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Conservation tillage and manure effect on soil aggregation, yield and energy requirement for wheat (*Triticum aestivum*) in vertisols

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ABSTRACT

Conservation tillage is gaining significant economic and environmental importance under changing climatic conditions. Hence this study was carried out to assess interactive effect of conservation tillage and manure treatments on soil aggregation, crop performance and energy requirement for wheat (*Triticum aestivum* L.) crop under vertisols of central India. The experiment was taken in a split plot design for four consecutive cropping seasons since 2008, with two tillage treatments, no tillage (NT) and reduced tillage (RT) in the main plot, and seven manure treatments in the sub plots. The effects were compared to farmer's practice, i.e. conventional tillage (CT). The seven manure treatments included application of FYM at the rate of 0, 0.5, 1.0 and 2.0 Mg C/ha, applied every year and 2.5, 5.0 and 10.0 Mg C/ha, applied at initiation of experiment. After four years of experiment, the mean weight diameter of soil aggregates was 1.4 and 1.2 times higher under NT and RT, respectively, as compared to CT. Averaged over manure treatments, the grain yield was higher by 1.17 and 0.59 Mg/ha in NT and RT, respectively, than the CT. The energy requirement was 4.68 and 2.32 times higher under CT, as compared to NT and RT systems. Also, the cost of production of wheat was 40.62% and 21.12% higher in CT as compared to NT and RT, respectively, resulting in saving of ₹ 7 800 and ₹ 4 725/ha/year in the two conservation tillage systems.

Key words : Energy, No tillage, Reduced tillage, Soil properties, Yield

Land use and land management practices have significant influence on maintaining soil health and improving carbon sink potential of soils (Lenka *et al*. 2012). In this context, conservation tillage practices are gradually gaining importance as effective mitigation options for changing climate conditions. Studies show no tillage (NT) and reduced tillage (RT) to have favourable effect on soil properties and crop performance. Upon appropriate residue management, NT and RT systems reduce soil erosion, increase soil aggregate stability, and helps soil carbon sequestration (Madejon *et al*. 2007, Lenka *et al*. 2012). The role of conservation tillage practices in conserving soil moisture, with the subsequent effect on crop yields, has also been observed in Indian conditions (Singh *et al*. 2008, Kar and Kumar 2009). Though, wheat (*Triticum aestivum* L.) yield under conservation tillage methods was higher or similar to that under conventional tillage (CT), the time and energy requirement in land preparation was higher in the former than the latter (Bonciarelli and Archetti 2000, Singh *et al*. 2008).

Tillage in vertisols is a time and energy consuming process due to high clay content, swelling and shrinkage properties, low hydraulic conductivity and poor soil structure. Since excessive and continuous soil tillage strongly influence soil properties, it is important to apply appropriate tillage practices that reduce degradation of soil structure, maintain crop yield as well as ecosystem stability (Greenland 1981, Lal 1985). Further excessive tillage without supplementation of manures may degrade soil physical quality, decrease soil organic carbon (SOC) concentration, and reduce crop yield (Ahmad *et al*. 1996). Soil aggregates are sensitive to management practices and decrease with tillage intensity (Lal *et al*. 1999, Lenka and Lal 2013). Increased aggregate disruption due to tillage may lead to relocation and stratification of soil organic matters as reported by many investigators (Deen and Kataki 2003). The effect of conservation tillage methods have been found to be advantageous in terms of reduced soil compaction in long run and less investment on machinery and energy requirement and timely planting of crops. Therefore, this study was taken to evaluate the NT and RT systems in terms of wheat

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productivity, energy needs for cultural practices, soil properties and profitability with different levels of manure application through FYM, with specific reference to vertisols of Central India.

MATERIALS AND METHODS

The study was conducted for four consecutive cropping seasons under wheat crop at the research farm of the Central Institute of Agricultural Engineering (CIAE), Bhopal, Madhya Pradesh, India situated at 23° 18' N longitude, 77° 24' E latitude and 485 m above mean sea level. The soil on site was a non-calcareous vertisol (Isohyperthermic Typic Haplustert) with 52% clay content, bulk density of 1.34 Mg/m^3 at 0.27 g/g soil water content, and available water capacity of 10.16 cm. The soil was neutral to alkaline in reaction (pH - 7.5) with 7.0 g/kg soil organic carbon, electrical conductivity of 0.3 ds/m and Ca^{2+} as the dominant exchangeable cation in the Ap horizon.

The experiment started in July 2008 with wheat crop (HD 1531) grown in *rabi* (November to April) season in all the 4 years. The experimental layout was split plot with tillage levels as the main plot and manure - C levels as subplots, replicated three times. The tillage treatments (main plot), consisted of no tillage (NT, direct sowing by rotary slit no-till-seed cum fertilizer drill) and reduced tillage (RT: one pass rotavator and sowing by seed cum fertilizer drill)). There were seven FYM-C treatments (Mg/ha), viz. T_1 (0), T_2 (0.5), T_3 (1), T_4 (2), T_5 (2.5), T_6 (5.0) and T_7 (10.0). The farmyard manure (FYM) was applied every year in T_2, T_3 and T_4 and at initiation of the experiment in T_5, T_6 and T_7. The FYM was analyzed for C content in TOC analyzer (Analytic Zena Inc.) every year before application and applied on dry weight basis one week before sowing. The recommended dose of fertilizer was applied at the rate of 100 : 60 : 30 kg N – P_2O_5 – K_2O per ha to all the treatments. The N fertilizer was applied in split dose while 100% P and K was applied as basal. In both RT and NT, weed control was carried out through application of 2, 4-D herbicide at 20-24 days after sowing. The effects were compared to farmer's practice, i.e. CT, with two times ploughing + sowing with seed drill.

Four years after initiation of the experiment, observations on soil and crop parameters were taken in the month of April 2012 after harvest of wheat crop. The bulk density of the soil was determined by core method (Blake and Hartge 1986) for depths of 0 - 15, 15 –30 and 30-45 cm. The shear strength (cone index) of soil was measured using 'Eijkelkamp penetrologger kit' during the sowing of wheat. For analysis of soil aggregate stability, soil samples were collected by cores from three different depths, viz. 0-5, 5-15, and 15-30 cm depths. Soil samples were gently broken apart along natural break points, and passed through an 8-mm sieve. Plant and organic debris in the sieved soil were removed. The soil aggregate analysis was carried out using Yodders' apparatus. Mean Weight Diameter (MWD) was calculated according to procedure developed by Kemper and Rosenau (1986). Mean Weight Diameter is equal to the sum of the products of (a) the mean diameter (d_i) of each size fraction and (b) the proportion of the total sample weight (w_i) occurring in the corresponding size fraction, where the summation is carried out over all 'n' size fraction including the one that passes through the finest sieve (Equation 1).

$$MWD = \Sigma_{i=1}^{n} d_1 \, w_t \qquad \text{Eq. 1}$$

At maturity, crop was harvested manually from three sampling sites of 1.0 m × 1.0 m size each. Clean grain and straw were weighed separately. The field capacity (ha/h) of machines used for no-tillage (rotary slit till seed cum fertilizer drill), reduced tillage (one pass rotavator and seed cum fertilizer drill) and conventional tillage (two times ploughing by duckfoot cultivator and sowing with seed cum fertilizer drill) was measured by recording the area covered in unit time operation. The fuel (high speed diesel, l/ha) consumed, time and labour required (h/ha) under no tillage, reduced tillage and conventional tillage operation were recorded for each machine used with 35 hp tractor during the field operation. Energy equivalent and cost of production were determined as per the procedure of Devasenapathy *et al*. (2009) and Rautaray (2005).

All the data recorded were analyzed by using the standard procedures of statistical analysis for split-plot design (Gomez and Gomez 1984). Analysis of variance (ANOVA) was used to determine the effect of each treatment. When F ratio was significant, a multiple mean comparison was performed using Fisher's least significant difference test (0.05 probability level). The crop yield data of NT and RT was averaged across manure treatments in each replication and compared against CT following the standard procedures of completely randomized block design (Gomez and Gomez 1984).

RESULTS AND DISCUSSION

Bulk density and shear strength

The bulk density (B D) of soil in NT, RT and CT varied from 1.26, 1.16 and 1.12 Mg/m^3 at 0-15 cm soil depth, with higher values of 1.32, 1.28 and 1.24 Mg/m^3 at 15–30 cm soil depth (Table 1). In general, the BD in the 0-15 cm soil depth was higher by 13% and 4% in NT and RT, respectively, as compared to CT. However, below 30 cm layer, there was no significant effect of NT and RT, as compared to CT. Shear strength increased with soil depth up to 30 cm for all the treatments. Higher values were obtained under NT compared to RT and CT methods. The shear strength was higher at 15-30 cm depth in NT (2.44 N/mm^2) as compared to RT (2.24 N/mm^2) and CT (1.88 N/mm^2). Higher soil strength under NT has also been reported by Martino and Shaykewich (1994). The difference in soil strength among the three tillage systems is because of the difference in periodicity of surface disturbance and pulverization. Below 30 cm soil depth, shear

Table 1 Effect of tillage methods on bulk density and shear strength of soil at sowing of 4th season wheat crop

Depth (cm)	Moisture content range, % (db)	Bulk density (Mg/m^3)			Shear strength (N/mm^2)		
		No-tillage	Reduced tillage	Conventional tillage	No-tillage	Reduced tillage	Conventional tillage
0-15	21.9 - 22.5	1.26	1.16	1.12	1.40	0.48	0.24
		(0.04)	(0.03)	(0.05)	(0.09)	(0.08)	(0.02)
15-30	21.9 - 22.7	1.32	1.28	1.24	2.44	2.24	1.88
		(0.03)	(0.05)	(0.04)	(0.05)	(0.04)	(0.08)
30-45	22.1 - 22.8	1.48	1.44	1.41	1.84	1.74	1.70
		(0.06)	(0.04)	(0.05)	(0.07)	(0.05)	(0.08)

Note: Values are means with standard deviation in parenthesis (n = 21 in NT and RT and 6 in CT)

strength under all the three tillage systems decreased with increase in depth. The values of shear strength for NT and RT was near to that of the CT (1.65 N mm^{-2}) at $\geq$ 45 cm depth.

Aggregate stability

Tillage and manuring significantly affected the stability of aggregates for the 0 - 30 cm soil depth. The mean weight diameter (MWD) under NT was 1.4 times higher than RT, at 0 - 15 cm depth. The magnitude of difference decreased at lower soil depths. The MWD at 15-30 cm soil depth was only 1.1 times higher in NT than RT and difference below 30 cm was not significant. The quantity and frequency of application of FYM also significantly affected the stability of aggregates by increasing the MWD at 0-5 cm depth (Table 2). Across tillage methods, the increase in quantity of FYM from 0 to 2 Mg/ha, applied at yearly interval, improved soil MWD from 0.89 to 1.20 in NT and from 0.59 to 0.93 in RT. However application of higher dose of FYM at the beginning of the experiment resulted at par or lower MWD than application of lower level of FYM every year. Organic inputs improve and help in stabilization of the aggregates through formation of clay-humus complexes. On the other hand, conventional tillage disrupts the network of fungal hyphae by mechanical breakdown of macroaggregates and then releasing particulate organic matter from macroaggregates resulting in decrease of aggregate stability (Ashagrie *et al.* 2007).

Yield

The mean grain and total biological (grain and straw) yield of wheat under NT, RT and CT were 5.64, 5.06, 4.47 Mg/ha and 15.28, 13.52, 12.32 Mg/ha, respectively (Table 3). The NT with manure treatments of T_4, T_5, T_6 and T_7 resulted in significantly higher yield as compared to RT and CT methods. It was due to greater availability of moisture, release of nitrogen by the decomposing stubbles, lower weed intensity, better germination and contact of moisture to grain under furrow made by inverted "t" type furrow opener used

Table 2 Mean weight diameter (mm) at different soil depth as influenced by tillage and manure treatments

FYM* treatment	Soil depth (cm) 0–5			5–15			15–30		
	RT	NT	Mean	RT	NT	Mean	RT	NT	Mean
T_1 (0)	0.59	0.89	0.74	0.52	0.75	0.64	0.54	0.61	0.58
T_2 (0.5)	0.74	0.93	0.84	0.64	0.81	0.73	0.64	0.70	0.67
T_3 (1.0)	0.81	1.12	0.97	0.81	1.08	0.95	0.76	0.81	0.79
T_4 (2.0)	0.93	1.20	1.07	0.89	1.10	0.99	0.82	0.89	0.86
T_5 (2.5)	0.78	1.04	0.91	0.76	0.94	0.85	0.75	0.81	0.78
T_6 (5.0)	0.77	1.04	0.91	0.79	1.01	0.90	0.74	0.80	0.77
T_7 (10.0)	0.76	1.11	0.94	0.72	1.10	0.91	0.78	0.82	0.80
Mean	0.77	1.05		0.73	0.97		0.72	0.78	
$LSD_{0.05}$ FYM-C		0.03			0.04			0.05	
Tillage		0.15			0.17			ns	
Tillage × FYM-C		0.19			0.13			0.17	

Note: T_1 to T_4 refer to FYM - C at the rate of 0, 0.5, 1.0, 2.0 Mg/ha applied every year; T_5, T_6, T_7 are FYM-C application at 2.5, 5.0 and 10.0 Mg/ha at the beginning of the experiment

Table 3 Interactive effect of conservation tillage and manure on the yield of wheat crop

FYM – C (tonnes/ha)	Grain yield (Mg/ha)			CT	Total biological yield (Mg/ha)			CT
	NT	RT	Mean		NT	RT	Mean	
T_1 (0)	4.91	4.75	4.83b		17.50	13.76	17.83b	
T_2 (0.5)	5.16	4.90	5.03b		14.32	12.76	14.70b	
T_3 (1.0)	5.28	4.95	5.12ab		14.94	13.64	15.25ab	
T_4 (2.0)	5.99	5.95	5.97a		17.28	13.69	16.73a	
T_5 (2.5)	5.70	5.42	5.56ab		15.34	13.47	15.84ab	
T_6 (5.0)	5.70	5.48	5.59ab		14.59	13.82	14.68ab	
T_7 (10.0)	5.09	5.34	5.22ab		13.01	13.49	13.28ab	
Mean	5.64a	5.06a		4.47a	1 5.28a	13.52 b		12.32b
LSD (P=0.05)	Tillage × FYM-C: 0.82				Tillage × FYM-C: 3.21			

*Means in a column followed by common letter are not significantly different at P=0.05
Means in a rows followed by common letter are not significantly different at P=0.05

in no till-slit-drill. Averaged across tillage (NT and RT) methods, application of manure resulted in higher wheat yield than the no-manure treatment. The T_4 treatment, i.e. application of FYM-C (2.0 tonnes/ha) or approximately 6 tonnes/ha FYM every year in conjunction with recommended dose of NPK, increased wheat yield by 24% over and above recommended rates of NPK (T_1). Better crop yield under integrated nutrient management (inorganic + organic) than only inorganic treatment is also reported by Aulakh *et al.* (2008). Application of FYM enhances the soil organic C content (SOC) and has direct and indirect effects on soil properties and processes. The potential benefits of organic manure in maintaining and sustaining soil health and productivity has been reported by several workers Lenka *et al*. (2012), Lenka *et al.* (2011), Mohanty *et al*. (2006).

Energy requirement

The energy requirement of wheat for CT, RT and NT systems were 13 457, 2 537 and 12 231 MJ/ha, respectively, whereas the cost of production varied from ₹ 27 000, ₹ 22 275 and ₹ 19 200 per ha, for the three tillage systems, respectively (Table 4). The specific energy per tonne of grain produced in NT, RT and CT were 2 168, 2 537 and 3 017 MJ, respectively. The higher energy requirement under CT was due to the energy involved in tillage operations (two tillage operations by tractor operated duckfoot cultivator) as compared to RT (one tillage operation by tractor operated rotavator) and NT (no tillage operation). This showed that energy expenditure was 4.68 and 2.32 times more in CT as compared to NT and RT systems. The results of this study was in agreement with that of Dixit *et al.* (2003), who reported 5.95 times higher energy requirement per tonne of grain produced in CT as compared to NT in wheat crop.

The cost of production of wheat crop was 40.62% and 21.12% higher in CT as compared to NT and RT methods, respectively. Thus, NT and RT systems resulted saving of ₹ 7800 and ₹ 4 725/ha/year over CT in wheat crop under vertisol conditions. Management practices used in the crop

Table 4 Conservation tillage and manure interactive effect on energy requirement and cost of production

Particulars	Conservation tillage		Conventional tillage,
	NT	RT	CT
Energy equivalent for tillage and sowing/ha			
Human labour (MJ/ha)	9.33	9.80	43.51
Tractor + drill machine used (MJ/ha)	33.41	35.10	155.84
Fuel consumption (MJ/ha)	536.07	1126.10	2514.80
Energy equivalent for FYM (MJ/ha)	900.00	900.00	
Human labour for application of FYM (MJ/ha)	19.20	19.20	
Energy equivalent for herbicide (2–4 D) (MJ/ha)	240.00		
Human labour (MJ/ha)	9.6		
Energy equivalent for fertilizers: 100:60:30, kg/ha			
Human labour(MJ/ha)	19.20	19.20	19.20
N (MJ/ha)	6060.00	6060.00	6060.00
P_2O_5 (MJ/ha)	666.00	666.00	666.00
K_2O (MJ/ha)	201.00	201.00	201.00
Energy equivalent for irrigation –2 Nos.			
Human labour, (MJ/ha)	70.56	78.4	78.4
Diesel motor + pump used (MJ/ha)	34.99	38.88	38.88
Diesel consumption (MJ/ha)	2229.88	2477.64	2477.64
Energy equivalent for harvesting and threshing			
Human labour (MJ/ha)	116.00	116.00	116.00
Tractor + thresher used (MJ/ha)	297.92	297.92	297.92
Diesel consumption (MJ/ha)	788.34	788.34	788.34
Total energy (MJ/ha)	12231.50	12838.58	13457.53
Energy required (MJ/tonnes of grain)	2168.71	2537.27	3010.63
Cost of production (₹/ha)	19200	22275	27000

production system affects the energy balance of that system. Bonciarelli and Archetti (2000) observed that reducing soil tillage always resulted in notable savings of fuel consumption and working time, though slight advantage in crop yield were observed in winter wheat. Singh *et al*. (2009) observed that operational energy was higher in CT than RT in production of maize and wheat.

From the above results, it can be concluded that conservation tillage (NT and RT) in the long term improve the soil aggregation and crop yield in wheat. In the vertisols of central India, the NT and RT are proved to be remunerative alternate tillage methods with 28% and 16% lower specific energy requirement and 41% and 21% lower cost of production, as compared to conventional tillage methods.

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