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Effect of conservation tillage and organics and inorganics on soil fertility in different aggregate size classes

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ABSTRACT

Conservation tillage as widely used soil management system, allows 30% soil surface being covered with crop residues after seeding of the subsequent crop. The experiment was conducted at Indian Institute of Soil Science during 2016-17 to study the effect of conservation tillage and organics and inorganics on soil fertility in different aggregate size classes. The experiment was laid out in randomized block design with four treatments and five replications. Result revealed that the tillage and nutrient management increased organic carbon content in > 2 mm and <0.250 mm aggregate size classes. Reduced tillage with application of NPK + FYM-C (2.0 t ha^{-1}) increased the amount of available N in all aggregate fractions including the whole soil. Soil available N was greater in <0.250 mm (micro aggregate) fraction than in other fractions.

KEYWORDS: Conservation tillage, soil organic C, available N, aggregate classes

INTRODUCTION

Conservation tillage as part of the solution to mitigate climate change effects and to ensure sustainable agriculture was initially promoted to reduce soil erosion and improve soil organic matter content. Conservation tillage (CT) is defined as a tillage system in which at least thirty percent of crop residues are left in the field and is an important conservation practice to reduce soil erosion. Conservation agriculture has been adopted worldwide with numerous benefits to soil functioning and processes. Because of these beneficial effects there is wide spread adoption of conservation agriculture, including retaining or incorporating residues to agricultural systems, amounting to 124.8 million hectares globally. Significant benefits of conservation tillage reported by many researchers are increase in soil aggregation and soil organic carbon in 0-15 cm soil layer. Several models of SOC turnover in soil include pools of physically protected SOC presented a conceptual model of soil structure that describes the binding of primary mineral particles into microaggregates (50-250 µm in dia.) and of microaggregates into macroaggregates (>250 µm in dia.). The more persistent agents (e.g., clay-polyvalent metal-humified organic matter complexes) that bind microaggregates are generally characterized as older, more humified, or recalcitrant SOM. The more temporary (e.g., roots and fungal hyphae) and transient (e.g., polysaccharides) agents that bind microaggregates into macroaggregates are generally considered to be relatively more labile or decomposable. The total amount of carbon in the world's soil is estimated to be 1500 PgC and is approximately twice the atmospheric carbon pool. The most prevalent form of carbon in the soil is organic C. Therefore, Soil organic carbon is a substantial component of global carbon pools. Several studies have envisaged the multifold benefits of CT, including soil C sequestration and the favorable effect on soil health through improving soil physical, chemical and biological quality, reducing soil erosion, sustaining agricultural productivity and allowing the soil to perform the ecosystem services. Therefore, the present investigation was undertaken, to find out theeffect of conservation tillage and nutrient management on soil organic C and soil available N in different aggregate size classes.

MATERIALS AND METHODS

The present investigation was carried out during kharif and rabi season of 2016-17 at Indian Institute of Soil Science, Bhopal, Madhya Pradesh. The soil for the present study was taken from the long-term experiment under conservation tillage in soybean-wheat system. The study area falls under semi-arid and sub-tropical zone characterized by hot summer and cold winter. Mean annual precipitation is about 650 mm, most of which is received during the

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monsoon period from July to September. The average maximum temperature during summer was 35^{0}C, while the average minimum temperature during winter was 21^{0}C. 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^{-1} 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^{-1} soil organic carbon, electrical conductivity of 0.3 dS m^{-1} and Ca^{2+} as the dominant exchangeable cation in the Ap horizon.

Treatment were as: RT-T1 - Reduced tillage (one pass rotavator + sowing by seed cum fertilizer drill) + RDF (recommended dose of fertilizer in soybean and wheat), RT-T4 - Reduced tillage (one pass rotavator + sowing by seed cum fertilizer drill) + RDF in soybean and wheat + 6 t FYM ha^{-1}every year in soybean,NT-T1- No tillage (Direct sowing by no till drill) + RDF and NT-T4 -No tillage (Direct sowing by no till drill) + RDF + 6 t FYM ha^{-1}every year in soybeanThe 4 mm dry soil was sieved through nest of 2 mm and 0.250 mm sieve to obtain aggregate size class > 2 mm (large macroaggregate), 2-0.250 mm (small macroaggregate) and < 0.250 mm (microaggregate and silt+clay size). The samples were then thoroughly mixed by spatula and air-dried for analysis of physico-chemical properties. Soil organic carbon was estimated by wet digestion (Walkley and Black, 1934) method and available nitrogen was estimated by alkaline potassium permanganate (Subbaiah and Asija, 1956) method. Collected data were analyzed using analysis of variance (ANOVA) two factor analysis (CRBD) with statistical software SPSS 11.5. For a significant F-value, the means were separated with least significant difference (LSD) with $p < 0.05$.

RESULTS AND DISCUSSION

Soil organic carbon

The amount of SOC ranged from 8.5 to 9.1 g kg^{-1} across different land management and aggregate size class. SOC was significantly influenced by land management (tillage and nutrient) and interaction of land management and aggregate size classes (Table 1). However, the difference among aggregate size class was not significant on SOC content at 0-15 cm soil depth. Among the land management treatments SOC content was significantly highest in NT-T4 and greater than 2 mm aggregate size class 9.8g kg^{-1} and lowest in NT-T1 and whole soil7.1g kg^{-1}. Among land management the SOC content followed the order NT-T4 > RT-T4 > RT-T1 > NT-T1 across aggregate size classes. Further, in aggregate size classes the SOC content order was (<0.250 mm) > (>2 mm) > whole = 2-0.250 mm. Among treatments, soil organic C concentration was typically lower under NT-T1 than under other treatments in all size classes.

Table 1: Effect of tillage and nutrient management on SOC (g kg^{-1}) in different aggregate size classes at 0-15 cm soil depth

Land management	Aggregate size class				Mean
	whole	>2 mm	2-0.250 mm	<0.250 mm	
RT-T1	8.7	7.9	8.3	8.6	8.4
RT-T4	9.0	9.2	8.9	9.0	9.0
NT-T1	7.1	8.0	7.8	9.0	8.0
NT-T4	9.1	9.8	8.8	8.6	9.1
Mean	8.5	8.7	8.5	8.8	
LSD (p=0.05)	Land management 0.34		Aggregate size class NS		Interaction 0.68

Note: RT-T1: Reduced tillage + RDF in soybean and wheat; RT-T4: Reduced tillage + RDF + 2 t FYM-C/ha every year in soybean; NT-T1: No tillage + RDF in soybean and wheat; NT-T4: No tillage + RDF in soybean and wheat + 2 t FYM-C/ha every year in soybean.

Soil organic carbon concentration was relatively uniform across aggregate size classes, although values tended to be greater in the <0.250 mm and >2.00mm class. No tillage and reduced tillage with application of FYM have no significant difference on SOC content at 0-15 cm soil depth (Fig.1). Though tillage increases the disruption and turnover of soil aggregates which may increase exposure of protected SOM within aggregates to oxidation. However, the effect of both the treatment (NT-T4 and RT-T4) on SOC content was the same. Probably due to stratification effect of tillage on SOC distribution in the soil profile and increase in upper few cm of

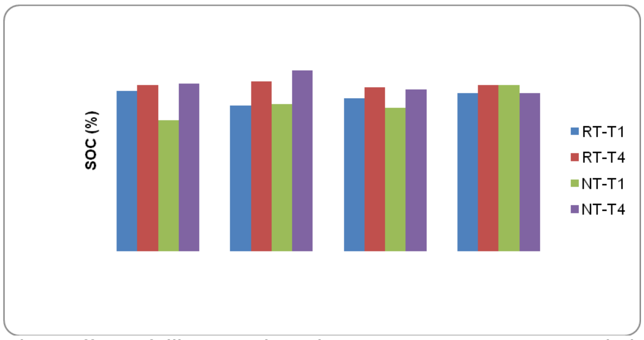

Fig.1 Effect of tillage and nutrient management on SOC (%) in different aggregate size classes at 0-15 cm soil depth

soil surface is compensated by decrease or no change of SOC in the deeper soil layer. Tillage strongly influences SOC distribution and storage by physically mixing soil and by distributing crop residues in the soil. Conservation tillage (CT) generally increases the SOC concentration in surface few centimeters when compared to conventionally tilled soils (Lenka *et al.*, 2014). The use of CT does not always result in an increased SOC storage when compared for the entire soil profile. Additionally, an increased C content in the top soil in CT can be compensated by a decrease of C in the deeper soil layers. Increases in aggregation concomitant with increases in organic carbon have been observed in NT and RT systems (Six *et al.*, 2000; Lenka *et al.*, 2015). The influence of tillage on SOC seems to depend on the depth to which the tillage/ploughing operation incorporates plant material. Below the plough depth, SOC would be dependent on the long-term vegetation and cropping history of a field. If amount of residue retention is same across tillage, then in NT, the crop residue is on the surface. On the other hand, reduced and conventional tillage provides scope for incorporation of the same amount of residue, which adds to SOC of deeper soil layer.

Reduced tillage with inorganic fertilizer alone has been found to induce a loss of macroaggregates and a gain of microaggregates (Six *et al.*, 2000). Integrated use of chemical fertilizer with organic manure and compost resulted in higher SOC content compared to inorganic fertilizers application in both the tillage treatments. Our results are in conformity with works of Gregorich *et al.*, (2001). Several studies have reported that FYM plus inorganic N applications in irrigated systems resulted in reduced bulk density, higher SOC and hydraulic conductivity and improved soil structure and microbial communities (Bhattacharyya *et al.*, 2007; Lenka *et al.*, 2014).

Soil available nitrogen

Soil N content ranged from 168.3 to 224.2 kg ha^{-1} across land management and aggregate size classes. Soil available N content was highest in RT-T4 and aggregate fraction (<0.250 mm) and lowest in NT-T4 and whole soil. Farmyard manure application along with inorganic increased the available N by 8-9% in comparison to inorganic fertilizer alone. Among the aggregate size classes soil N followed the order <0.250 mm > 2-0.250 mm = >2 mm > whole. Available soil N was greater by 22-23 % in reduced tillage (RT) than no tillage (Table2).

Table 2: Effect of tillage and nutrient management on soil available N (kg ha^{-1}) in different aggregate size classes at 0-15 cm soil depth

Land management	Aggregate size class				
	whole	>2 mm	2-0.250 mm	<0.250 mm	Mean
RT-T1	177.7	211.1	209.0	232.0	207.5
RT-T4	215.3	229.9	217.4	234.1	224.2
NT-T1	146.3	175.6	177.7	173.5	168.3
NT-T4	183.9	175.6	188.1	186.0	183.4
Mean	180.8	198.0	198.0	206.4	
LSD (p=0.05)	Land management 3.08		Aggregate size class 3.08		Interaction 6.16

Reduced tillage with application of NPK+FYM (RT-T4) increased the soil available N compared to NT-T1 (Figure 2). Tillage changes the local soil microclimate, which may also lead to increased decomposition of crop residues. Further, results suggest that ploughing disrupts the aggregate structure and increases the decomposition of incorporated crop residues and mineralization of SOM that was protected within the structure of the soil.Although no tillage tillage and conservation tillage is promoted as a soil-fertility enhancing technology, application of crop residues poor in N, such as wheat stover, may result in prolonged immobilization of mineral N (Giller *et al.*, 1997). In no tillage (NT) system reduced N availability observed in the present

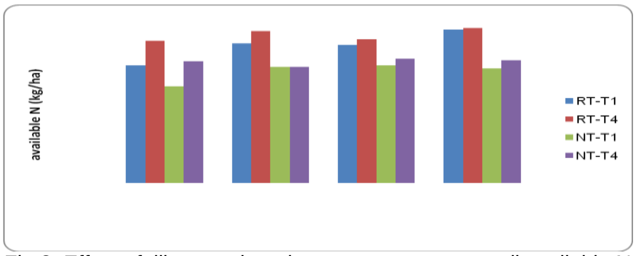

Fig.2. Effect of tillage and nutrient management on soil available N (kg/ha) in different aggregate size classes at 0-15 cm soil depth

investigation has been attributed to slow residue decomposition and N losses from leaching and denitrification (Angás *et al.*, 2006). However, in NT application of NPK+FYM significantly increased availability of N compared to NPK treatment this may be attributed to reduced N leakage and increase nutrient use efficiency in no tillage. Across land management soil available N was greater in <0.250 mm (micro aggregate) fraction than in other fractions, suggests that a major proportion of active N pools is preferentially stored in microaggregates and silt and clay fractions where most of the C mineralization occurs (Sainju, 2006). Also the C in microaggregates is stable and resistant to decomposition than macroaggregates due to their increased physical protection in macroaggregates.

It may be concluded from the study that soil organic C content was relatively uniform across aggregate size classes, although values tended to be greater in the <0.250 mm and >2.00mm class. No tillage and reduced tillage with application of FYM have no significant difference on SOC concentration at 0-15 cm soil depth. Integrated use of chemical fertilizer with organic manure resulted in higher SOC content compared to inorganic fertilizers applications in both the tillage treatments. Significant differences in soil available N in aggregates between land management and their interaction occurred in all samples. Reduced tillage with application of NPK+FYM (RT-T4) increased the soil available N compared to NT-T1. No tillage treatment with application of NPK+FYM significantly increased availability of N compared to NPK treatment. Across land management soil available N was greater in <0.250 mm (micro aggregate) fraction than in other fractions, suggests that a major proportion of active N pools is preferentially stored in microaggregates and silt and clay fractions where most of the C mineralization occurs.

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