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ASSESSMENT OF LONG-TERM ORGANIC AMENDMENTS EFFECT ON SOME SENSITIVE INDICATORS OF CARBON UNDER SUBTROPICAL CLIMATIC CONDITION

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ABSTRACT

The present study deals with the effect of long-term organic amendments on some sensitive indicators of soil carbon pools. Organic manures addition increased the amount of labile carbon (C_l) by 54.5-77.3 % as compared to chemical fertilizer applied alone in soil depth 0-10 cm. The amount of carbon pools decreased on increasing soil depth (0-10 cm > 10-20 cm > 20-30 cm). In the soil depth 0-10 cm, carbon management index (CMI) values were 1.80-1.62 times more in organic manure added treatments as compared to chemical fertilizer applied alone. Sensitivity index (SI) of labile carbon for different treatments showed positive values, which indicates positive impact of the management practices on soil organic matter content and on the soil quality. The management practices are approaching towards natural ecosystem.

INTRODUCTION

Organic farming practices provide invaluable insight in improving the soil fertility and its productivity for sustainable agriculture. The basic perspective for application of organic amendments is required to maintain organic carbon pool and microbial activity in the soil. Lability of carbon (L), carbon management index (CMI) and sensitivity index (SI) are the sensitive indicators to study the behavior of soil organic carbon (SOC) and its effect on different management practices. CMI compares the changes that occur in carbon pools as a result of agricultural practices with respect to natural ecosystem (Blair *et al.*, 1995). The sensitivity index (SI) was used to compare the magnitude of changes in different carbon fractions relative to a more stable reference soil (Banger *et al.*, 2010).

Soil quality is related to nutrient status, physical and chemical properties of soils. The increase in soil nutrient content on inorganic and organic amendments might be due to the consistent supply of organic matter and essential nutrients for plant growth (Nayak *et al.*, 2015). Organic amendments improve the physical structure of soil enhancing the water retention (Vanilarasu *et al.*, 2014). SOC plays a major role in both the cycling of nutrients and in soil structure. The carbon in form of small or large pools is there whose availability helps to determine the sustainability of the soil. The loss of carbon from a small pool *i.e.* labile pool is more critical than the loss of carbon from a large pool *i.e.* non-labile pool (Blair *et al.*, 1995). In general, manure alone or in culmination with mineral fertilizers plays an important role in increasing the amount of carbon pool (Brar *et al.*, 2013; Kumar *et al.*, 2013).

Though the effect of manures and fertilizers on carbon pools and CMI has been studied extensively but there is very meager holistic information on a study of the impact of organic amendment combinations on carbon pools and CMI under organic farming system. We hypothesized that addition of organic amendments could have considerable impact on the pools of carbon and their lability. To test the hypothesis, we have estimated the lability of carbon, CMI and SI under a long-term organic farming system in different soil depths and their use as a sensitive indicator for assessing organic farming effect on SOC.

MATERIALS AND METHODS

Study site

This research was carried out as a part of an ongoing project "Development of organic farming package for system based high value crops" under the network project research program of the PDFSR, Modipuram (now Indian Institute of Farming System Research) with Scented Rice-Potato-Onion crop rotation initiated in 2004-05 at the farm of Bihar Agricultural College, Sabour (24°13'N, 87°3'E and 12 m above mean sea level) under humid subtropical climate. The initial soil characteristics of the site are given in the Table 1.

Experimental design

The field experiment comprised of five different combinations of treatments in plot size of 264 m^2 (22 m X 12 m), each plot was divided into four quadrants and soil sampling was done from each quadrant, considering each quadrant as a replication in a randomized block design. These treatments were NPK- 100% NPK , NPKF- 50% recommended NPK through mineral fertilizers + 50% N as FYM, FVN- Different organic sources each equivalent to 1/3rd of recommended N (FYM + vermicompost + neem cake), FBBP- 50% N as FYM + biofertilizer for N + bone meal to substitute P requirement of crops + phosphate solublizing bacteria (PSB), FVNP- Different organic sources each equivalent to 1/3rd of recommended N (FYM + vermicompost + neem cake)+ biofertilizer containing N and P carrier (PSB). The recommended doses of scented rice, potato and onion are 100 kg N + 40 kg P_2O_5 +20 kg K_2O ha^{-1}; 150 kg N + 90 kg P_2O_5 + 100 kg K_2O ha^{-1} and 100 kg N + 80 kg P_2O_5 + 80 kg K_2O ha^{-1}, respectively.

Soil sampling and analysis

Soil samples were collected in duplicate at three different depths (0-10, 10-20 and 20-30 cm) after the harvesting of scented rice crop in October, 2013 and October, 2014. One part of the sample was used for determination of bulk density and rest of the sample used for analysis of carbon pools. The soil characteristics of the treatments were estimated as explained in Table 2. The sample collected from uncultivable area with similar texture and taxonomy from the mentioned depths was treated as reference sample. Collected soil samples were air-dried, ground and passed through 2-mm sieve size. Labile carbon (C_l) content of soil sample was determined by oxidizing with the 333mM $KMnO_4$ (Blair *et al.* 1995). Non labile carbon (C_{nl}) was calculated by subtracting labile carbon from total organic carbon (C_t) measured by wet oxidation method proposed by Snyder and Trofymow, 1984. The CMI was calculated as follows (Blair *et al.* 1995):

$$\text{CMI} = \text{CPI} \times \text{LI} \times 100$$

Where,

$$\text{CPI (Carbon Pool Index)} = \frac{\text{Sample Ct (Mg g}^{-1}\text{)}}{\text{References Ct (mg g}^{-1}\text{)}}$$

$$\text{L (Lability of Carbon)} = \frac{\text{Cl}}{\text{Cnl}}$$

$$\text{LI (Lability Index)} = \frac{\text{Sample L}}{\text{Reference L}}$$

The Sensitivity Index (SI) was calculated using the following formula (Banger *et al.*, 2010):

Table 1: Initial Soil Properties

Soil Properties	
Sand (%)	35.6
Silt (%)	53.1
Clay (%)	11.3
pH (Soil:Water-1:2.5)	8.1
Organic carbon (g kg^{-1})	5.0
Available nitrogen (kg N ha^{-1})	153.4
Available phosphorus (kg P_2O_5 ha^{-1})	26.9
Available potassium (kg K_2O ha^{-1})	122

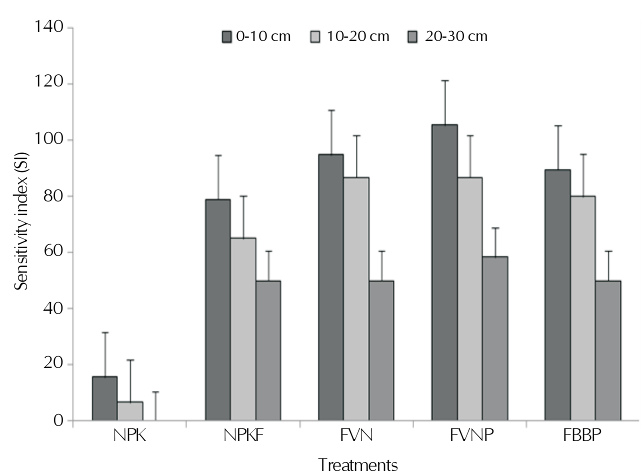
$$\text{SI} = \frac{\text{C fraction in Soil of a given treatment} - \text{C fraction in reference soil}}{\text{C fraction in reference soil}} \times 100$$

The treatment effect was analyzed using analysis of variance (ANOVA) (Gomez and Gomez, 1984) and Duncan's Multiple Range Test (DMRT) was performed as post hoc mean separation test where ANOVA was significant ($P<0.05$). Pearson's Correlation was also done to evaluate the relationships among the various parameters. Statistical analysis was performed by Microsoft Excel (Microsoft Corporation, USA) and SPSS window version 16.0 (SPSS Inc., Chicago, USA).

RESULTS AND DISCUSSION

Effect of organic amendments on bulk density and carbon pools

Bulk density of the soils ranged from 1.41 to 1.69 Mg m^{-3} (Table 2). It slightly increases with depth which could be attributed to decreased organic matter content and secondary accumulation of illuviated clays in deeper layers (Nayak *et al.*, 2015). Organic manures addition significantly increased the amount of C_l and C_{nl} in comparison to chemical fertilizer applied alone. At soil depth 0-10 cm, C_l increased by 77.3, 68.2, 63.6 and 54.5% with the application of FVNP, FVN, FBBP and NPKF over the treatment NPK. Similar trend was observed in case of soil depth 10-20 cm with respect to the above mentioned different treatments over the treatment NPK (Table 3). C_l was maximum in the treatment FVNP and at par with FVN and FBBP and minimum in the treatment NPK. The C_l is one of the most easily oxidized C fractions could be used as more sensitive indicators, and be applied to monitor the changes that occur in the soil organic matter (SOM) contents caused by management practices as well as to investigate the soil quality status. Similar, sensitivity of C_l to management practices was reported by Blair *et al.*, 1995 and Yang and Kay, 2001. The amount of C_{nl} was higher than C_l in all the



*Bars represent mean value with standard error at $p<0.05$

Figure 1: Comparison of the treatment effects on sensitivity indices of labile carbon in the different soil depths

Table 2: Effects of long term fertilization on measured characteristics of the silt loam soil under scented rice-potato-onion cropping system (pooled data of treatments)

Soil depths(cm)	Treatments	BD Mg m^{-3}	SOC g kg^{-1} soil	TOC
0-10	NPK	1.49	6.4	9.4
	NPKF	1.46	7.1	8.4
	FVN	1.42	7.4	7.9
	FVNP	1.41	7.2	13.1
	FBBP	1.47	7.5	12.3
10-20	NPK	1.58	5.4	10.1
	NPKF	1.56	6.3	15.5
	FVN	1.53	6.8	13.0
	FVNP	1.51	6.6	11.8
	FBBP	1.56	6.9	14.3
20-30	NPK	1.69	5.0	12.3
	NPKF	1.65	5.7	11.5
	FVN	1.64	5.9	15.9
	FVNP	1.64	5.6	13.1
	FBBP	1.66	5.9	12.2

Table 3: Labile carbon (C_l), non labile carbon (C_{nl}), C_l/TOC and carbon management index (CMI) following indicated treatments in 2014 in the long term organic farming system

Treatment	C_l	C_{nl}	C_l/TOC	CMI
	0-10 cm			
NPK	2.2c	7.2c	23.4b	118b
NPKF	3.4ab	9.4ab	26.6a	191ab
FVN	3.7a	12.0a	23.6b	199a
FVNP	3.9a	12.3a	24.1b	212a
FBBP	3.6a	11.5a	23.8b	195ab
	10-20 cm			
NPK	1.6b	6.3c	20.3b	108b
NPKF	2.7a	9.6ab	22.0a	186a
FVN	2.8a	11.2a	20.0b	188a
FVNP	2.8a	10.3a	21.4ab	191a
FBBP	2.7a	10.1a	21.1ab	184a
	20-30 cm			
NPK	1.2a	5.9b	16.9ab	100b
NPKF	1.8a	9.0a	17.1a	150a
FVN	1.8a	9.9a	15.2b	147a
FVNP	1.9a	10.3a	15.6b	155a
FBBP	1.8a	9.9a	15.5b	146a

Values within a column, followed by different letters are significantly different at $p < 0.05$ by Duncan's multiple range tests.

Table 4: Pearson's Correlation coefficients (r) among bulk density (BD), soil oxidizable carbon (SOC), total organic carbon (TOC) and carbon management index (CMI)

	BD	SOC	TOC	CMI
BD	1.00			
SOC	-0.886*	1.00		
TOC	0.432	-0.210	1.00	
CMI	0.556	-0.338	0.975**	1.00

*Significant at $p<0.05$ and ** Significant at $p<0.01$

treatments. This might be due to the maximum portion of the added manures contributed to the non labile pools (fraction less susceptible to biodegradation) of soil organic matter over a longer period of time. This results in increased formation of macro-aggregates by acting as binding agent due to retention inside the soil for longer period of time (Simpson *et al.*, 2004).

The C_l/TOC was observed maximum in NPKF over all the treatments among all the different soil depths (Table 3). This represents that in the treatment NPKF, TOC has more contribution towards C_l. The amount of carbon pools decreased with increasing soil depth (0-10 cm> 10-20 cm> 20-30 cm) (Table 3). This may be due to more addition of root biomass, root exudates and plant biomass in the different treatments (Padre *et al.*, 2007; Brar *et al.*, 2013).

Effect of organic amendments on carbon management index (CMI)

In the soil depth 0-10 cm, CMI value was 1.80, 1.69, 1.65 and 1.62 times more for the treatments FVNP, FVN, FBBP, NPKF, respectively as compared to the treatment supplemented with mineral NPK. Similar trend was observed in soil depths 10-20 cm and 20-30 cm (Table 3). Among all the treatments FVNP was found to be the best treatment as agricultural practice. This shows that the organic manure addition improves the CMI value, which ultimately improved the sustainability of crop production. The CMI values obtained for different treatments showed values higher than 100 in the all the soil depths (Table 3) indicates positive impact of the management practices on soil organic matter content and on the soil quality. Similar results were reported by Blair *et al.* 1995 and Banger *et al.* 2010.

Effect of organic amendments on sensitivity index (SI) of labile carbon

In soil depth 0-10 cm, trend of SI obtained for the treatments was FVNP (105) > FVN (95) > FBBP (89) > NPKF (79) > NPK (16). Similar trend was observed in soil depths 10-20 cm and 20-30 cm (Fig. 1). For different treatments the obtained SI value was positive in all the soil depths. This indicates lability of carbon improved on organic manure addition in different management practices (Banger *et al.*, 2010).

Correlation matrix between soil properties and carbon management index (CMI)

Table 4 represents carbon management index (CMI) had a positive and highly significant correlation with TOC ($r= 0.975^{**}$). This shows that the CMI depends on total organic carbon (TOC) content not on SOC. CMI indicates the influence of management practices on relative conversion between labile and non labile carbon. Addition of organic amendments for a long period substantially improve non labile carbon pools (Bhattacharyya *et al.*, 2011), thus resulted improved physical structure and enhanced the water retention of soil (Vanilarasu *et al.*, 2014).

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