

Original Research Article

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Soil Carbon Fractions as Influenced by Long-Term Integrated Nutrient Management under Rice-Wheat Cropping System in Calcareous Soil of North Bihar

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ABSTRACT

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A study was conducted in an ongoing field experiment started during *Rabi* 1988-89 in calcareous soil at Research Farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. The experimental design was split-plot with four fertilizer levels (0, 50, 100 & 150% NPK) in main plots and four levels of manures (no manures, compost @10 t ha⁻¹, crop residues and compost @10 t ha⁻¹ plus crop residues) in sub-plots. The present investigation was undertaken with objectives to investigate the effect of combined use of NPK and different organics (compost and crop residues) on oxidisable carbon fractions of soil. Application of fertilizers along with compost and crop residues resulted in significant buildup of soil organic carbon fractions. Very labile soil organic carbon was the maximum (3.75 g kg⁻¹) in the treatment receiving both compost (10 t ha⁻¹) and crop residues and it was 34.30% higher than that in the treatment receiving no manure application. The maximum non-labile soil organic carbon (6.06 g kg⁻¹) was found to be in the treatment receiving both compost and crop residue and was 2.9, 3.41 and 36.48% higher than that in the treatments crop residue, Compost @ 10 t ha⁻¹ and no manure application, respectively. The improvement in non-labile carbon fraction was more than labile carbon fractions suggesting higher carbon sequestration in the soil.

Introduction

Soil organic matter (SOM) plays a key role in the improvement of soil physical, chemical and biological properties. Cultivation has caused reductions in C content of agricultural soils, contributing to increases in atmospheric CO₂ concentration. Organic carbon is a key attribute of soil fertility, as it serves as soil conditioner, nutrients source and substrate for microbial activity, preserver of the

environment and sustainer of agricultural productivity (Benbi *et al.*, 2011). Application of manures and fertilizers at an optimum rate increases the crop production which, in turn, results in greater residue- input balanced application of inorganic fertilizers or organic manure plus inorganic fertilizers can increase.

Soil organic carbon (SOC) and maintain soil productivity. Balanced application of inorganic fertilizers or organic manure plus

inorganic fertilizers can increase SOC and maintain soil productivity (Blair *et al.*, 2006).

The soil organic matter (SOM) on an average contains 30% labile and 70% stable components; however, the values are not rigid and may vary from soil to soil and are influenced by management history (Schnitzer, 1991). The SOC stock is comprised of labile or actively cycling pool and stable, resistant/recalcitrant pools with varying residence time. Labile C pool is the fraction of SOC with rapid turnover rates. The labile carbon pool of TOC have rapid turn-over rate and it is the main sources of nutrients which affect the quality and productivity of soils (Chan *et al.*, 2001, Majumdar *et al.*, 2008). Soil quality is an integrated characteristic determined by biological, chemical and physical soil properties defining a soil's capacity to function.

Soil organic carbon (SOC) is the most frequently reported soil attribute from long-term agricultural studies and is commonly selected as the key indicator of soil quality and agronomic sustainability because of its impact on other physical, chemical and biological elements of soil quality (Reeves, 1997). Long-term fertility experiments (LTFE) play an important role in understanding the complex interaction of plant, soil, climate and management practices and are the primary source of information to determine the effects of cropping systems, soil management, fertilizer use, and residue utilization on the quantitative and mechanistic changes on soil quality as well as on SOC pools.

Materials and Methods

A study was conducted in an ongoing field experiment under AICRP on Soil Test Crop Response Correlation, initiated in *Rabi*, 1988-89 in light textured highly calcareous soil at

Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India, having 25° 94' N latitude, 85° 67' E longitude and an altitude of 52.00 meter above mean sea level. The climate is sub-tropical having average annual rainfall 1135 mm.

The experimental design was split-plot with four fertilizer levels (0, 50, 100 & 150% NPK) in main plots and four levels of manures (no manures, compost @10 t ha⁻¹, crop residues and compost @10 t ha⁻¹ plus crop residues) in sub-plots. The soil of experimental area having texture sandy loam, pH 8.5, organic carbon 5.02 g/kg and CaCO₃ content 36.6 %.

Rice and wheat crops are being grown continuously under rice-wheat system during *Kharif* and *Rabi* seasons respectively. The chopped straw of previous crops treated as crop residues. The source of N, P and K was urea, SSP, muriate of potash (MOP) and period of the investigation was the year 2017-18. Different fractions of carbon was determined by following methods.-

Organic carbon

It was determined by rapid titration method as described by Walkley and Black (1934).

Total Organic Carbon (TOC)

0.25 g of processed soil sample is weighed out into a 25 ml volumetric flask, 20 ml of 0.4 N chromic acid solution is added to the soil samples and similar quantity is taken for the blank (without soil). The mixture is heated in H₃PO₄ bath and heated on hot plate at such a rate that a temperature of 155⁰C is reached in 20 to 25 minutes. The temperature is held at 155⁰C to 160⁰C for an additional 5 minutes. The chromic acid solution, cooled to room temperature, is diluted with distilled water to 200 ml, then 1g NaF and 2-4 drops di-phenyl

ammine indicator added. The solution is back titrated with the 0.2 N ferrous ammonium sulfate until the solutions color turns from violet to light green (Jackson, 1973).

$$\text{TOC (\%)} = 10.67 \times (\text{B} - \text{S})/\text{B}$$

Where, B= Blank Titration (ml),
S= Sample titration (ml)

Organic carbon fraction

The content of oxidizable carbon (C_{oc}) and its different fractions in the soil were estimated through the Walkley and Black (1934) method as modified by Chan *et al.*, (2001) using 5, 10, and 20 mL of concentrated (18.0 M) H_2SO_4 and $K_2Cr_2O_7$ solution. This resulted in three acid-aqueous solution ratios of 0.5:1, 1:1, and 2:1 that corresponded to 6.0, 9.0, and 12.0 M H_2SO_4 , respectively, and caused the production of different amounts of heat of reaction to bring about oxidation of SOC of different oxidizability. The amounts of oxidizable carbon thus determined allowed separation of total organic carbon into the following four fractions of decreasing oxidizability as defined by Chan *et al.*, (2001):

Fraction I (C_{frac1} , very labile): Organic C oxidizable under 6.0 M H_2SO_4

Fraction II (C_{frac2} , labile): The difference in C_{oc} oxidizable under 9.0 M and that under 6.0M H_2SO_4

Fraction III (C_{frac3} , less labile): The difference in C_{oc} oxidizable under 12.0 M and that under 9.0 M H_2SO_4 (the 12.0 M H_2SO_4 is equivalent to the standard (Walkley and Black method)

Fraction IV (C_{frac4} , non-labile): Residual organic C after oxidation with 12.0 M H_2SO_4 when compared with total organic carbon.

Results and Discussion

Soil Organic Carbon (SOC)

Soil organic carbon content increased from 5.54 to 6.51 g kg⁻¹ (Table 1) with increasing levels of fertilizers i.e. No NPK to 150% NPK. The SOC value (6.51 g kg⁻¹) was obtained in the treatment received 150% NPK which was 4.2, 9.6 and 17.5% higher than treatments received 100%, 50% and No NPK, respectively. This might be due to treatment receiving 100% and 150% NPK resulted in better crop growth due to balance nutrient fertilization which leads to better growth of root biomass and therefore increase in organic matter in soil. A similar observation was reported by Bhardwaj *et al.*, (2010). Organic carbon content not significantly affected by the treatment receiving 100% and 150% NPK. In manure levels, organic carbon varied from 4.99 to 6.70 g kg⁻¹. The maximum SOC (6.75 g kg⁻¹) was found in the treatment receiving both compost and crop residue which was 8.41, 5.01 and 34.26% higher than treatments receiving compost @ 10 t ha⁻¹, crop residues, crop residues and Compost @ 10 t ha⁻¹ application. This might be due to continuous addition of organic matter through crop residue and compost resulted in increased SOC content.

Total Organic Carbon (TOC) and Contribution of SOC fractions to TOC

The total organic carbon content varied from 10.97 to 12.14 g kg⁻¹ (Table 1) with increasing levels of fertilizer i.e. no NPK to 150% NPK. The total organic carbon content (12.14 g kg⁻¹) was recorded in the treatment receiving 150% NPK which was 10.66% higher than treatment receiving no NPK. Treatments receiving 50%, 100% and 150% NPK not significantly affect the total organic carbon content of soil. TOC due to different manure levels varied from 9.42 to 12.76 g kg⁻¹. The

maximum total organic carbon (12.76 g kg⁻¹) was found in the treatment receiving both compost and crop residue which was 35.45% higher than no manure application.

Table.1 Effect of long-term integrated nutrient management on organic carbon (Walkley & Black) and Total Organic Carbon (TOC)

Fertilizer Level (kg ha ⁻¹)	Organic Carbon (Walkley & Black)	Total Organic Carbon (TOC)	Manure Level	Organic Carbon (Walkley & Black)	Total Organic Carbon (TOC)
NO NPK	5.54	10.97	No Manure	4.99	9.42
50% NPK	5.94	11.48	Compost @ 10 t ha ⁻¹	6.38	12.24
100% NPK	6.25	11.89	Crop Residue	6.18	12.06
150% NPK	6.51	12.14	Compost @ 10 t ha ⁻¹ + Crop Residue	6.70	12.76
SEm±	0.09	0.207	SEm±	0.07	0.084
CD (P=0.05)	0.33	0.73	CD (P=0.05)	0.20	0.25

Table.2 Effect of long-term integrated nutrient management on very labile and labile carbon

Fertilizer Level (kg ha ⁻¹)	Very Labile Carbon	Labile Carbon	Manure Level	Very Labile Carbon	Labile Carbon
NO NPK	3.14	1.81	No Manure	2.74	1.62
50% NPK	3.39	1.86	Compost @ 10 t ha ⁻¹	3.68	1.98
100% NPK	3.56	1.91	Crop Residue	3.56	1.85
150% NPK	3.63	2.04	Compost @ 10 t ha ⁻¹ + Crop Residue	3.75	2.17
SEm±	0.08	0.01	SEm±	0.06	0.01
CD (P=0.05)	0.30	0.06	CD (P=0.05)	0.20	0.04

Table.3 Effect of long-term integrated nutrient management on less labile and non-labile carbon

Fertilizer Level (kg ha ⁻¹)	Less Labile	Non-Labile Carbon	Manure Level	Less Labile	Non-Labile Carbon
NO NPK	0.58	5.43	No Manure	0.62	4.44
50% NPK	0.67	5.55	Compost @ 10 t ha ⁻¹	0.70	5.86
100% NPK	0.77	5.64	Crop Residue	0.75	5.89
150% NPK	0.82	5.62	Compost @ 10 t ha ⁻¹ + Crop Residue	0.77	6.06
SEm±	0.02	0.13	SEm±	0.01	0.06
CD (P=0.05)	0.07	NS	CD (P=0.05)	0.05	0.17

Figure.1 Contribution of oxidisable fractions of carbon to total organic carbon

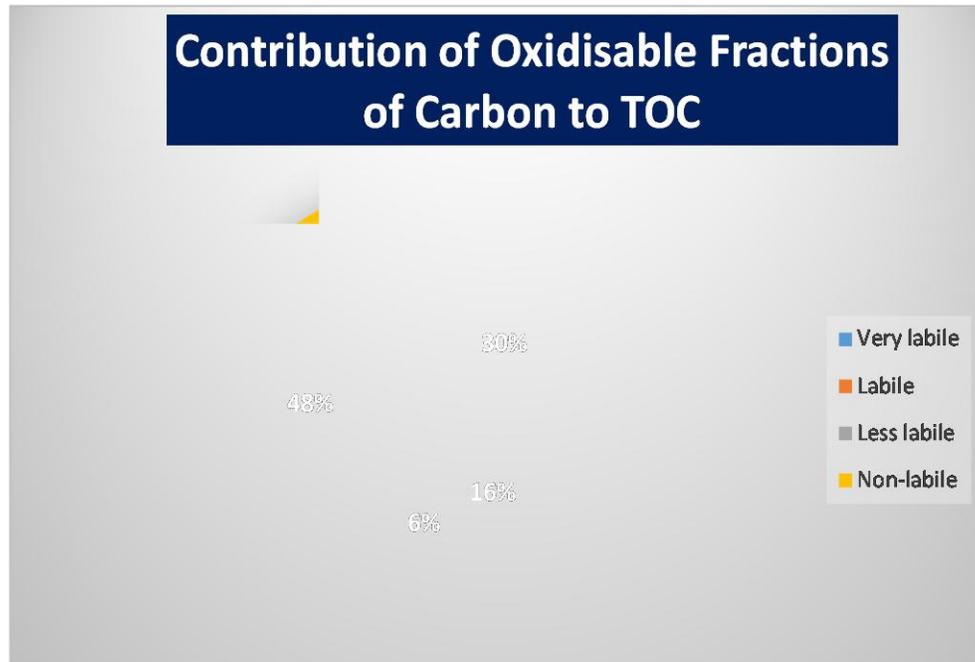
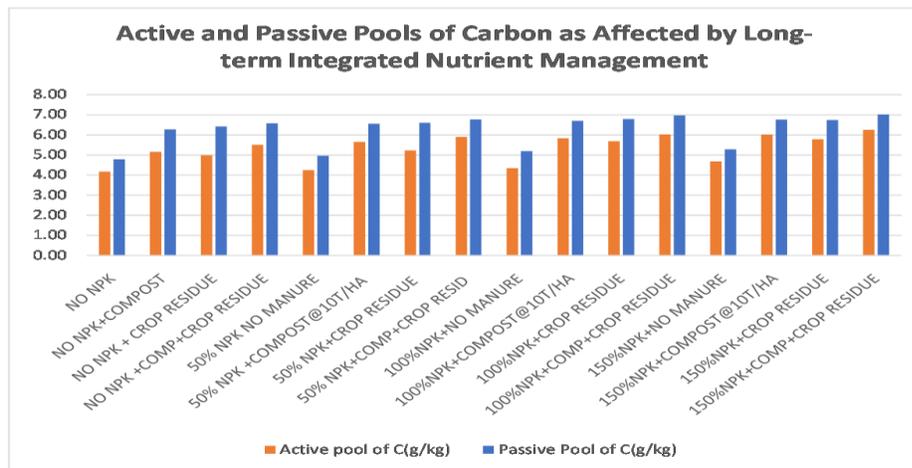


Fig.2 Active (Very Labile + Labile) and passive (Less labile + Non-labile) pools of carbon as affected by long-term integrated nutrient management



The contribution of non-labile (NL), less labile (LL), labile (L) and very labile (VL) fractions of carbon to TOC was 47.8, 5.9, 16.4 and 29.6 %, respectively (Figure 1). The passive pool of carbon (LL+ NL) was in relatively higher proportion (53.7%) than active pool (VL+L) (46.3%) (Figure 2).

Similar result was found by Benbi *et al.*, (2015) and Majumdar *et al.*, (2008). They reported that under rice-wheat system, a greater proportion of organic carbon was in the group of recalcitrant and less-labile fractions.

Oxidizable organic carbon fractions

Average across the main plot and sub-plot treatments different oxidizable organic carbon fractions in surface soil were in the order: NL > VL > L > LL. After 28 years of experiment very labile soil organic carbon varied from 3.14 to 3.63 g kg⁻¹ (Table 2) with increasing levels of fertilizer i.e. no NPK to 150% NPK. Very labile soil organic carbon (3.63 g kg⁻¹) was obtained in the treatment receiving 150% NPK which was 1.96, 7.07, and 15.61% higher than treatments receiving 100%, 50% and no NPK, respectively. Very labile soil organic carbon fraction was not significantly affected by the treatments receiving 100% and 150% NPK. Very labile soil organic carbon in manure levels varied from 2.74 to 3.75 g kg⁻¹. The maximum very labile soil organic carbon (3.75 g kg⁻¹) was found in the treatment receiving both compost and crop residue followed by treatment received compost @10 t ha⁻¹. Treatments receiving compost and crop residue separately not significantly affect the very labile soil organic carbon content of soil.

The labile organic carbon increased from 1.81 to 2.04 g kg⁻¹ (Table 2) with increasing levels of fertilizer i.e. no NPK to 150% NPK. The highest labile organic carbon (2.04 g kg⁻¹) was obtained in the treatment receiving 150% NPK which was 6.80, 9.67 and 12.70% higher than treatments receiving 100%, 50% and no NPK, respectively. Labile soil organic carbon fraction was not significantly affected by the treatment receiving 50% and no NPK. In manure levels, organic carbon varied from 1.62 to 2.17 g kg⁻¹. The maximum labile soil organic carbon (2.17 g kg⁻¹) was found in the treatment receiving both compost and crop residue which was 33.95% higher than no manure application. All the manure treatments significantly improved the labile organic carbon contents of the soil.

Less labile soil organic carbon varied from 0.58 to 0.82 g kg⁻¹ (Table 3) with increasing levels of fertilizer i.e. no NPK to 150% NPK. Less labile soil Organic carbon (0.82 g kg⁻¹) was obtained in 150% NPK treatment which was 6.49, 22.38 and 41.37% higher than treatments receiving 100%, 50% and No NPK, respectively. Less labile soil organic carbon in manure levels varied from 0.62 to 0.77 g kg⁻¹. The maximum less labile soil organic carbon (0.77g kg⁻¹) was found in the treatment receiving both compost and crop residue which was 2.7, 10.0 and 24.2% higher than treatments received crop residue, compost and no manures, respectively. Treatments receiving crop residue and both compost + crop residue not significantly improved the less labile soil organic carbon content of soil, which might be due to crop residue contains more amount of polyphenols and lignin, which is resistant to decomposition leading to improvement in less labile carbon pool.

Non-labile soil organic carbon increased from 5.43 to 5.62 g kg⁻¹ (Table 3) with increasing levels of fertilizer i.e. no NPK to 150% NPK. The value of non-labile soil organic carbon content (5.62 g kg⁻¹) was obtained in the treatment receiving 150% NPK. Different graded levels of fertilizers showed non-significant effect on non-labile soil organic carbon. In manure levels, non-labile soil organic carbon varied from 4.44 to 6.06 g kg⁻¹. The maximum non-labile soil organic carbon (6.06 g kg⁻¹) was found in the treatment receiving both compost and crop residue which was 2.9, 3.41 and 36.48% higher than treatments received crop residue, Compost @ 10 t ha⁻¹ and no manure application, respectively.

Soil organic carbon (SOC) concentration in surface soil (0 to 15 cm) were slightly increased by 28 years of fertilizer treatments (150%, 100%, 50% and no NPK) but they

were sharply increased by the manure and straw amendment (Crop residues, Compost @ 10 t ha⁻¹). Thus, returning crop residue to the soil or adding compost and crop residues on soil surface is crucial to improving the SOC level.

In conclusion the application of fertilizers along with compost and crop residues resulted in significant buildup of soil organic carbon fractions. The improvement in non-labile carbon fraction was more than that in labile carbon fractions suggesting higher carbon sequestration in the soil.

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