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Impact of different Tillage practices on Soil Organic Carbon and Nitrogen Pool in Rice-Wheat Cropping System

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ABSTRACT

Conventional agriculture can result in loss of organic matter (OM), resulting in degradation of cultivated soil. A study was conducted to assess the impact of different tillage treatments in rice and wheat cropping system on soil organic carbon and nitrogen pool. The experiment was carried out in split plot design with four main plot treatments viz. P_1 (direct dry seeding by zero till drill), P_2 (direct seeding of sprouted rice in puddle condition), P_3 (hand transplanting) and P_4 (transplanting by self-propelled rice trans planter) while the sub plot treatment (for wheat) included T_1 (conventional sowing), T_2 (bed planting), T_3 (strip till drilling) and T_4 (zero till drilling). Significant variations in SOC and soil nitrogen pool were observed in wheat tillage treatments for D_1 (0-10cm) soil depth. The T_4 and T_3 treatments had significantly higher values of SOC pool as compared to T_1. Similar trend was also observed for soil nitrogen. Rice tillage treatments did not have any significant impact on SOC and soil nitrogen at D_1 or subsequent depths. The summarized depths 0-30 and 0-60 cm did not show any impact of the tillage treatments on SOC or soil nitrogen pools.In rice tillage treatments, SOC pool ranged from 26.06 Mg/m^3 (P_4) to 27.61 Mg/m^3 (P_1) while the range for wheat tillage treatment was 26.30 Mg/m^3 (T_4) to 26.75 Mg/m^3 (T_1). At D_1 depth soil N pool was found to be statistically higher for T_3 and T_4 tillage treatments in wheat, whereas T_2 tillage treatment was found to be statistically at par with T_1. This is because of the presence of higher amount of SOM in T_3 and T_4. A high and positive correlation between SOC and total N was observed because most of the nitrogen present in soil is in organic form.

Keywords: Carbon sequestration, climate change, SOC, water soluble aggregate, zero tillage.

INTRODUCTION

Rice (*Oryza sativa* L.) and wheat (*Triticum aestivum* L.) are the two most important energy giving food globally (Singh *et al.*, 2012a and Meena *at al.*, 2013). Rice and wheat grown sequentially in an annual rotation (Singh and Singh, 2007) constitute a rice-wheat cropping system (RWCS) and in a system occupy nearly 13.5 million hectares area in the Indo-Gangetic plains (IGP) of South Asia. Tillage has a long history dating back millennia, and aimed to give soil aeration and to control weeds. Tillage operations also stimulate N release from SOM. The increase in aeration of the soil and the intense disturbances are the main factors stimulating the mineralization of organic matter by soil micro-organisms. Tillage plays a main role in the "de-protection" of organic matter present in macro (and to some extent micro) aggregates (Balesdent *et al.*, 2000). Tillage can promote soil carbon loss by several mechanisms. It disrupts soil aggregates, which protect SOM from decomposition. It may stimulate microbial activity through enhanced aeration and it mixes fresh residues into the soil where conditions for decomposition are often more favourable than on the surface. Furthermore tillage can leave soils more prone to erosion resulting in further losses of carbon.

Numerous strategies for increasing carbon in cultivated soils have been identified (Singh *et al.*, 2012b. These can be broadly classified into four main approaches (i) reduction in tillage intensity (ii) intensification of cropping systems (iii) adoption of yield promoting practices, including improved nutrient amendment (iv) re-establishment of permanent perennial vegetation. Reducing tillage of agricultural soils may improve agricultural sustainability by reducing fossil fuel consumption, labour needs, equipment maintenance and soil erosion and increase soil water conservation and soil C sequestration (Unger *et al.*, 1997; Lal, 2001). In conservation tillage (CT) systems where shoots primarily remain on soil surface and roots are left intact, roots and hyphae are directly incorporated within aggregates as protected organic matter (Jastrow and Miller, 1998). In conservation agriculture crop residues should cover more than 30 per cent of the soil surface (Lal, 1997). Under conservation agriculture 0.5-1.0 t C/ha/yr can be sequestered in humid temperate conditions, while 0.2-0.5 t C/ha/yr in humid tropics and 0.10.2 t C/ha/yr in semi-arid zones (Lal, 1999). But zero tillage with cover crops and/or green manures in a complex rotation pattern leads to large amount of carbon sequestered. The favorable effects of conservation tillage are very high during the initial years and then reach a plateau. They can also be rapidly reversed if conventional tillage is reintroduced. Adopting less energy intensive methods such as zero tillage can reduce the total emissions budget. For each tonne of cereal or vegetable from industrialized high input systems, 3,000-10,000 MJ of energy are consumed in its produce. But for each tome of cereal or vegetable from sustainable farming only 500-1000 MJ are

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consumed (Pretty and Ball, 2001). Zero till systems also have an additional benefit of requiring less fossil fuel for maintaining passes.

Rice-wheat cropping systems occupies first place in area (around 11 mha), and production (more than 150 million tones) in India (India, 2002). Nearly 25 per cent of the total rice area of the country is grown in rotation with wheat (Sen and Sharma, 2002) and it is the back bone of country's food security with a yield potential of 8.12 t/ha/yr (Singh *et al.*, 1996; Bhandari *et al.*, 1992). Noting the above fact and considering the potential for agricultural soils to sequester carbon a study was conducted at Pantnagar, university farm to assess the impact of different tillage treatments in Rice-Wheat cropping system on soil organic carbon (SOC) and nitrogen pool.

MATERIALS AND METHODS

Field experiment was conducted to access the impact of different tillage practices in rice-wheat cropping system on soil organic carbon (SOC) and nitrogen pool. The experimental design was split plot. The tillage treatment for the main plot (in rice) were P_1 (direct dry seeding by zero till drill), P_2 (direct seeding of sprouted rice in puddle condition), P_3 (hand transplanting) and P_4 (transplanting by self-propelled rice trans planter) while the tillage treatments in the sub plot (for wheat) included T_1 (conventional sowing), T_2 (bed planting), T_3 (strip till drilling) and T_4 (zero till drilling). The rice and wheat variety used were Narendra 359 and PBW 343. The soil samples for analysis were collected after rice and wheat harvest at 0-10 cm, 10-30 cm and 30-60cm depth and analysis was performed as per standard procedure. Soil organic carbon was determined by rapid titration. Total soil nitrogen was determined using Kjeldahl procedure as explained by Bremner, 1965. The soil organic carbon (SOC) and nitrogen (N) pools were determined by method as described by Jarecki and Lal, 2005. It was calculated by multiplying soil mass by SOC or N concentration.

RESULTS AND DISCUSSION

Soil organic carbon pool was calculated after three years of operation of the experiment. The results obtained are presented in the Table 1 & 2. The SOC pool was found to be significantly affected only for the surface soil (10 cm depth) and that too in the wheat tillage treatments. At D_2 (10-30 cm) and D_3 (30-60 cm) no significant changes were observed in SOC pool in either the tillage treatments. At D_1 (0-10 cm) depth highest value for SOC pool was obtained for P_1 tillage treatment (13.63 Mg/ha) whereas the lowest was for P_4 tillage treatment (10.70 Mg/ha) in case of rice tillage treatments. The P_1 tillage treatment had 18.7 per cent larger higher SOC pool as compared to P_3 (conventional transplanting of rice).

Table 1 **:** Impact of different tillage treatments on SOC pool (Mg/ha)

Treatments	Depths								
	0-10 cm			10-30 cm			30-60 cm		
P_1	13.63			22.05			27.61		
P_2	11.52			21.51			26.35		
P3	11.48			21.66			25.51		
P4	10.70			21.44			26.06		
T1	9.95			21.13			26.75		
T2	11.34			21.50			26.85		
T3	12.65			22.20			25.63		
T4	13.39			21.80			26.30		
Effects	P	T	P×T	P	T	P×T	P	T	P×T
CD 5%	NS	1.74	NS	NS	NS	NS	NS	NS	NS
SEm±	–	0.845	–	–	–	–	–	–	–

In case of wheat tillage treatments, SOC pool varied form 9.95 Mg/ha for T_1 to 13.39 Mg/ha for T_4 at D_1 (0-10 cm) depth. The T_3 (i.e. strip till drilling) and T_4 (zero till drilling) had significantly higher values of SOC pool as compared to T_1 tillage treatment which is conventional sowing. This higher value may be attributed to the formation of macro aggregates around particles of undecomposed SOM, providing protection from decomposition (Gupta and Germida, 1988; Gregorich *et al.*, 1989; Six *et al.*, 2002).

In case of rice tillage treatments at D_2 (10-30 cm) soil depth maximum value for SOC pool was found for P_1 (22.05 Mg/m^3) and the minimum for P_4 (21.44 Mg/m^3). No significant difference was observed among different tillage treatments. In case of wheat tillage treatments SOC pool for D_2 depth followed the order T_3> T_4> T_2> T_1 and all the treatments were found to be statistically at par. At D_3 depth also no significant difference in SOC pool was observed. In rice tillage treatments, SOC pool ranged from 26.06 Mg/m^3 (P_4) to 27.61 Mg/m^3 (P_1) while the range for wheat tillage treatment was 26.30 Mg/m^3 (T_4) to 26.75 Mg/m^3 (T_1) (Table 1).

Table 2 : Impact of different tillage treatments on SOC pool (Mg/ha) at Summarized depth

Treatments	Summarized depth								
	0-10 cm			0-30 cm			0-60 cm		
P_1	13.63			35.68			63.29		
P_2	11.52			33.03			59.39		
P3	11.48			33.14			58.64		
P4	10.70			32.14			58.20		
T1	9.95			31.09			57.83		
T2	11.34			32.84			59.69		
T3	12.65			34.85			60.49		
T4	13.39			35.21			61.51		
Effects	P	T	P×T	P	T	P×T	P	T	P×T
CD 5%	NS	1.74	NS	NS	NS	NS	NS	NS	NS
SEm±	–	0.845	–	–	–	–	–	–	–

Even when the depth were summarized into three groups 0-10 cm, 0-30 cm and 0-60 cm, no significant changes in SOC pool was observed either for rice tillage treatments or for wheat (Table 2).

This indicates that zero tillage affected SOC pools only for 0-10 cm, while at lower depths no changes were observed. Similar observations were also made by Zibilske and Bradford 2007 who observed that under semi-arid conditions conservation tillage effects on soil C and N were greater in 0-5 cm depth.

Table 3 : Effect of different tillage treatments on soil nitrogen pool (Mg/ha)

Treatments	Depths								
	0-10 cm			10-30 cm			30-60 cm		
P1	1.21			2.30			3.46		
P2	1.02			2.24			3.49		
P3	0.96			2.21			3.49		
P4	0.93			2.21			3.64		
T1	0.87			2.17			3.54		
T2	1.01			2.21			3.65		
T3	1.07			2.21			3.49		
T4	1.18			2.27			3.40		
Effects	P	T	P×T	P	T	P×T	P	T	P×T
CD 5%	NS	0.139	NS	NS	NS	NS	NS	NS	NS
SEm±	–	0.068	–	–	–	–	–	–	–

In case of rice tillage treatments no significant change in soil N pool was observed at D_1, however the direct dry seeded rice plot (P_1) recorded the highest value (1.21 Mg/ha) which was 26.0 per cent higher than the manual transplanting (P_3) of rice. Both at D_2 and D_3 depths no significant changes were observed with regard to soil N pool. For rice tillage treatments at D_2 depth the soil N pool followed the order P_1 (2.30) > P_2 (2.24) > P_3 (2.21) = P_4 (2.21), while in wheat tillage treatments the order was T_4 (2.27) > T_2 = T_3 (2.21) > T_1 (2.17). At D_3 depth following sequence was observed P_4 (3.64) > P_3 (3.49) = P_2 (3.49) > P_1 (3.46) for rice and T_2 (3.65) > T_1 (3.54) > T_3 (3.49) > T_1 (3.40) for wheat tillage treatments

Table 4**:** Effect of different tillage treatments on soil nitrogen pool (Mg/ha)

Treatments	Depth								
	0-10 cm			0-30 cm			0-60 cm		
P1	1.21			3.52			6.98		
P2	1.02			3.26			6.75		
P3	0.96			3.17			6.66		
P4	0.93			3.14			6.79		
T1	0.87			3.04			6.58		
T2	1.01			3.23			6.88		
T3	1.07			3.37			6.87		
T4	1.18			3.45			6.86		
Effects	P	T	P×T	P	T	P×T	P	T	P×T
CD 5%	NS	0.139	NS	NS	NS	NS	NS	NS	NS
SEm±	–	0.068	–	–	–	–	–	–	–

Even when the depth was considered into three categories from surface viz. 0-10 cm, 0-30 cm and 0-60 cm, no significant changes in soil N pool were observed except for 0-10 cm which has already been mentioned. A comparison between conventional sowing for rice and wheat with NT sowing indicates that at 0-30 cm direct seeded rice plots (P_1) had 11.04 per cent higher soil N as compared to manual transplanting (P_3) while the same was reduced to 4.8 per cent in case of (0-60 cm) category. In case of wheat direct seeded wheat plots (T_4) had 13.48 per cent and 4.25 per cent higher soil N as compared to conventionally sown wheat (T_1) plots for 0-30 cm and 0-60 cm depths respectively.

CONCLUSION

We can conclude from our research that reduced tillage helps in improvement of soil organic carbon (SOC) and soil nitrogen pool in the upper 10 cm depth of soil.

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