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Depthwise variation in selected soil properties as influenced by tillage and residue management in sandy loam soil of North-West Himalayas, India

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ABSTRACT

The present study aimed to determine the effect of varying tillage and residue management in a sandy loam soil under maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) sequence. The research was carried out at ICAR- Indian Institute of Soil and Water Conservation, Research Centre, Chandigarh, research farm, located at Panchkula, Haryana, in maize (*kharif*)-wheat (*rabi*) cropping sequence during 2009–2017. Six treatments implemented were Conventional tillage (CT); Deep tillage once in three years (DT); Conventional tillage with integrated nutrient management (CT-INM); Conventional tillage with brown manuring in maize + cowpea (1:2) and wheat + pea (4:1) ratio (CT-BM); Conservation tillage (CST) ; Conservation tillage with brown manuring (CST-BM). The compaction level attained under conservation tillage based systems were lower than the corresponding levels in the conventional tillage control. The highest percentage of macro aggregates was found in CST-BM treatment (48%), followed by CST (45%) and CT, DT and CT-INM recorded much lesser macro aggregate (29.3, 28 and 31%). Conventional tillage (CT) reduced macroaggregates with a concomitant increase in microaggregates (<0.25 mm) percentage. The mean soil moisture percentage average in surface (0–15 cm) and sub surface soil (15–30 cm) were found to be higher under DT, CST and CST-BM treatments over CT and CT-INM treatments. In general, the soil moisture was found to be proportional to the amount of biomass added under various treatments. The mean soil available nitrogen were 15.4% and 17.5% higher under CT-BM and CST-BM treatments respectively, over the control (CT).

Keywords: Brown manuring, Carbon fractions, Conservation tillage, Soil aggregation

Indian Himalayan region is characterized by light textured soils, erratic rainfall, undulating topography, and highly eroded soils. This particular combination of climate, soil along with prevailing tillage practices makes agriculture especially vulnerable to structural degradation (Bhattacharyya *et al*. 2009). Poor long-term management practices under intensive maize (*Zea mays* L.)–wheat (*Triticum aestivum* L.) cropping system on sloping lands may have adverse impacts on soil-plant-environmental sustainability. Appropriate interventions like integration of conservation tillage with brown manuring has significant potential to improve soil quality, carbon retention potential and lesser soil loss (Yadav *et al.* 2019). In this context, soil management practices, such as conservation tillage and brown manuring, have the potential to enhance SOC and improve soil aggregation under rainfed agricultural conditions of Shivalik Himalayas.

The development of well-structured soils is a key goal for achieving sustainable and productive agricultural systems. The distribution of soil in different aggregates is important because of their susceptibility to movement by wind and water. The erodibility of soils decreases as aggregate stability increases. The abundance and stability of the aggregates are critical for several soil functions, such as plant growth, resistance to erosion, soil organic matter turnover and diversity of organisms (Six *et al*. 2006).

Addition of organic matter to the soil provides substrate that leads to improved soil aggregation. Many researchers emphasize that C accumulation in soils is altered by management practices (Das *et al*. 2014). This process is governed by the interplay of climate, soil type, substrate biochemistry, land use, addition of organic residues, C inputs and associated microbial community structure (Pal and Panwar 2013, Venkatesh *et al*. 2013, Pal and Petra 2016).

The farmers' adoption of conservation tillage and brown manuring practices is limited, due to the lack of sufficient field level research. In present study, a combination of tillage methods along with intercrop and nutrient management strategies were designed with objective to determine the impacts of varying tillage and residue management practices on selected soil properties.

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MATERIALS AND METHODS

The research was carried out at experimental field of the ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Chandigarh, research farm area, located at Panchkula district of Haryana, during 2009–2017. As per the USDA soil taxonomy, the soil of the study area has been classified as light-textured hyperthermic Udic Ustochrept. The soil is sandy loam in texture, well drained, with low water-holding capacity. The average soil *p*H (1:2) is 7.8; EC 0.29 dS/m; organic carbon 0.54%; available N 303 kg/ha; P_2O_5 27.5 kg/ha, K_2O 217 kg/ha; Zn 1.03 mg/kg; Cu 0.52 mg/kg; Fe 2.85 mg/kg and Mn 5.87 mg/kg, texture sandy loam with low water holding capacity. The area receives 1100 mm of mean annual rainfall, of which 80% occurs during the monsoon season (June–September). The research started in the year of 2009. The experimental trial was laid out in Randomized Block Design with four replications. Twenty-four plots of size 8 m × 5 m were prepared with a uniform slope of 1.5% in 2009–10. Treatments were T_1: Conventional tillage in maize-wheat (CT), T_2: Deep tillage in maize-wheat (DT) once in three years, T_3: Conventional tillage in maize-wheat with integrated nutrient management (CT-INM), T_4: Conventional tillage with brown manuring in maize + cowpea (1:2) and wheat + pea (4:1) cropping sequence (CT-BM), T_5: Conservation tillage in maize-wheat cropping sequence (CST); T_6: Conservation tillage in maize-wheat cropping sequence with brown manuring (CST-BM).

Brown manuring is simply a 'no-till' version of green manuring, using an herbicide to desiccate the crop before flowering instead of cultivation. In this technique, green manure crops are grown in standing cereal crops and killed with the help of herbicide for manuring where the plant residues are left standing in the field along with main crop without incorporation/*in situ* ploughing until its residue decomposes itself in the soil aiming to add organic manure beside weed suppression. The post-emergence herbicide spray on green manure leaves results in loss of chlorophyll showing brown in colour is referred to as brown manuring (Tanwar *et al.* 2010).

The cropping system followed in experiment was maize-wheat. Fertilizer application rate were 80 kg N/ha, 40 kg P/ha and 20 kg K/ha for maize and 60 kg N/ha, 40 kg P/ha and 20 kg K/ha for wheat. In both the conservation tillage treatments (T_5 and T_6), grass was cut above ground once and applied on the field surface itself. During 2009–10, wheat (var. WH 711) was grown after maize (var. Bisco X92) with one pre-sowing and two post sowing supplemental irrigations.

After the harvest of wheat crop in 2017, plot-wise soil samples in triplicate were collected from the surface (0–15 cm) and sub surface (15–30 cm) layer. The soil samples were air dried, grounded and passed through a 0.2 mm sieve for determination of soil organic carbon (SOC). Soil samples for moisture content determination were collected from individual plots in all the replications up to depth of 60 cm at intervals of 0–15, 15–30, 30–45 and 45–60 cm, respectively. Soil moisture was determined by gravimetric method. A wet sieving procedure was modified for determination of aggregate-size distribution, and aggregate stability indices (Kemper and Rosenau 1986). Soil compaction was measured by using a cone penetrometer. Different fractions of SOC under a gradient of oxidizing conditions were determined through a modified Walkley and Black's (1938) method (Chan *et al*. 2001). The MSTAT C and MS Office Excel were employed for all of the statistical analyses. A one-way ANOVA was applied to test treatment effects on yield under various treatments.

RESULTS AND DISCUSSION

Soil compaction under different treatments: The fields cultivated with conventional tillage recorded soil compaction values in the range of 339.7–1697 Kpa at various depths (Fig 1). In control treatment, soil compaction values increased sharply with increase in soil depth and increased to 893 and 1628.5 Kpa at 7.5 and 15 cm depths, respectively. The values remained fairly constant in the range of 1625 –1710 Kpa, on moving further depths up to 30 cm soil depth. The compaction level attained under conservation tillage-based systems were lower than the corresponding levels in the conventional tillage control (CT).

Drummond (2000) reported sub-surface compacted (>2 Mpa) horizon below plough layer in shallow tilled soils of central Kansas, USA while no-tilled soils offered comparatively less resistance to penetration up to 50 cm

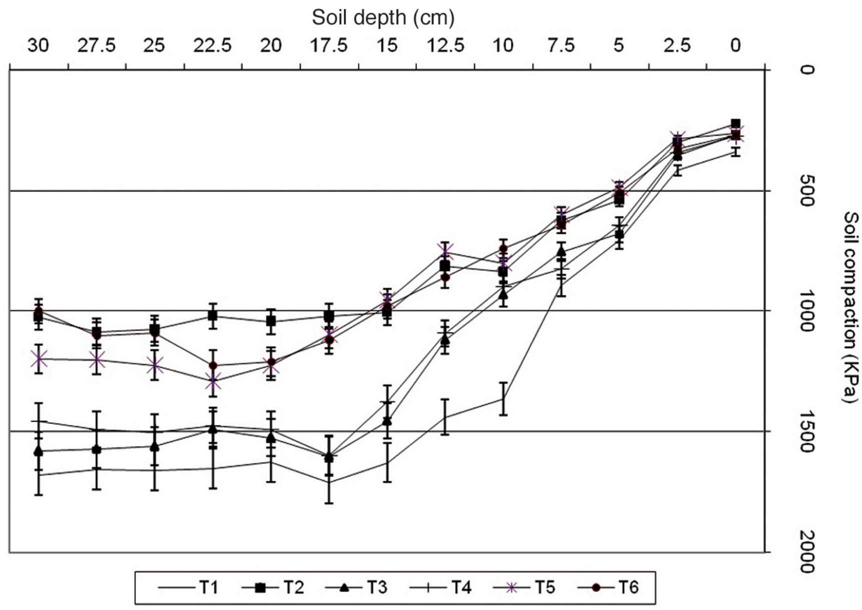

Fig 1 Soil compaction under different treatments.
Treatment details given under Materials and Methods.

Table 1 Soil aggregation and available nitrogen under different treatment

Treatment	Percentage distribution of aggregates under different size fraction				Available nitrogen (kg/ha)	
	>2 mm	2–1 mm	1–0.25 mm	<0.25 mm	0–15	15–30
T_1	29.30	24.30	27.65	18.75	247.7	192.9
T_2	28.00	22.81	29.30	19.89	241.5	198.4
T_3	31.00	25.74	29.76	13.50	251.2	223.4
T_4	43.16	29.11	22.50	5.23	285.0	261.9
T_5	45.00	35.44	16.54	3.02	255.4	211.7
T_6	47.00	31.40	17.65	3.95	291.1	270.0

Treatment details given under Materials and Methods.

depth.

Soil aggregation under different treatments: In present study, among six treatments, highest percentage of macro aggregates was found in T_6 that is CST-BM treatment (48%), followed by T_5, CST (45%) and T_1, T_2 and T_3 recorded much lesser macro aggregate (29.3, 28 and 31%). On the contrary, conventional tillage (T_1) reduced macroaggregates with a concomitant increase in microaggregates (<0.25 mm) percentage (Table 1). The decline in the size of aggregates with CT could be attributed to mechanical disruption of macroaggregates, which might have exposed soil organic matter previously protected from decomposition (Six *et al*. 2000).

Tillage systems retaining large crop residues, viz. CST-BM, CST and CT-BM had higher soil moisture throughout the soil depth. Water conservation benefits of conservation tillage involving residues result from protection of soil surface against raindrop impact, reduced soil aggregate dispersion and reduced soil water evaporation.

The use of minimum tillage is recommended for sustainable agriculture because of its positive effect on soil aggregation and TOC (Lal 2008). The primary effect of tillage is to physically disturb the soil structure. Tillage usually disrupts soil aggregates and lowers TOC, CEC, nutrients that contribute to aggregation (Jiang *et al.* 2011). The development of well-structured soils is a goal for achieving sustainable and productive agricultural systems. This is particularly true for the Himalayan soils that are prone to soil loss.

Thus, it is very imperative to better understand conservation tillage effects on the process of C stabilization. Mikha and Rice (2004) observed that conventional tillage significantly (P<0.05) reduced macroaggregates (>2.0 mm and 0.25–2 mm) with a concomitant increase in microaggregates (<0.25 mm) after 10 years of study in a US silt loam soil. The decline in the size of aggregates with CT could be attributed to mechanical disruption of macroaggregates, which might have exposed SOM previously protected from decomposition (Six *et al.* 2000).

Soil structure and soil organic matter (SOM) are strongly related as organic matter binds mineral particles into aggregates and reduces soil erodibility. Similar to the results of this study, several authors (Whalen *et al.* 2003) reported that improvements in aggregation can occur within 2–3 years of establishing conservation practices. Soil properties such as water stable aggregate play important roles in crop yield by virtue of improving soil water retention characteristics, increasing plant available water capacity and decreased soil erodibility, which help reduce soil and nutrient losses (Bhattacharyya *et al.* 2008).

Soil moisture under different treatments: The mean soil moisture percentage after harvest of wheat (2017) was found to be significantly different under different treatments (Fig 2). The mean soil moisture percentage average in surface (0–15 cm) and sub surface soil (15–30 cm) were determined. It is found to be higher under DT, CST and CST-BM treatments over CT and CT-INM treatments. In general, the soil moisture was found to be proportional to the amount of biomass added under various treatments. Surface residue cover under different tillage system was helpful to prevent evaporation and maintenance of soil moisture in surface soil. The residue retained plot under zero till rice and wheat followed by *Sesbania* brown manuring resulted in more soil moisture content at 0–15 cm and 15–30 cm soil depth and lower soil moisture was reported under direct seeded

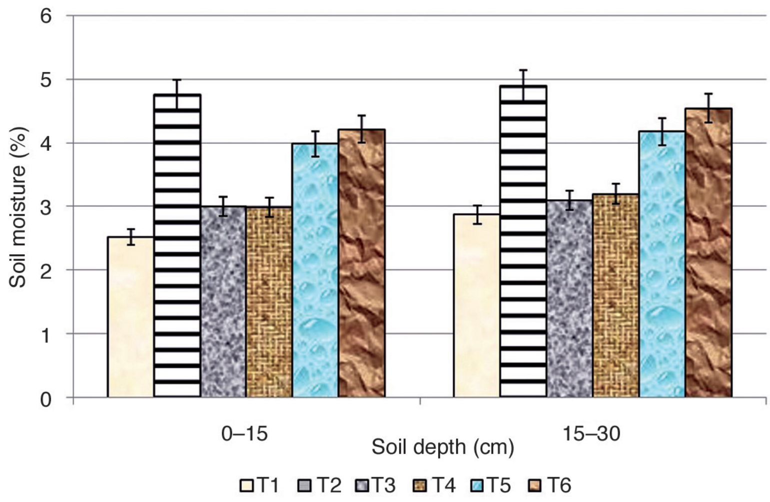

Fig 2 Soil moisture under different treatments.
Treatment details given under Materials and Methods.

rice followed by conventional wheat with incorporation of *Sesbania* (Paliwal *et al.* 2017).

Soil available nitrogen under different treatments: The mean soil available nitrogen varied significantly across the treatments (Table 1). In surface soil (0–15 cm), soil available nitrogen under CT-BM and CST-BM was significantly higher compared to other treatments. The mean soil available nitrogen were 15.4% and 17.5% higher under CT-BM and CST-BM treatments, respectively, over the control (CT). A similar trend was also seen in sub-surface soil (15–30 cm).

In a study on effect of brown manuring on soil organic carbon and post harvest available nitrogen showed 13.4% increase in soil available nitrogen with brown manuring (Iliger *et al.* 2017). Brown manuring improves the soil organic matter, aggregation, available nitrogen, available nutrients and reduces the bulk density, controls N-losses through leaching and soil erosion.

Hiremath *et al*. (2019) studied organic carbon, available N, P and K of soil in different green and brown manuring crops in maize-wheat cropping system. Cowpea green manure significantly increase soil available nitrogen. Significantly higher organic carbon and available NPK were noticed with sunnhemp green manuring in 1:2 row proportion compared to sole maize.

Conservation tillage-based treatments improved soil aggregation and soil moisture, and reduced soil compaction. Brown manuring increased soil available nitrogen, thus, improved soil fertility. Conservation tillage systems, increased the proportion of macroaggregates, which was attributed to higher soil organic C level and less mechanical disturbance compared to with conventional tillage.

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