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Effect of resource conservation technologies on soil structural conditions in temporary waterlogged alluvial plains of the river Yamuna

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ABSTRACT

A study was conducted in farmers' fields of Rai block of Sonepat district, Haryana, India to study the long term impact of two widely adopted resource conservation technologies (RCT's) namely bed planting and zero tillage on structural properties of soils of recent alluvial plains of the river Yamuna. Aggregate mean weight diameter by dry sieving and wet sieving (DS-MWD and WS-MWD) under different RCT's were studied to compare structural condition of the soils under continuous use of these technologies. Other important structural indices such as dispersion ratio (a measure of ease of dispersion; DR), colloid moisture equivalent ratio (a measure of ease of percolation; CMER), erosion ratio (ER), stability index (SI), soil organic carbon (SOC), clay ratio (CR) were also studied to monitor the susceptibility of soil to erosion in the study area. Results revealed that in the surveyed villages under conventional tillage (CT), the mean (of 6 samples) magnitude of DR and ER were 0.58 and 0.82, respectively, and CMER was <1, which indicated the erodible nature of these soils. Analysis of data of bed and conventional systems revealed that on an average, there was about 19.08 % increase in SOC in bed planted system compared to conventional system. The decrease of DR, ER and CR from 0.66, 0.52 and 4.25 under CT to 0.42, 0.28 and 2.38 under beds indicated reduced eroding tendency of these soils under bed planting. Comparison of soil data of ZT and CT showed improvement (33.19 %) in SOC, and reduction in BD and PR under ZT plots compared to CT. The decrease of DR, ER and CR from 0.74, 0.63 and 5.99 under CT to 0.6, 0.46 and 3.8 under ZT indicated improved aggregation under ZT. Similarly increase in CMER and SI from 0.66 and 9.21 under CT to 0.7 and 20.4 under ZT also indicated improved soil structural condition by adoption of zero tillage. Thus, it was concluded that by adopting suitable RCT's, soil carbon and aggregation were improved and soils became more resistant to erosion.

Key words : Conventional tillage, Erodibility indices, Mean weight diameter, Resource conservation technologies, Soil organic carbon, Zero tillage

Intensive cultivation of agricultural soils can lead to deterioration of soil structure and other soil physical properties and consequently reduction in crop productivity. Thus, the need for tillage has been questioned in the last few decades because of the excessive erosion from farmland after tillage. At the same time, it is known that inappropriate use of applied inputs and overexploitation of natural resource base, principally land and water, in many situations in the past had led to secondary salinization in low-quality aquifer zones, groundwater table recession in fresh water aquifer zones, physical and chemical deterioration of the soil and water quality due to nutrient mining. Pollution of ground water in some locations also occurred due to over application of nitrogenous fertilizers and of environment through crop residue burning and pesticide use (Pingali and Shah 2001, Gupta *et al.* 2003).

Rice–wheat system of the eastern IGP has remained largely labor intensive and less mechanized. Farmers use low inputs because of socio-economic constraints and serious problems of drainage congestion and rainwater management (Narang and Virmani 2001). In the IGP, new resource conservation technologies (RCT's) for proper land and water management are being developed for enhancing crop productivity (RWC 2004). Resource conservation technologies are defined as any practice that improves the efficiency of use of natural resources, including water, air, fossil fuels, soils, inputs, and people (Gupta *et al.* 2007). Adoption of the RCT's offers newer opportunities of better livelihood for the resource poor small and marginal farmers. At the same time, these technologies are generating alternative sources of productivity growth through diversification and intensification of production systems.

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Experiences from Pakistan (Punjab, Sindh and Baluchistan provinces) showed that with zero tillage (ZT) farmers were able to save the land preparation costs (Aslam *et al.*1993). Zero tillage allowed timely sowing of wheat, enabled uniform drilling of seed, improved fertilizers use efficiency, saved water and increased crop yields up to 20% (Hobbs *et al.* 2008). The use of zero till drills by farmers for timely sowing of wheat in saline alkali patches and fine textured soils of Haryana and Punjab has increased tremendously in the past few years (RWC 2004). Farmers have also adopted bed planting of vegetables. Bed and furrow planting of cotton is finding favour with the farmers due to savings in irrigation water and related benefits of improved use-efficiency of applied fertilizers, reduced soil crusting etc.

Now the main issue is the selection of appropriate RCT for a given soil type, climatic condition and crop. Since not much work has been done on development of RCT's for different regions of IGP, there is a need to evaluate the impact of these technologies on crop productivity and also on soil quality, mainly soil structural conditions. Unstable soil structural conditions created by a given soil management practice may lead to soil and water erosion in the form of increased sediment yield and runoff (Kay 1990). However, there are also some soil types that are unsuitable for minimum tillage. In order to evaluate the impact of management practices on the soil environment, it was necessary to quantify the soil structural by changes by the adoption of these practices (Dexter 1988, Kay 1990). A number of the indices had been proposed for assessing soil stability including mean weight diameter (MWD), geometric mean diameter (GMD), water-stable aggregation (WSA) (Kemper and Rosenau 1986), aggregate stability index (ASI), erosion index and dispersion ratio.

In literature very little work has been reported showing the long term effect of different soil management practices on soil structural stability presented in terms of aggregate stability indices. Hence the present study was conducted in the farmers' fields under different blocks of Sonepat district of Haryana (part of trans-Indogangetic plains), India, where such RCT's are being practiced from the past several years and measurement of important and relevant soil physical properties was carried out for computing soil structural indices under different RCT's. Appropriate sustainable, ecofriendly and economically viable RCT's for different agricultural lands would be suggested on the basis of their merit in terms of increase in soil structural stability along with better soil physical health and productivity of different cropping systems. Hence, the objectives of the proposed study were to compute soil structural indices under different RCT's in temporary waterlogged alluvial plains of the river Yamuna.

MATERIALS AND METHODS

The present study was conducted in Rai block of Sonepat district in Haryana, India, located at 28°48'15" to 29°17'10" North latitude and 76°28'40" to 77°12'45" East longitudes and at an altitude of 228 m above mean sea level. Rai block in Sonepat district is a part of the Eastern Haryana plain (Trans Indo-Gangetic Alluvial plains).

The climate of the district is characterized by the dryness of the air with an intensely hot summer and a cold winter. The mean annual rainfall of the district was 624 mm, 76% of the annual rainfall is received during the south-west Monsoon from July-September and the rest was received through 'Western Disturbances' from December to February.

The soil texture is mainly sandy loam, sandy clay and sandy clay loam. The soils belong to order Entisol, suborder fluvents and great group ustifluvents.

Soil samples were collected from villages where these 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. Soil samples were collected in August-September 2011 (*kharif* season) and February-March (*rabi* season) 2012. Comparing bed planting system with conventional system, three soil samples were taken from the 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 conventional tilling (2 times harrow + 2 times tiller followed by planking. Soil samples (in triplicate) were also taken from the 0-15 and 15-30 cm depth layers in the first week of January in farmers' fields, where wheat was sown by zero seed drill in mid-November. Simultaneously, triplicate soil samples were also collected from nearby conventionally tilled wheat fields to compare soil properties under zero tilled wheat with those under conventionally tilled wheat. Since none of the farmers in that area practiced direct sowing of rice without tillage, no observation could be recorded to compare zero tilled rice with conventionally puddled (wet tilled) rice.

Summary of the treatments studied

Treatment name	Specification
Conventional versus zero tillage system	
CTR - CTW	Puddled rice followed by conventional tilled wheat
DR /ZR- ZT	Direct seeded rice followed by zero till wheat
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 samples were taken by a core sampler for determination of properties such as pH, electrical conductivity (EC), bulk density (BD), soil texture (by dispersing with water and also by completely dispersing it by using hexametaphosphate), soil organic carbon, saturated hydraulic

Table 1 Methods used for studying important soil properties

Parameter	Method
Texture analysis	International Pipette method
Bulk density	Core method by Blake and Hartge (1986)
Saturated hydraulic conductivity in field and lab	Guelph permeameter (In-situ) and constant head permeameter (lab)
Soil water retention at FC and PWP	Pressure plate apparatus (Klute 1986)
Oxidisable soil organic carbon	Walkley and Black method (1934)
pH	pH meter
EC	EC meter

conductivity(K_s), soil water contents at saturation, field capacity and wilting point. Besides field saturated hydraulic conductivity (K_{fs}) was determined *in situ* using a Guelph permeameter. Above mentioned properties were determined by standard procedures mentioned in Table 1.

Dry aggregate stability (Chepil 1962) were used to compute dry sieving mean weight diameter (DS-MWD).

$$\text{DS-MWD} = \Sigma x_i w_i / \Sigma w_i$$

where w_i is the weight of each aggregate class *i* in relation to the weight of soil sample taken for analysis, x_i the mean diameter of the class (mm).

Wet aggregate stability (Yoder 1936). were used to compute wet sieving mean weight diameter (WS-MWD).

$$\text{WS-MWD} = \Sigma x_i w_i / \Sigma w_i$$

where w_i is the oven dry weight of each aggregate class *i* in relation to the oven dry weight of soil sample taken for analysis, x_i the mean diameter of the class (mm).

Saturated hydraulic conductivity (K_{fs}) in field was measured using a Guelph permeameter, which is a constant head well permeameter (Reynolds *et al.* 2002). Equation for one-head analysis for K_{fs}:

$$K_{fs} = \left[\frac{CQ}{2\pi H^2 + \pi a^2 C + 2\pi H/\alpha}\right]$$

where K_{fs}- Field-saturated hydraulic conductivity (entrapped air present), cm/sec; R - Steady state rate of fall of water in the reservoir tube of the permeameter, cm/sec; Alpha parameter (α) - slope of the natural log of K–Q curve = 0.12 cm^{-1} for most of agricultural soils, H - Well height in cm, a - Well radius, in cm; Q = XR, where X - reservoir constant = 35.43 cm^2; C-Factor - a numerically derived shape factor, dependent on the well radius and head H of water in the well.

Soil organic carbon (SOC)for each sample was measured following the procedure as outlined by Walkley and Black (1934).

Calculation of few structural/erodibility indices required determination of calgon (sodium hexametaphosphate) dispersed and water dispersed silt clay. The other important parameter required for computation of few indices was moisture equivalent which was considered equal to soil water content at field capacity. The different erodibility indices calculated were dispersion ratio, erosion ratio, clay moisture equivalent ratio, clay ratio and stability index.

1. Dispersion ratio (Middleton 1930) = % water dispersable (silt+ clay)/ % calgon dispersable (silt+ clay)
2. Erosion ratio (Middleton 1930) = dispersion ratio/clay moisture equivalent ratio
3. Clay moisture equivalent ratio =% clay/% moisture equivalent
4. Clay ratio =% (sand+silt) / % clay
5. Stability Index =Sb – Sa

Sb = % calgon dispersable (silt+clay)
Sa = % water dispersable (silt+clay)

Mostly soil with DR >0.15(15%), ER >0.1(10%) and CMER <1.5 are considered as erodible.

Descriptive statistical analysis was carried out and multiple regression equations (Pedotransfer functions) were developed for K_{fs}, BD, θ_{PWP}, θ_{FC}, θ_{SAT}, AWRC, OC%, sand%, silt%, clay%, DR, DS-MWD, WS-MWD, CMER, ER and CR using "Statistica Pro-2008 " software package.

RESULTS AND DISCUSSION

Descriptive statistics

Statistical analysis of soil data of conventionally planted surveyed site revealed that variation of clay and sand was within 9.6-36% and 41.6-80%, respectively (Table 2). Prominent texture classes of the area included sandy clay loam, sandy loam and sandy clay. In most of the area, pH was less than 8.5 and EC was less than < 4 dS/m, which indicated that soils were non-saline. Range of saturated hydraulic conductivity both in field (K_{fs}) and laboratory (K_s) 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 (1.25 Mg/m^3) to higher (1.70 Mg/m^3). Both lower Ks and higher BD in sub-surface indicated the presence of compact layer. In 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). Range of WS-MWD showed the presence of poor to strong aggregate stability. Results of erosion indices such as dispersion ratio (a measure of ease of dispersion of primary particles) showed that in most of the area the value of DR was >0.15 (0.15-0.97), which indicated that soils of this region are prone to erosion. Similarly, another ratio termed as colloid moisture equivalent ratio (CMER, a function of ease of percolation and absorptive power of soil) was also computed. Higher value of this ratio is an indicator of high percolation rate

Table 2 Descriptive statistics of soil samples collected in the farmers' fields (number of sites = 54)

	0–15 cm				15–30 cm			
	Mean	Minimum	Maximum	Std Dev	Mean	Minimum	Maximum	Std Dev
Clay%	23.64	12.00	36.00	7.17	18.82	9.60	33.60	6.52
Sand%	57.88	41.60	76.80	8.32	17.86	41.60	80.0	7.76
Silt%	18.49	4.80	35.20	8.46	63.33	4.80	35.20	9.91
K_{fs} (cm/h)	13.26	1.75	49.11	13.04	–	–	–	–
pH	8.04	7.65	8.38	0.18	8.04	7.65	8.44	0.18
EC(dS/m)	3.39	1.70	6.80	1.24	3.46	1.60	5.80	1.35
OC %	0.45	0.23	0.71	0.20	0.42	0.24	0.62	0.13
BD (Mg m^{-3})	1.44	1.25	1.70	0.11	1.46	1.28	1.60	0.10
K_S (cm/h)	0.47	0.15	1.91	0.50	0.47	0.19	1.22	0.24
FC (%)	25.68	21.48	30.00	2.22	22.54	19.63	31.75	2.75
PWP (%)	11.18	8.36	16.70	2.13	10.89	7.99	13.92	1.76
AWC %	14.50	9.81	19.58	2.40	11.65	5.91	19.59	3.24
NCP %	11.15	6.44	18.45	3.45	11.45	4.97	20.11	6.18
Saturation %	36.83	30.66	46.61	3.62	33.51	27.01	49.85	5.46
DS-MWD	5.15	4.68	5.94	0.33	5.02	4.47	5.71	0.35
WS-MWD	1.44	0.52	2.17	0.44	1.49	1.03	1.91	0.22
Dispersion ratio (DR)	0.58	0.14	0.97	0.26	0.42	0.07	0.83	0.25
Clay moisture equivalent ratio (CMER)	0.92	0.36	1.82	0.38	0.87	0.36	1.82	0.34
Erosion ratio (ER)	0.82	0.11	1.94	0.55	0.56	0.06	1.94	0.47
Clay ratio (CR)	4.58	1.78	9.42	2.12	4.46	1.78	9.42	1.75

which decreases soil erodibility. In most of the surveyed area, the value of this ratio was <1. Both DR and CMER were indicative of erodible nature of soil, and both ratios vary inversely, so a combination was accomplished by dividing DR by CMER and was designated as erosion ratio (ER). Lower value of ER (<1) was indicative of non-erodible nature of the soil. Computation of ER showed values more than 0.25 in the study area, which again reconfirmed the erodible nature of soil.

Correlation among various structural indices

DS-MWD, which is an indicator of aggregates' resistance to abrasion by external agencies like wind, was not correlated to any of the computed water stable aggregation indices (Table 3). The other significant correlations included positive correlation of DR with ER and CR and its negative correlation with CMER and stability index (SI). The positive correlation between DR and CR was due to the fact that in both cases, total proportion of clay was in denominator and as the soils were non-saline and also non-sodic, higher proportion of clay improved the binding between inter and intra aggregates and reduced the amount of water dispersible clay. On the other hand, the presence of total proportion of clay in denominator in DR and in numerator for CMER was the reason for negative correlation between DR and CMER. Similarly the explanation for negative correlation between DR and SI was that less DR means less water dispersible silt+clay, which made SI more.

Development of pedotransfer functions

WS-MWD was negatively correlated with pH and EC, thus an increase in WS-MWD value would increase dispersion due to more absorption of Na^+ ions by clay colloids (Table 4). Again, lower NCP and more clay content favored stronger inter- and intra-aggregate bonds. Soil pH, EC, OC, BD, AWC, NCP, clay content and sand content altogether accounted for 59% variation in WS-MWD.As mentioned earlier, even though DS-MWD was not much affected by presence of OC, it significantly affected WS-MWD, i.e. soils with lower OC were less stable and had lower WS-MWD. Thus, change in MWD of aggregates was also appreciable. Similarly, positive correlation between CMWD and NCP was due to higher NCP weakened the inter-particle bonding of aggregates and reduced WS-MWD and, hence, increased CMWD (Zhang 1993).

Data of multi-regression analysis of DR as a function of soil parameters showed that it was significantly and positively correlated with AWC, NCP and sand and negatively with BD (Table 5). Similar results were reported by Korkanc *et al.* (2008) and Su *et al.* (2004). Higher AWC and NCP and lower BD means more pore space and weak inter and intra-aggregate bonding and, hence, more dispersion by water. Higher

Table 3 Correlation among various erosion/aggregation indices

	DS-MWD (mm)	WS-MWD (mm)	DR	CMER	ER	CR	CMWD (mm)	SI (%)
DS-MWD (mm)	1.00	0.25	–0.08	0.27	–0.22	–0.32	0.43	0.12
WS-MWD (mm)	0.25	1.00	–0.21	0.01	–0.11	0.06	* –0.73	–0.04
DR	–0.08	–0.21	1.00	* –0.56	* 0.83	* 0.62	0.21	* –0.93
CMER	0.27	0.01	* –0.56	1.00	–0.84	* –0.89	0.13	* 0.62
ER	–0.22	–0.10	* 0.83	* –0.84	1.00	* 0.92	0.01	* –0.83
CR	–0.32	0.06	* 0.62	* –0.89	0.92	1.00	–0.21	* –0.69
CMWD (mm)	0.43	* –0.73	0.21	0.13	0.01	–0.21	1.00	0.07
SI (%)	0.12	–0.04	* –0.93	* 0.62	*–0.83	*–0.69	0.07	1.00

Table 4 Linear multi regression equation relating wet sieving mean weight diameter (WS-MWD) with other basic soil parameters

		Coefficient	St error	T-value	R^2
WS-MWD	Intercept	8.610	3.880	2.219	0.59
	pH	–0.972	0.497	* –1.957	
	EC (dS/m)	–0.143	0.066	* –2.159	
	OC %	0.520	0.509	1.022	
	BD (Mg/m^3)	–0.530	1.253	–0.423	
	AWC %	0.063	0.039	1.600	
	NCP %	–0.115	0.039	* –2.917	
	Clay %	0.035	0.017	* 2.086	
	Sand %	0.021	0.012	1.729	

Table 5 Linear multi regression equation showing Dispersion ratio (DR) as a function of basic soil parameters

		Coefficient	St error	T-value	R^2
DR	Intercept	–0.496	2.704	–0.184	* 0.43
	pH	–0.007	0.006	–1.271	
	EC (dS/m)	–0.705	0.386	–1.828	
	OC %	0.083	0.048	1.717	
	BD (Mg/m^3)	–0.074	0.282	* –0.263	
	AWC	1.652	0.821	* 2.013	
	NCP	0.070	0.028	* 2.482	
	Clay %	–0.023	0.012	* –2.006	
	Sand %	0.019	0.009	* 2.227	

proportion of total sand on the other hand indicated lower proportion of of total ‘silt+clay’, which made the ratio higher.

Regression analysis showed that CMER was positively correlated with K_{fs}, pH, NCP and negatively correlated with EC and saturation percentage. Higher NCP and K_{fs} indicated higher macro-porosity and relatively lower micro-porosity and hence lower field capacity moisture content which resulted in higher CMER (Table 6). Clay ratio was positively correlated to K_{fs} because higher the clay ratio means more the coarser fraction in soil, and therefore, higher K_{fs} (Table 7).

Table 6 Linear multi regression equation showing clay moisture equivalent ratio (CMER) as a function of basic soil parameters

		Coefficient	St error	T-value	R^2
CMER	Intercept	–7.089	2.695	–2.631	0.77
	K_{fs} (cm/h)	0.018	0.006	* 3.269	
	pH	1.492	0.382	* 3.911	
	EC (dS/m)	–0.095	0.047	* –2.001	
	OC %	–0.402	0.361	–1.115	
	BD (Mg/m^3)	1.067	0.928	1.150	
	AWC %	0.023	0.031	0.748	
	NCP %	0.088	0.035	*2.505	
	Saturation %	–0.116	0.035	* –3.332	
	Clay %	–0.022	0.013	–1.736	
	Sand %	–0.031	0.009	* –3.541	

Table 7 Linear multi regression equation showing clay ratio (CR) as a function of basic soil parameters

		Coefficient	St error	T-value	R^2
CR	Intercept	47.302	22.812	2.074	0.55
	K_{fs}(cm/h)	0.095	0.044	* 2.184	
	pH	–8.176	2.992	* –2.732	
	EC (dS/m)	0.517	0.371	1.393	
	OC %	1.264	2.828	0.447	
	BD (Mg/m^3)	2.759	7.280	0.379	
	AWC %	–0.111	0.245	–0.455	
	NCP %	–0.385	0.277	–1.393	
	Saturation %	0.690	0.273	* –2.528	
	Sand %	0.021	0.080	0.267	
	Silt %	–0.148	0.098	–1.505	

Soil physical environment under bed and conventional systems

Organic carbon of the 0-15 and 15-30 cm soil layers of bed planted fields varied between 0.47-0.52% (av. 0.48%) and 0.36-0.46% (with a mean value of 0.42%), whereas that under conventional planting varied between 0.32 to 0.44% (with a mean value of 0.40%) and 0.3-0.41 % (with a mean value of0.35%) (Fig 1). The reason for 0.07-0.08% increase

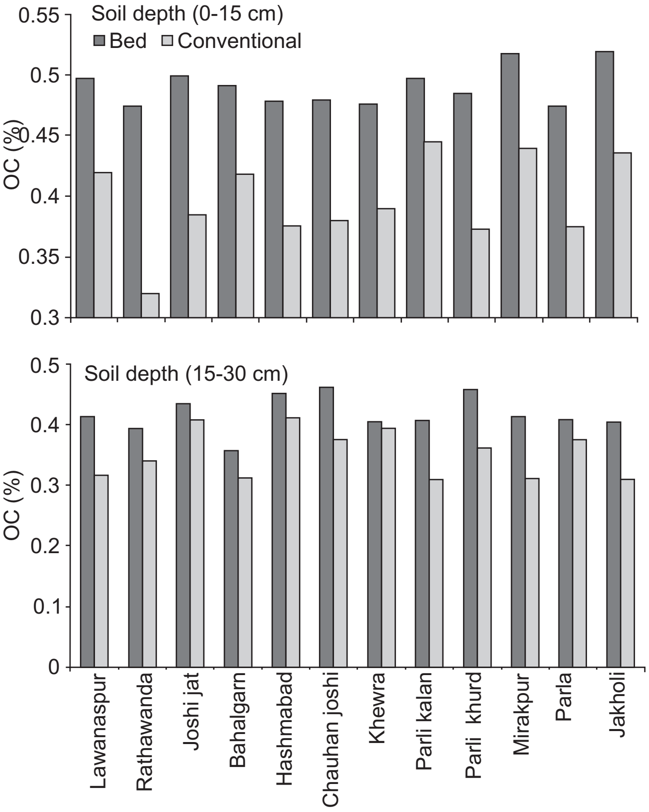

Fig 1 Soil organic carbon (OC) under bed and conventional system in surveyed villages

in OC in bed planted system was fewer disturbances due to re-shaping the existing beds for at least two seasons.

Soil penetration resistance (PR) in Khurrampur village (Fig 2) measured under coriander planted beds showed lower value in the upper 10 cm but higher in the deeper layers. It was because in the upper layer the soil was very loose compared with conventional system and, therefore, in spite of the fact that bed was drier, its PR value was lower. However, in the deeper layers, which were more moist under conventional tillage (as it received more irrigation water due to flooding method of irrigation), PR values were less. It was even higher in furrow because of compaction due to tractor movement (Aggarwal *et al*. 2006).

Structural indices under bed and conventional systems

The dispersion ratio (Fig 3) in beds varied from 0.05–0.72 with an average of 0.42, while in CT it varied from 0.30–0.98 with an average of 0.66. The lower dispersion ratio in beds was an indicator of improvement in aggregate stability. Similarly the erosion ratio in beds varied from 0.04–1.3 with a mean of 0.28, while in CT it varied from 0.33-1.44 with a mean of 0.52. Thus, lower erosion ratio in beds in most of the surveyed sites showed that bed system reduced eroding tendency of these soils. Again in most of the soils, the magnitude of CMER was higher in beds (0.6-1.65, average 1.1) compared with conventional plots (0.4-1.1, average 0.75). This trend again reconfirmed the effectiveness of bed planting technology in improving soil structure.

Soil physical properties and structural indices under ZT and CT

Mean soil organic carbon (OC) of surface layer in the plots under ZT was about 38% higher than the CT plots (mean = 0.40%) (Fig 4). The higher OC in the case of ZT was due to rotting of crop residues of the previous crops and least soil disturbance due to direct sowing of the wheat crop. Similar results have been reported by Bhattacharyya *et al.* (2006) and Panday *et al.* (2008). The AWC in the plots under

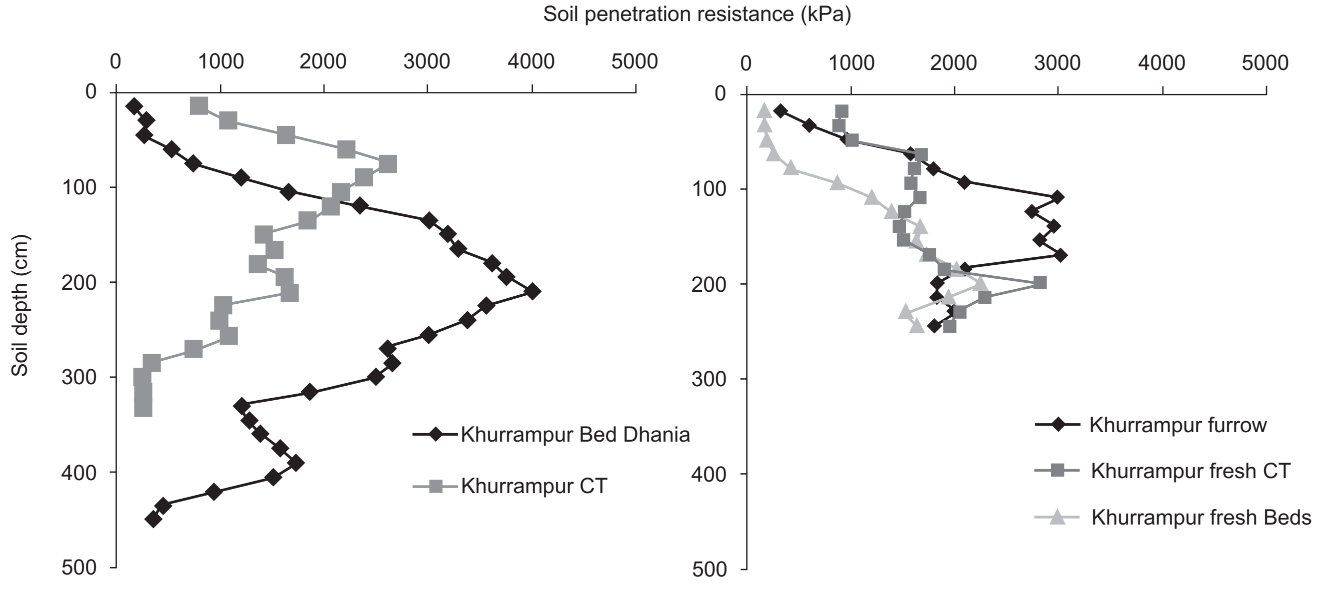

Fig 2 Penetration resistance of soil under bed and conventionally planted system (Sampling date: 24/2/2012)

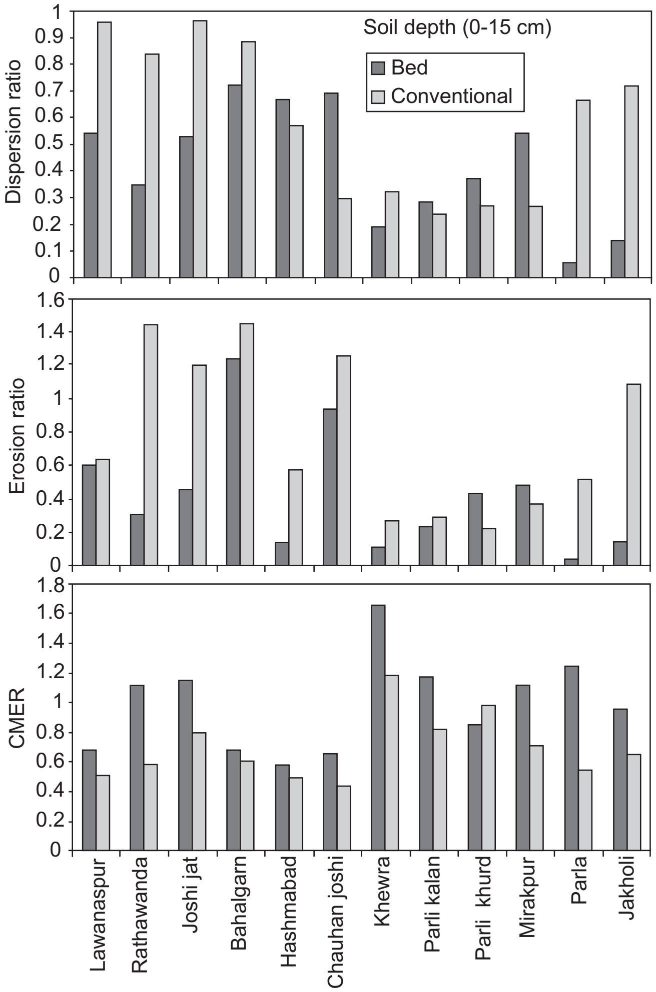

Fig 3 Dispersion ratio, erosion ratio and clay moisture equivalent ratio (CMER) under bed and conventional system in surveyed villages

ZT varied from 15-21 cm/m, but in conventional tillage it was 13-17 cm/m. The higher AWC in the plots under 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 (McGarry *et al.* 2000, Bhattacharyya *et al.* 2006).

In Pritampura and Jhakauli villages, observations of soil penetration resistance under (Fig 5), both zero and conventionally tilled fields were taken. The zero tilled area, due to more amount of decomposed crop residue in upper 0-15 cm soil, was less compact as evident from lower soil PR, although soil water content of both soils was low. Similar results were reported by Aggarwal *et al.* (2006).

The dispersion ratio varied from 0.27–0.69 (mean = 0.56) in ZT while it varied from 0.45–0.98 (av. 0.74) in CT. The lower dispersion ratio in the plots under ZT was an indicator of improved aggregate stability. Similarly, lower erosion ratio in the plots under ZT (0.46) in most of the surveyed sites showed that ZT reduced eroding tendency of these soils. Again in most of the soils, the magnitude of CMER was higher in ZT plots compared with CT, which again reconfirmed the effectiveness of ZT in improving soil structure. Similarly clay ratio was lower and stability index was higher in the ZT plots than CT. The decrease of ER and CR from 0.63 and 5.99 under CT to 0.46 and 3.86 in the plots under ZT indicated improved aggregation under ZT. Similarly increase in CMER and SI from 0.66 and 9.21 under CT to 0.7 and 20.4 under ZT also indicated improved soil structure condition by adoption of ZT. Similar comparisons had been made by (Wischmeier and Mannering 1969, Singh and Prakash 1985; Kukal *et al.* 1993) under different land uses.

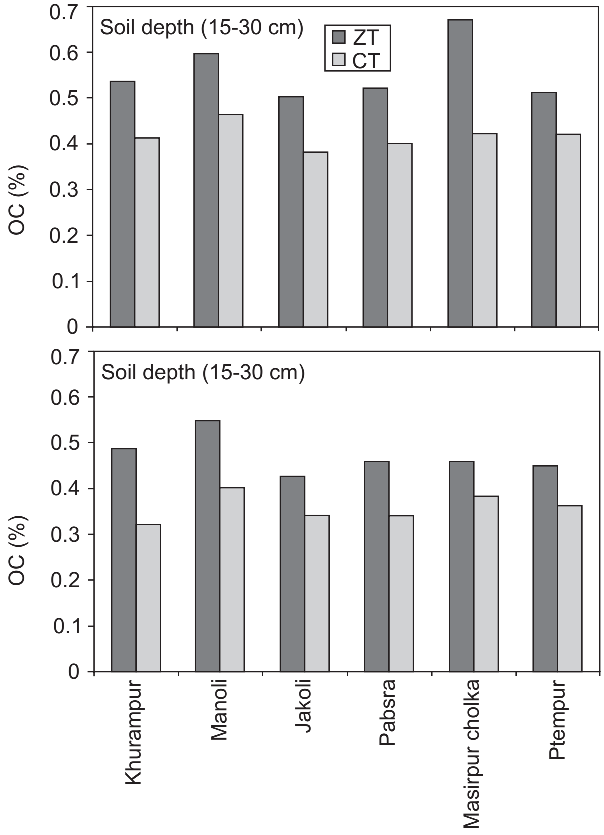

Fig. 4 Soil organic carbon (SOC) under zero tillage and conventional system in surveyed villages of Rai block in Sonipat

Analysis of the aggregate stability of the soils of surveyed area clearly reveals that these alluvial plain soils near the river Yamuna are highly erodible in nature. The main physical constraints are low organic matter, low sub surface permeability and poor aggregate stability. These constraints 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 RCT's. Other erosion indices such as DR, ER and CR were less and CMER and SI were more in the plots under bed and ZT compared

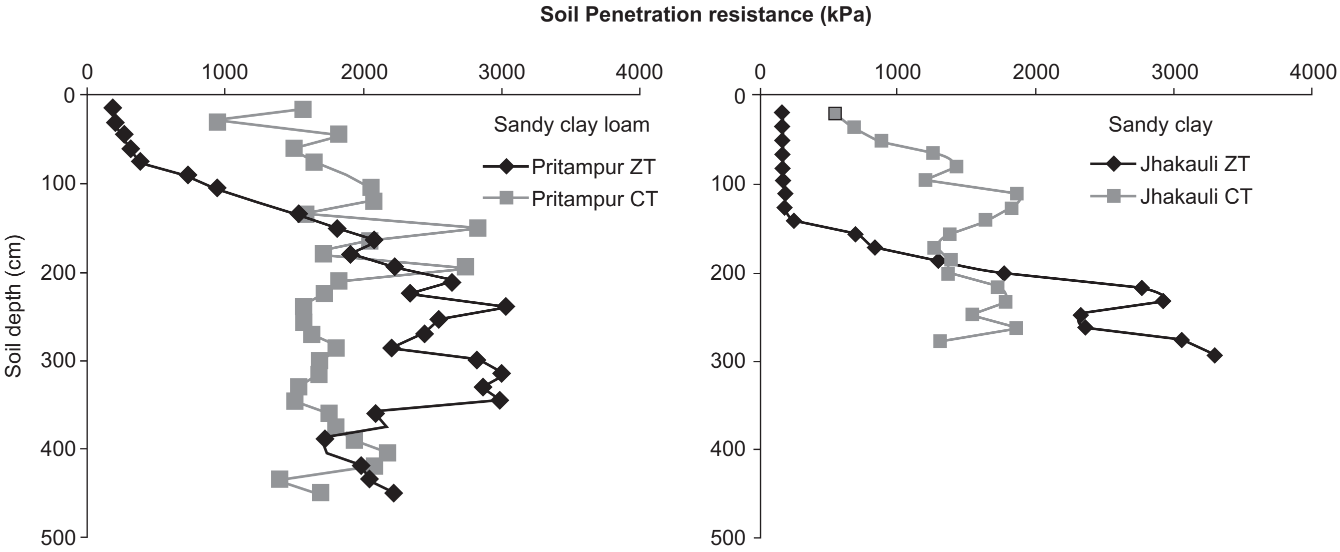

Fig 5 Penetration resistance of soil under zero and conventionally tilled wheat in Jhakauli village (24. 2.2012)

with conventional system, which revealed that adoption of RCT's in this region would make the soils more resistant to erosion by water and wind.

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