density was measured to a depth of 20-cm at intervals of 5-cm soil depth using the core-ring method and one core per stratus of each plot was collected and the samples were oven-dried for 48 h at 105^{0}C, weighed and bulk density calculated according to Blake and Hartge (1986). The infiltration rate was measured using a double-ring infiltrometer.

RESULTS AND DISCUSSION

Crop Productivity: Straw retention increased yield rapidly, starting from the second crop cycle. This is an important finding because, if repeated on farmers' fields, farmers will quickly realise the benefits and be more interested in adopting the technology (Table 2), presents the grain yields cropwise and year wise. The highest yield was observed in wide beds with 100% residue retention. Yields tended to be lower in T_7 than T_1. Yields on raised beds consistently increased as residue retention increased from 0% to 100% but the differences between T_3 and T_5 were not always significant for the three maize- wheat crop cycles. Permanent beds with residue retention increased yield by 11-17% in maize and 12-15% in wheat as compared to conventional practices. This is an important finding in relation to practical management of such systems by farmers. Since there is high demand for straw for fodder, fuel or building materials in the IGP especially by small- and medium-scale farmers, it is encouraging that retaining only 50% of the straw will provide adequate benefit to the crop while the remainder can be removed for other uses. The crop residues retained as surface mulch (partially anchored and partially loose) would have helped in regulating the soil temperature and moisture, but it is assumed that the greater yield response was mainly due to the aberration in weather conditions during the crop growth period (winter 2009-10 was abnormal in terms of weather). Green and Lafond (1999) reported that surface residues in a no-till system helped to buffer soil temperature and that, during winter, soil temperature (at 5 cm depth) with residue removal and conventional tillage was on average 0.29 °C lower than that with no tillage and surface retained residues. Conversely soil temperature during summer was 0.89 °C higher under conventional tillage than the no-till situation with surface residue retained.

Moisture conservation and water productivity*:* Straw retention significantly influenced the soil moisture in wheat crops at 40 DAS. In the 0-30 cm soil layer the maximum soil moisture (18.6%) was in residue retention + permanent raised beds,more than double that (7.8%) of 0% without residue retention. Retention of straw improves soil water-holding capacity, and retention on the soil surface also reduces soil evaporation (Sanchez 1976). In this trial also it was observed that the straw retention allowes sufficient water to be saved (Table 2) in maize-wheat system to either reduce the number of irrigations by one or delay irrigation time by an average of 19%, or to increase yield in water limiting situations.Without straw retention at the ground coverage of the crop was far less (~30% at 40 DAS). The input water application including the irrigation water applied and the rain water during the maize-wheat season of 2008-09 to 2010-11 was remarkably lower with permanent beds compared to other practices (Table 2). Higher irrigation water was applied in maize-wheat system under residue removal treatments as compared to residue retained plots. The savings in water use with beds with residue retained plot and residue removal plot were 11.2

Table 2:Yield and Water Productivity of Maize-wheat Cropping System Under Various Tillage and Crop Establishment Techniques

	Crop Establishment Grain Yield (t/ha)						Water productivity (kg grain m^{-3})					
	2008-09		2009-10		2010-11		2008-09		2009-10		2010-11	
	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat	Maize	Wheat
T_1	3.15	4.85	3.35	5.05	3.50	5.03	0.78	1.26	0.85	1.36	0.92	1.44
T_2	3.55	4.96	3.75	5.15	3.86	5.20	0.90	1.34	1.00	1.49	1.09	1.60
T_3	3.80	5.10	3.95	5.30	4.25	5.35	1.03	1.49	1.13	1.63	1.25	1.70
T_4	3.70	5.05	3.85	5.20	4.05	5.25	0.98	1.46	1.07	1.58	1.21	1.54
T_5	3.95	5.08	4.06	5.25	4.27	5.40	1.10	1.54	1.18	1.67	1.31	1.83
T_6	4.04	5.25	4.18	5.45	4.53	5.60	1.15	1.62	1.25	1.79	1.46	1.96
T_7	3.35	4.25	3.40	4.65	3.60	4.73	0.70	0.94	0.74	1.07	0.82	1.14
C D at 5 %	0.23	0.37	0.29	0.45	0.18	0.31	–	–	–	–	–	–

% to 21.5 % in maize and 12.3% to 19.7 % in wheat as compared to conventional seeding.

Planting System and Soil Quality: Soil from permanent raised beds with full residue retention had significantly higher mean weight diameter (MWD) compared to conventional tilled raised beds or compared to those with residue removal (Figure 4). Aggregate breakdown is a good measure for soil erodibility, as breakdown to finer, more transportable particles and micro-aggregates, increases erosion risk. Similar results were found for infiltration rates on top of the raised bed and in the furrow. Infiltration rates in the bottom of the furrow were significantly higher for conventionally tilled compared to permanent raised beds, but not on top of the raised beds (Figure 2). A lower aggregation results in a reduction of the infiltration and storage capacity of the soil by forming a relatively impermeable soil layer by sealing of pores. At initial time bulk density of surface layers remained lower under residue retained bed planting than under conventional tillage. This is because top of beds remains loose. The lower bulk density means more porosity especially in upper surface (Figure 1). With the passage of time the differences between soil physical parameters get narrowed (Limon *et al.,* 2006) because height of bed gets reduced and become compacted. The adoption of permanent beds led to controlled traffic thereby providing a healthy root environment. Fine tilth and better aeration causing less penetration resistance are responsible for better root development thereby producing higher yield (Figure 3). The residues lying on the soil surface in conservation agriculture protect the soil from raindrop impact. No protection occurs in conventional tillage, which increases suscepti-bility to further disruption (Table 3). Moreover, during tillage a redistribution of the soil organic matter takes place. Small changes in soil organic carbon can influence the stability of macro-aggregates.

Permanent raised bed planting practices have been developed to reduce production costs while conserving resources and sustaining the environment and numerous benefits have been observed in comparison with other planting systems. Less is known, however, about how residue management, partial or completely

Figure 1: Effect of Conservation Agriculture on Bulk Density in Maize Wheat System After 3 Years

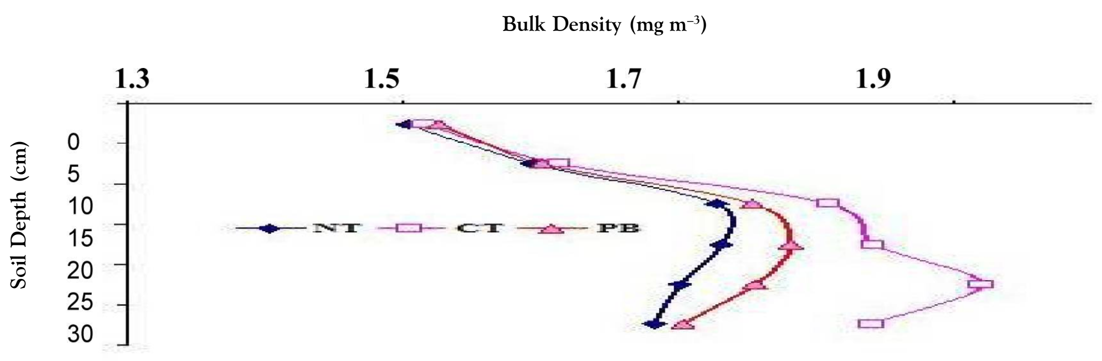

Figure 2: Effect of Conservation Agriculture on Cumulative Infiltration Rate in Maize Wheat System After 3 Years

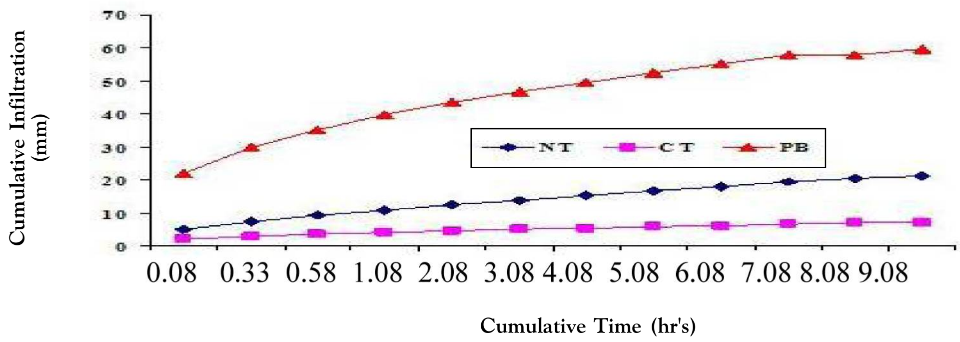

Figure 3: Effect of Conservation Agriculture on Soil Resistance in Maize Wheat System After 3 Years

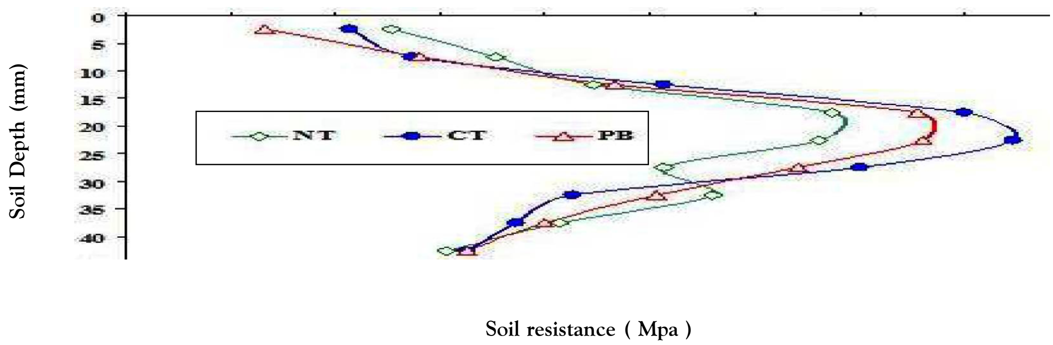

Figure 4: Effect of Conservation Agriculture on Mean Weight Diameter of Aggregates Under Maize Wheat System After 3 Years

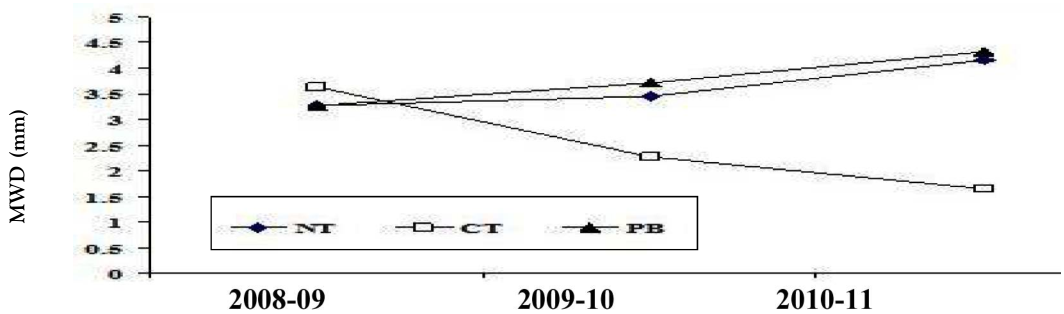

Table 3:Effect of Residue Retained on Water Stability of Aggregates,Clod Breaking Strength and Soil Organic Carbon (%) in a Silty Loam Soil Under Maize-Wheat Cropping System

Crop Establishment	Water Stable Aggregates >0.25 mm (%)	Aggregate Porosity (%)	Clod Breaking Strength (kPa)	Soil Organic Carbon (%)
No- Till without residue	66.7	39.6	418.7	0.54
No Till 50% Residue retained	72.9	40.2	367.5	0.58
No –Till 100% Residue retained	79.0	41.3	332.9	0.61
Permanent Beds without residue	80.3	40.8	289.7	0.55
Permanent Beds+50%Residue retained	81.9	42.7	235.6	0.59
Permanent Beds+100%Residueretained	82.8	43.2	204.8	0.63
Conventional practices	59.1	36.2	423.8	0.52
C D at 5%	5.3	1.74	95.3	0.53**

Note: **Initial value.

retained, or tillage practices, i.e., permanent raised beds versus conventional tillage in which raised beds are formed each year, affect physical and chemical soil quality.Crop yields on beds with straw retention, rose by about 11-17% for maize and 12-15% for wheat over a 3-year cycle compared with conventional tillage on the flat beds. Conservation agriculture improved soil aggregation compared to conventional tillage systems without retention of sufficient crop residues. Infiltration is generally higher and runoff reduced in permanent raised beds with residue retention compared to conventional tillage with residue removal due to the presence of the crop residue cover that prevents surface crust formation and reduces the runoff velocity, giving the water more time to infiltrate.

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