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LONG-TERM EFFECT OF RESOURCE CONSERVATION TECHNOLOGIES ON SOIL PHYSICAL HEALTH IN TEMPORARY WATERLOGGED ALLUVIAL PLAINS OF THE RIVER YAMUNA

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ABSTRACT

Soil data of conventionally planted surveyed farmers' fields site of Gohana and Kharkhoda block of Sonipat district revealed that 50% of area had PI between 0.5-0.6 *i.e.* expected yield of the crop will be between 50-60% of the potential yield under normal levels of fertilizer and water inputs. Improved soil OC (30%) in bed system increased wet sieve mean weight diameter (WS-MWD) (1.69mm) as compared to CT (1.45 mm). Change in mean weight diameter (CMWD) was also lower in beds as compared to CT, which indicated improvement in aggregate stability by adoption of bed planting system. Comparison of soil data of ZT and CT showed improvement in OC and AWC by 59% and 22.45% under ZT as compared to their values of 0.42% and 16.51%, respectively, under CT. Similarly, bulk density (BD)of surface 0-15 cm layer under ZT were reduced by 75 % compared to their values of 1.46 Mgm^{-3} under CT. Improved soil OC in ZT increased WS-MWD (1.58 mm) as compared to CT (1.28 mm). Thus, by long term adoption of both RCTs *i.e* bed planting and zero tillage at appropriate locations, soil carbon, soil aggregation and overall soil physical health were improved.

KEY WORDS
Bed planting
Zero tillage
Soil physical health

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INTRODUCTION

Soil health deterioration during last three decades is one of the most serious problems in India, causing decline in food grains production and productivity and also threatening the soil biosphere. The problem is more acute in high productivity areas of Indo-Gangetic plain region (IGPR) *i.e.* Trans Gangetic Plains (TGP, Representing Delhi, Punjab and Haryana) and Upper Gangetic Plains (UGP, representing western U.P.), where intensive cropping systems are being followed and indiscriminate use of heavy machinery is done for most of the agricultural operations (Yadav *et al.* 2002). Depletion of soil organic carbon (SOC) both in terms of quality and quantity is the major soil health problem emerged due to continuous adoption of intense tillage, followed by other constraints like emergence of multi-nutrient deficiencies and deterioration of soil physical properties-especially sub-surface compaction and poor aggregation (Divya and Belagali, 2012). For instance, the negative effect of wet- tillage (Puddling) for transplanted rice on sub-soil compaction, and also on the growth and yield of subsequent wheat crop in Rice-wheat cropping system in the IGPR is well documented (kukal and Aggarwal 2003).

Resource conservation technologies (RCT) are much more complex than the conventional systems. Managing these systems efficiently will be highly demanding in terms of understanding of basic processes and component interactions, which determine the whole system performance. For example, surface maintained crop residues which act as mulch and reduce soil water losses through evaporation and maintain a moderate soil temperature regime. Tillage based conventional agriculture is assumed to have led to soil organic matter decline, water runoff and soil erosion (Kumar *et al.,* 2015) and other manifestation of physical, chemical and biological soil degradation (Benites, 2008). Conservation tillage *i.e* bed and zero tillage system also has emerged as one of the most promising sustainable soil/crop management technology to reduced input use (Kumar *et al.*, 2015). Permanent beds save irrigation water use, facilitate timely planting of maize in rice fallow, improve soil health and farm profitability. Further, raised bed planting provides opportunity for diversification through intensification with introduction of high value intercrops that improves resource use efficiency and farm profitability. Zero tillage systems provide higher yields at less cost and also save on fuel use and tractor wear and tear. Thus resource conserving technologies help farmers to reduce cost of cultivation, increase crop productivity and their profitability. Hence, the objectives of the proposed study were to compute the long-term effect of resource conservation technologies on soil physical health in temporary waterlogged alluvial plains.

MATERIALS AND METHODS

The present study was conducted in Gohana and Kharkhoda block of Sonipat district in Haryana, India, located at 28°47'26.959" to 29°11'55.306" North latitude and 76°37'47.601" to 77°3'10.875" East longitudes. Gohana and Kharkhoda in Sonipat district is a part of the Eastern Haryana plain (Trans Indo-Gangetic Alluvial plains). Bhalaut sub branch of western Yamuna canal passess through Gohana and Delhi branch of western Yamuna canal crosses besides Kharkhoda block.

Selection of bed planting and zero tillage adopted villages

A survey was conducted in the Gohana and Kharkhoda block for locating the areas where both resource conservation technologies (RCT's) *i.e.* bed planting and zero tillage were being adopted by most of the medium and big farmers for more than 6-7 years. Villages selected for taking soil samples in farmer's fields practicing RCT's were Gohana, Kanwali, Anwali, Biblan, Puthi, Rukhi, Giwana, Jasrana, Jauli, Jharaut and Katwal. Out of these selected villages , soil samples were collected in August - september, 2011 (kharif season) in 6 villages where Tomato, brinjal, chilli, Pumpkin, Okra and carrot were grown on beds in fields and in other six villages. Soil observations were taken in Febraury, 2012 where farmers were growing cabbage, cauliflower, raddish, dhania, French bean and Beet leaf on beds. In each of the above mentioned village, for comparing bed planting system with conventional system, three soil samples were taken from 0-15 and 15 -30 cm soil layers under vegetable planted beds and simultaneously another three samples from three nearby fields where Jowar in Kharif and wheat in rabi were sown on flat lands after conventionally tilling (2times harrow+2times tiller followed by pata).Following treatments have been taken in present study-

a. Conventional versus Zero tillage system

Treatment Name	Specification
PTR - CTW	Puddle transplanted rice followed by conventional tilled wheat
PTR - ZTW	Puddle transplanted rice followed by zero tilled wheat

b. Conventional versus bed system

CTJ - CTW	Conventionally tilled Jowar in *kharif* followed by conventionally tilled wheat
Vegetables on bed	vegetables on beds in both *kharif* and *rabi* season

Soil properties studied

Soil samples were taken by a core sampler for determination of properties such as pH by pH meter, electrical conductivity (EC) by EC meter, bulk density (BD) by core method (Blake and Hartge, 1986), soil texture by international pipette method, soil organic carbon by Walkley and Black (1934) method, saturated hydraulic conductivity (K_s) by constant head method (Klute and Dirkson 1986), soil water contents at saturation, field capacity and wilting point by pressure plate technique. Soil penetration resistance (PR) was measured using cone penetrometer.

Computation of soil health index/Soil physical rating index (PI)

Computation of PI involved measurement of important physical properties such as soil depth, bulk density, infiltration rate, soil organic matter, available water storage capacity, non capillary pore space, land slope and water table depth. For a given site, each of these parameters was assigned a rating value corresponding to its actual value by referring to rating chart (Gupta, 1986). For range of PI >0.75, 0.50-0.75, 0.25-0.50 and <0.25, soil physical health status and accordingly its production potential could be labeled as very good, good, medium or poor, respectively. The data obtained from the laboratory studies were analyzed by statistical procedure as outline by Fischer (1950). Simple t-test will be done to test the level of significance.

RESULTS AND DISCUSSION

Descriptive statistics

Statistical analysis of soil data of conventionally planted surveyed site revealed that variation of clay and sand was within 4.0-40% and 24.0-80%, respectively (Table 1). Prominent texture classes of the area included sandy clay loam, sandy loam, loam and clay loam. In most of the area, pH was less than 8.5 and EC was more than 4 dS/m, which indicated that soils were saline. Range of saturated hydraulic conductivity (Ks) was variable and average value of Ks in the sub surface layer was lower than that of surface. Similarly, average bulk density (BD) also varied between optimum (1.30 Mg/m 3) to higher (1.77 Mg/m3). Both lower Ks and higher BD in sub-surface indicated the presence of compact layer. In

Table 1: Descriptive statistics of soil samples collected in farmers' fields (number of sites = 86)

	0-15 cm				15-30 cm			
Parameter	Minimum	Maximum	Mean	Std. Dev.	Minimum	Maximum	Mean	Std. Dev.
pH (1:2.5)	6.54	8.64	7.68	0.24	6.53	8.84	7.67	0.44
EC (dS/m)	1.59	6.80	4.69	2.57	1.45	5.74	5.01	2.73
OC (%)	0.28	0.81	0.44	0.11	0.24	0.74	0.41	0.10
BD (Mg m^{-3})	1.30	1.74	1.51	0.12	1.32	1.77	1.54	0.10
AWRC (%)	5.27	45.42	15.19	6.98	4.74	45.02	14.88	7.17
NCP (%)	1.80	34.00	16.13	7.95	1.52	33.89	16.63	8.41
WS-MWD (mm)	0.52	2.17	1.44	0.44	1.04	1.97	1.51	0.31
DS-MWD (mm)	4.68	5.94	5.15	0.33	4.47	5.73	5.02	0.35
K_s (cm/h)	0.15	1.91	0.57	0.50	0.19	1.22	0.47	0.24
Saturation %	30.66	46.61	36.83	3.62	27.01	49.85	33.51	5.46
Clay (%)	8.00	39.90	25.87	5.42	4.00	40.00	24.78	6.75
Silt (%)	4.40	40.00	19.50	8.51	4.00	50.00	19.90	9.56
Sand (%)	24.00	80.00	54.03	14.35	36.00	80.00	55.32	11.63

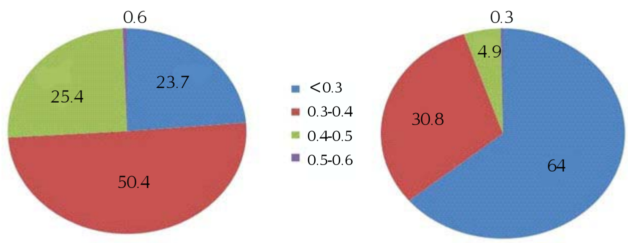

Figure1: Percentage distribution of surveyed area under different ranges of Physical rating index

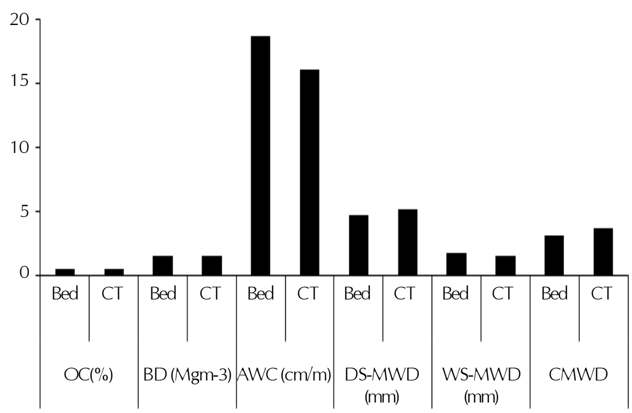

Figure 2: Different soil parameter of surface layer (0-15 cm) under bed and conventional tillage

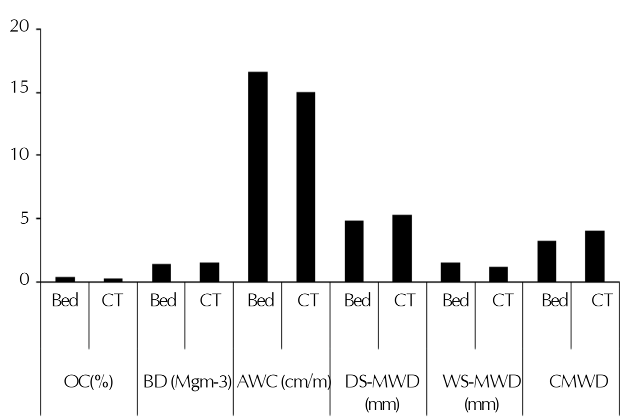

Figure 3: Different soil parameter of sub-surface layer (15-30 cm) under bed and conventional tillage

some areas, both available water retention capacity (AWRC) and non-capillary pores (NCP) were below their optimum ranges (15% for AWRC and 10% for NCP). Variation in values of dry mean weight diameter (DS-MWD) was less compared with water stable mean weight diameter (WS-MWD). Its range showed the presence of poor to strong aggregate stability.

Physical rating index (PI) values showed that 50% of area had PI between 0.5-0.6 which indicated that expected yield of the crop will be between 50-60% of the potential yield under normal levels of fertilizer and water inputs (Fig. 1). On the other hand for subsurface, majority of area had PI<0.4.

Linear regression analysis of PI and production potential of

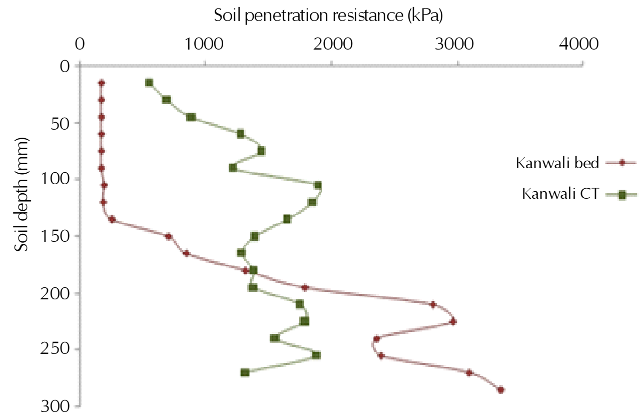

Figure 4: Penetration resistance of soil under bed and conventionally tilled system

soil (*i.e.* relative wheat grain yield, Y/Ymax) showed a good correlation ($R^2 = 0.79$).

$$\frac{Y}{Ymax} = 1.34x + 0.175 \text{, where } x = PI$$

These results support the earlier findings (Amirinejad *et al.*, 2011) that good soil physical health is essential for optimum sustained crop production. From the equation, it is clear that Y/Ymax is proportional to PI. In another word, one can say production potential of soil decreases with decrease in magnitude of PI. The above linear regression equation between the two variables thus indicated that expected yield of the crop cannot be more than 70% of the potential yield even under normal or higher levels of fertilizer and water inputs as PI <0.4 in subsurface (Kumar *et al.*, 2014).

Soil physical environment under bed and conventional system at harvest of wheat

Organic carbon of 0-15 and 15-30 cm soil layers of bed planted fields increased 0.07-0.08% over conventional tillage (Fig. 2 and 3). The reason for increase in OC was fewer disturbances due to reshaping the existing beds for at least two seasons. t_{cal} value is greater than t_{tab} value at 5% level of significance.

Similarly lower BD of bed planting was due to placement of heap of soil dug from furrow on bed which was pressed lightly by a iron bars while leveling the bed. Similar results had been reported by Aggarwal *et al.* (2006) and G³áb and Kulig (2008). Even at the end of the season, though BD increased in both system but the BD of bed system remained lower both in surface as well as subsurface. Not only total porosity in bed system was more as indicated by lower BD, water retention capillary pores (AWC) were also more (2.5-3.1%) in bed as compared to conventional system. Similar results had been reported by Bhattacharyya *et al.* (2008).

In one of the farmer's field in Kanwali village, soil penetration resistance (PR) (Fig. 4) measured under coriander planted beds showed lower value in the upper 10cm but higher value in the deeper layers. It was because in the upper 0-10 cm of bed the soil was very loose as compared to conventional system and therefore in spite of the fact that bed was drier, its PR value was lower but in the deeper layers which were more moist under conventional tillage (as it received more irrigation water due to

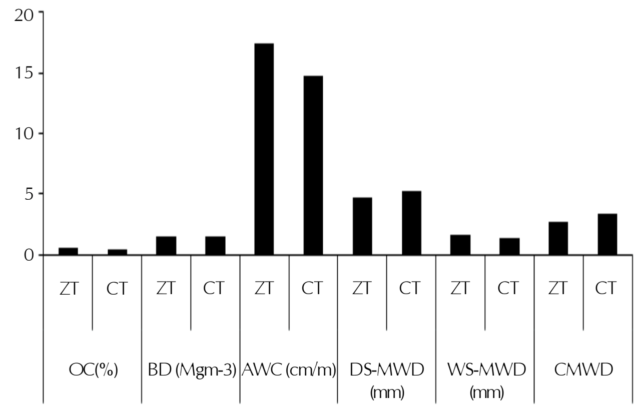

Figure 5: Different soil parameter of surface layer (0-15 cm) under zero and conventional tillage

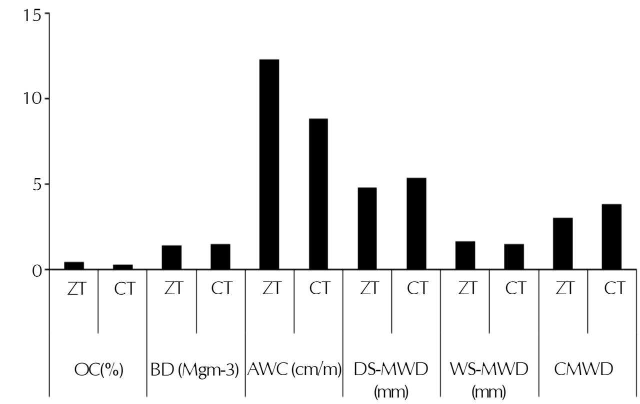

Figure 6: Different soil parameter of sub-surface layer (15-30 cm) under zero and conventional tillage

flooding method of irrigation) PR value less. Reading were taken again in another farmer's field in the same village, where fresh beds were made few days before and also in the adjacent land which was a fallow conventionally tilled plot. As there was no irrigation given to both lands, PR remained lower in upper 0-15 cm soil layer in bed as compared to CT. It was even higher in furrow because of compaction due to tractor movement.

The WS-MWD was higher by 0.24 mm in case of beds than conventional tillage (CT) because in beds , OC was higher which resulted in more stable aggregates probably due to hydrophobic and non-wetting nature of organic matter (Fig. 2&3). In contrast, DS-MWD of bed system showed a reverse trend. It might be due to higher organic carbon content of bed which decreased aggregate strength as explained by Zhang *et.al.*(1994). Besides due to higher aggregate porosity in beds, bonding between inter and intra aggregate became weak which made aggregates more fragile. Thus CMWD was lower in case of beds than CT. Similar results had been reported earlier (Zhang *et al.*, 1994).

Soil physical properties and structural indices under zero and conventional system

The bulk density under ZT in upper 0-15 cm varied from 1.35–1.50 Mgm^{-3} and in CT it varied from 1.44 – 1.56 Mgm-3. The lower bulk density in zero tillage as compared to conventional tillage was due to improvement of organic matter added through crop residues of previous crop (Fig. 5&6). The bulk density in lower 15-30 cm in zero and conventional tillage varied between 1.38-1.51 Mgm^{-3} and 1.54-1.64 Mgm^{-3} respectively. The higher bulk density in lower 15-30 cm layer in conventional tillage was due to formation of compacted sub surface layer. Similar results had been reported by Hobbs and Gupta (2002). The higher OC in case of ZT was due to rotting of crop residues of previous crop and least soil disturbance due to direct sowing of wheat crop. Similar results have been reported by Panday *et al.* (2008), Bhattacharyya *et al.* (2008). The AWC in ZT varied from 15 - 20 cm/m but in conventional tillage it was 13.2-16.5cm/m. The higher AWC in case of ZT was due to more plant residues were left on the soil surface which led to increase in OC and porosity. Other workers also reported similar results (Bhattacharyya *et al.*, 2008) In Jharaut village as, where texture of soils was fine and most of the cultivated lands were low lying, water logging was a common problem during Kharif and even after the harvest of Paddy in end of October, soil remained moist .Hence for past 7-8 years, wheat was sown by zero seed drill in middle of November by some farmers whereas few farmers sow their fields in middle of December after conventional tilling their drier fields. At the time of taking observations of soil penetration resistance, both zero tilled as well conventionally tilled fields were not irrigated for past three weeks and looked dry from surface. In zero tilled area due to more amount of decomposed crop residue in upper 0-15 cm soil, it was less compact as evident from lower soil PR although soil water content of both soils was low. Similar results were reported by Bhattacharyya *et al.* (2006).

Important aggregation index, WS MWD (Fig.4&5) increased from 1.28mm under CT to 1.58mm under ZT because in ZT organic carbon was higher which resulted in more stable aggregates probably due to hydrophobic and repellent nature of organic carbon, while DS MWD of ZT showed a reverse trend. It was mainly because higher organic carbon content decreases aggregate strength. Besides due to higher total porosity due to lower BD in ZT, bonding between inter and intra aggregate became weak which made aggregates more fragile. Several other workers also reported similar results (e.g. Zhang *et al* 1994 Ternan *et al.*, 1996). Thus CMWD was lower in ZT (2.70mm) than in CT (3.39mm).

Thus poor soil physical health could be alleviated through the adoption of appropriate resource conservation technologies, which over a period of time could add more carbon in soil through more residue incorporation and less disturbance to the soil. Structural stability measured through index like WS-MWD showed improvement in aggregate stability under both bed and zero tillage treatments over conventional planting.

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