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**Research Article**

# Conservation Agriculture Impact on Soil Hydro-physical Properties in a Maize-Wheat Rotation

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**ABSTRACT**

A long-term (12 years) experiment on conservation agriculture (CA) in a sandy clay loam soil under maize -wheat rotation at the Indian Agricultural Research Institute, New Delhi was characterized in terms of the soil hydro-physical properties. The impact of CA on soil hydro-physical properties was assessed in terms of bulk density (BD), aggregation, sorptivity (S), total porosity (TP) and pore size distribution. The CA reduced BD in both surface (0-15cm) and sub-surface layers with a concomitant increase in total porosity and micro- pores in the sub-surface layer. Soil aggregation was largely modified in favour of CA; however, increase in SOC was limited only to the near surface (0-5cm) layer. An improvement in the sub-surface soil (increase in total and micro-pore volume and decrease in BD) helped in improving the crop yield and CA in a maize-wheat rotation of semi-arid region of Delhi.

**Key words:** Soil Porosity, Sorptivity, Soil aggregation, Conservation agriculture

## Introduction

Soil tillage is the guiding component of soil management and has far reaching implications in agricultural production system. Understanding soil structure and function in absence of tillage is necessary for deciding the suitability of conservation agriculture (CA) practices as an alternate to the existing farming mode (conventional agriculture, CT). Soil bulk density and aggregation influence soil water retention and dynamics, the latter can be evaluated by the water intake to the soil following irrigation, and the distribution of pores in the soil profile. Bulk density influences soil pores and aggregation, facilitates water infiltration, maintains soil biota and ensures soil aeration usually, the macro-pores and micro-pores determine the fate and behaviour of water and solute transports in the soils (Paradelo *et al*., 2013; Soto-Gómez *et al*., 2016). Sorptivity(S) [$LT^{-1/2}$], introduced by Philip (1957), is an important hydraulic property (governing the early portion of infiltration) that describes the soil's capacity to uptake water rapidly. Organic carbon modifies soil parameters, and thereby influences energy and matter exchange. The CT generally fails to protect the C stocks in soils, which can otherwise be increased by keeping residue over the surface, through the adoption of CA (Ramnarine *et al*., 2018). The impact of CA varies widely across cropping systems and soils, and therefore need to be examined closely (Mondal *et al*., 2019). In this study, a few soil hydro-physical parameters have been evaluated along with the soil organic C (SOC) in a long-term experiment (since 2006) on CA in a sandy clay loam soil under the maize-wheat rotation.

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## Materials and Methods

### *Site and treatments*

The experimental field is located at ICAR-Indian Agricultural research Institute (IARI), New Delhi, India (28°35' N latitude to 77°12' E longitude; altitude of 228.16 m above mean sea level). The field has a fairly levelled topography; the soil is Typic Haplustept and belongs to Indo-Gangetic alluvium soil group, sandy clay loam (0-30 cm) and loam (> 30 cm) in texture with weak-to-medium angular blocky structure. The soil is neutral in reaction, non-calcareous and poor in available N, medium in available P and SOC. The climate is semi-arid with the annual rainfall of 710 mm. The CA is a no-tillage practice with residues retained over surface. Here a narrow (~5 cm) strip is drilled for sowing), which was evaluated against the CT in which the soil was ploughed (disc plough + tooth harrow) at ~10 cm depth, and smoothed using the tooth harrow every year just before maize or wheat seeding. Soil samples were collected from 0-15, 15-30, 30-45 and 45-60 cm layers.

### *Parameters under study*

Undisturbed soil cores were collected, processed in the laboratory, oven-dried and the bulk density was determined (Blake and Hartge, 1986). Another set of undisturbed soils were used for aggregate size analysis. Bigger clods were gently disintegrated, air-dried, passed through a 4 mm sieve, and wet-sieved through a set of three sieves (2, 0.25 and 0.053 mm) by using Yoder apparatus for a period of 10 min (Kemper and Rosenau, 1986). Aggregates retained on each sieve were collected, oven-dried and weighed. Proportion of macro- and micro-aggregates and the mean weight diameter (MWD) of aggregates were determined for evaluation of soil structure. The water content at saturation was taken as the total porosity of the soil layers. To determine the relative distribution of macro and micro-sized pores, undisturbed soil cores were subjected to 100 cm matric potential (corresponding to 60 and 30 μm equivalent pore size, respectively) in a hanging water column set-up (Berliner *et al*., 1980). Water drained from the cores at this potential was taken as volume of macro-pores (diameter, d > 60 μm), meso-pores (30 μm < d <60 μm), and micro-pores (d < 30 μm), and expressed as% of total pores (Lozano *et al*., 2013). The sorptivity measurement was taken in wheat 2017-18, following Smith *et al*. (1999), later modified by Shaver *et al*. (2013). A ring of 10 cm diameter was partially inserted into the soil and 78.5 ml of water (~1 cm standing water) was added. The time taken to absorb the water was precisely noted using a stop watch. Neighbouring soil samples were collected to determine the initial moisture content, and for correction of measured value, due to highly dependency of sorptivity on the soil moisture content. Sorptivity was then calculated following Smith (1999).

## Results and Discussion

### *Soil physical parameters*

The average bulk density (BD) of soil clearly indicated changes across depth with the adoption of CA. The BD value ranged from 1.60 to 1.79 g cm$^{-3}$ in CA and from 1.73 to 1.83 in CT. There was a reduction in BD values under CA, more so in the 0-15 cm layer and even at 15-30 cm layer where an apparent compact zone was identified. Frequent tillage operation in CT developed a higher BD at sub-surface over period of time. On the contrary, Moraes *et al*. (2016) reported that the CT treatment led to lower BD and macro porosity due to loosening of soil through tillage operations (Tormena *et al*., 2017). In present study, soil BD was significantly affected by

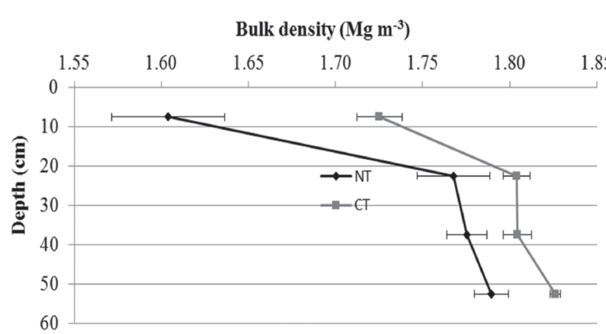


**Fig. 1.** Bulk density under the NT and CT tillage practices

tillage or cropping sequences. Results are in agreement with the findings that CA had significant effects on reducing BD (Kahlon *et al*., 2013; Kuotsu *et al*., 2014).

***Soil aggregates stability and MWD***

Effect of CA on soil aggregate stability was clearly visible (Fig. 2). There was significance difference in macro-aggregates stability between the both CA and CT treatment at different soil layers. Proportions of macro aggregates were larger in CA, and were 75%, 68%, 66% and 51% higher in 0-15, 15-30, 30-45 and 45-60 cm layers as compared to CT (Fi.2a). The greater aggregation through CA mostly in the upper surface have been extensively reported (Blanco-Canqui and Lal, 2009b; Fuentes *et al.,* 2012; Kahlon *et al.,* 2013; Mondal *et al*., 2019). The reverse trends were observed in case of micro-aggregates which shown treatment difference in 0-15 and 15-30 cm soil layers with CT values of 71%, 41%, rest of the layers shown non-significance (Fig. 2b.). Greater proportion of macro-aggregates led to larger mean weight diameter (MWD) in CA (0.55., 0.44, 0.39 and 0.30 mm at 0-60 cm) compared to CT (0.22, 0.19, 0.19 and 0.18 mm at 0-60 cm) (Fig. 2c). Higher proportion of macro-aggregates (a larger MWD) provides good drainage and ensures aeration to roots (Kihara *et al.,* 2011), which is beneficial to roots (Ben-Noah and Friedman, 2018; Chamindu Deepagoda *et al.,* 2012). Increase in MWD implies improvement in soil structural stability, which is critical for infiltration, root growth and resistance to erosion. It is highly sensitive to tillage (Mondal *et al*., 2019), and CA brings a condition conductive for the development of water-stable aggregates (WSA). The impact is highly visible at the 0-15 cm layer.

***Sorptivity and pore size distribution***

The sorptivity (S) and relative pore size distribution were modified by CA. Relatively, higher sorptivity was recorded in CT plots (0.080 cm $s^{-1/2}$) compared to the CA (0.0739 cm $s^{-1/2}$), which are taken during active-tillering stage (CA) and grain-filling period (CT) under maize-wheat

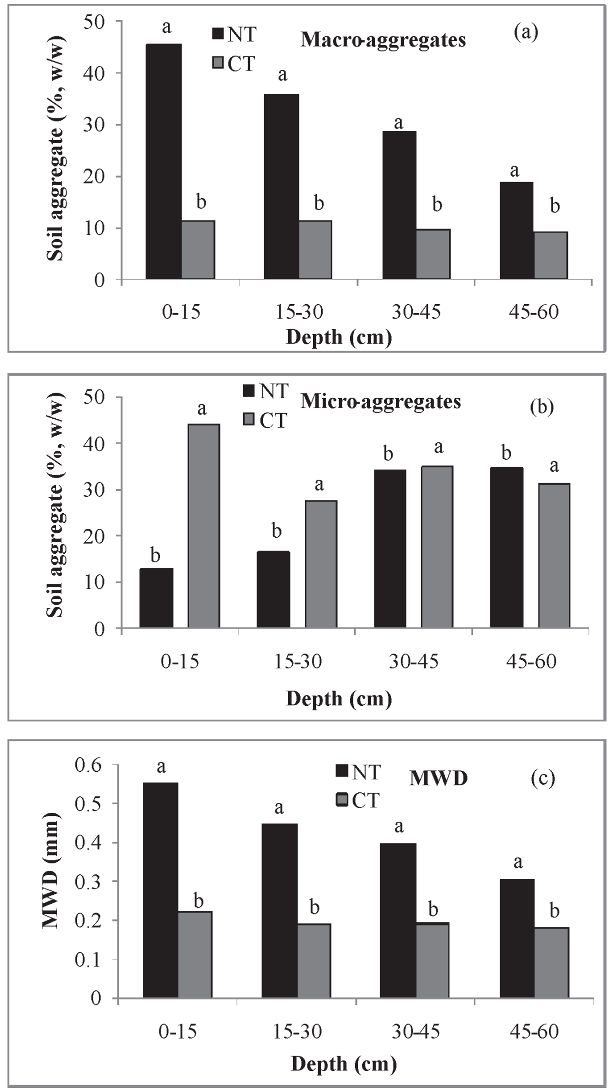


**Fig. 2.** (a) Macro-aggregates (b) micro-aggregates and (c) Mean weight diameter (MWD) under NT and CT

cropping system. The sorptivity value was lower under long-term CA possibly due to soil developed repellency due to residue retention on the surface and SOC decomposition which affected soil infiltration.

Total porosity (TP) and relative abundance of macro-, meso- and micro-pores have been affected tillage and residue management (Table 1). In rest of layers, CA and CT effect was similar. Mesopore volume did not show variations. In case of microspores, CT resulted in a higher volume in 0-15 cm layer, which microspore volume was greater in CA in the 15-30 cm layer. Higher

**Table 1.** Soil pore size distribution (TPTP: total porosity, $\theta_{mac}$: macro-porosity (diameter > 60μm), $\theta_{meso}$: meso-porosity (30 μm < diameter < 60 μm), and $\theta_{mic}$: micro-porosity (diameter < 30 μm)) under NT and CT for different soil layers (cm) LSD values at 5% level.

| Depth (cm) | Treatment | Total Porosity (%) | $\theta_{mac}$(%) | $\theta_{meso}$(%) | $\theta_{mic}$(%) |
|---|---|---|---|---|---|
| 0 - 15 | NT | 38.1a | 3.5a | 1.a | 32.2b |
| | CT | 40.3a | 3.1a | 1.3a | 35.4a |
| 15 - 30 | NT | 44.2a | 4.4a | 1.3a | 37.8a |
| | CT | 42.0b | 5. 6a | 1.6a | 33. 9b |
| 30 - 45 | NT | 42.6a | 3.2a | 0.7a | 38.5a |
| | CT | 41.7a | 5.3b | 1.5a | 34.1b |
| 45 - 60 | NT | 42.1a | 5.1a | 1.9a | 34.3a |
| | CT | 37.0a | 5.8a | 2.6a | 27.6b |

microspore volume indicates greater water retention in favour of CA (reference).The TP was 5% higher in CA in 15-30 cm layer compared to CT.

## Conclusions

From the above study it can be concluded that the effects of long-term (12 years) no-till tillage practice had clear impact on soil bulk density and aggregation in surface and sub-surface layers and the organic C content of near surface soil. The CA favourably changed the pore size distribution with higher total micro-pore volumes at the sub-surface layers. Increase in MWD and micro-pores volume revealed a scope of better water retention. Overall, CA promotes better soil physical condition, which helped in sustaining on increased system productivity in maize- wheat rotation.

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