

Estimation of different fractions of organic carbon and its implication to carbon dynamics in agricultural soil

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Abstract: Soil acts as a major sink to atmospheric carbon, thus plays a key role in global carbon cycle. Soil organic carbon (SOC) is composed of recalcitrant and labile carbon pools. Recalcitrant pool of carbon (humin and humic substances) is resistant to microbial degradation due to its complex chemical structure. Labile carbon is an oxidisable fraction of organic carbon. This pool of carbon is mainly composed of three components, i.e. physical fraction (including particulate organic matter), oxidizable fraction ($\text{KMnO}_4\text{-C}$) and biological fraction (microbial biomass). Recalcitrant fraction does not undergo mineralization easily, so it is not available for plant growth, only labile organic carbon fraction is available to plants and very rapidly responds to changes taking place in soil and surrounding environment. As, composition of total SOC determines the soil quality, it has beneficiary effects on soil quality and productivity. Agricultural practices also affect the soil organic pool as well as composition of SOC. Therefore, quantification of various fractions of soil organic carbon which is influenced by management practises is necessary for determining Carbon sequestration and as well as fertility status of soil.

Results indicate that Total carbon (TC), SOC and Total nitrogen (TN) ranged between 8.9-11.9 g/kg; 7.4-9.19 g kg⁻¹ and 0.82-1.12 g kg⁻¹ respectively. Pool I (Labile carbon) and II (Very labile carbon) together known as the labile pool, which ranged from 3.6 to 4.5 g kg⁻¹ and pool III and IV constitute together the recalcitrant/refractory pool, which ranged from 3.2 to 3.8 g kg⁻¹.

Keywords: Soil organic carbon, Carbon sequestration, soil quality, Organic matter, carbon pool

Introduction

Soil organic carbon (SOC) pool is a measure of fertility of agricultural soil. Organic matter is a rich pool of nutrients required by plants for their growth and sustenance. But due to increasing population and thereby its increasing demand for food have exerted a great pressure on agricultural lands, which resulted in degradation of soil quality and increased mineralization of soil organic matter. To improve the soil quality and nutrient availability a sustainable agricultural practice is required which can reduce the increasing pressure on agricultural soil. Recalcitrant fraction does not undergo mineralization easily, so it is not available for plant growth, only labile organic carbon fraction is available to plants. Composition of total SOC determines the soil quality.

The sedimentary/soil organic matter is widely distributed over the Earth's surface occurring in almost all terrestrial and aquatic environments (*Singh and Kazuo, 2004*). Sediments contain a large variety of organic matter ranging from simple sugars and carbohydrates to more complex proteins, fats, waxes, and organic acids. Important characteristics of the organic matter include their ability to form water-soluble and water-insoluble complexes with metal ions and hydrous oxides; interact with clay minerals and bind particles together; absorb and desorb both naturally occurring and anthropogenically introduced organic compounds; absorb and release plant nutrients; and hold water in the soil environment. Naturally occurring organic carbon-forms are derived from the decomposition of plants and animals. In soils and sediments, a wide variety of organic carbon-forms are present and range from freshly deposited litter (e.g., leaves, twigs, branches) to highly decomposed forms such as humus. Sorption of dissolved organic matter (DOM) on to settling particles

is considered to be a major process in the preservation of organic matter (OM) in marine sediments. Evidence for this hypothesis includes the close relationship between sediment particle surface area and organic carbon (OC) concentrations and strongly reduced biological degradability after DOM has adsorbed to mineral surfaces (*Kaiser et al., 2000*).

In this paper an attempt has been made to determine soil organic carbon (SOC) along with other linked constituents and a comparative investigation have been carried out on the influence of organic amendments in differential manner not only on the nature and properties but also fertility issues, productivity etc and to ascertain its important linkage with complex soil carbon dynamics using standard methods.

Materials and Methods

Soil samples (0-30 cm) were collected from wheat crop field with the help of PVC pipes. Soil samples (0–30 cm depth) were taken randomly in triplicate during August-September 2015-16, from the agricultural fields near Lucknow city, and analyzed individually. After initial soil identification other experiments were performed. In this investigation oxidizable-total organic carbon (SOC) was determined by using Walkley-Black method (Walkley and Black, 1934). Total N was determined by Gerhardt Kjeldhal method (Misra, 1968) that consists of three steps namely digestion, distillation and titration. The SOC content was calculated into different pools by the modified Walkley–Black method as described by Chan et al. (2001). All the fraction of SOC was estimated by using 12.0, 18.0 and 24.0 N H₂SO₄, respectively. Total SOC was divided into four different pools according to their order of stability against oxidation. Soil organic carbon, oxidized by 12.0 N H₂SO₄ was termed very labile pool (pool I). Labile pool (pool II) was calculated by taking difference in SOC oxidizable by 18.0 N H₂SO₄ and that by 12.0 N H₂SO₄, the difference in SOC oxidizable by 24.0 N H₂SO₄ and that by 18.0 N H₂SO₄ was pool III. The difference between total SOC and SOC oxidizable by 24.0 N H₂SO₄ was termed refractory pool (pool IV). Hence, it involves mixing 1N dichromate solution with H₂SO₄ in different proportions. The comparative analysis of physico-chemical properties of soil was done by different analytical methods. Soil pH and electrical conductivity (EC) were analyzed by pH and conductivity meter respectively. Phosphate – P and total Nitrogen – N were determined by Olsen’s sodium bicarbonate method (Mackereth, 1963) and Micro-kjeldahl distillation assembly (Misra, 1968), respectively. Available potassium K⁺ was estimated with the help of a flame photometer. Exchangeable sodium percentage was calculated as follows: ESP = (exchangeable sodium concentration (cmol/kg)/cation exchange capacity (cmol/kg))×100.

Results

Soil Analysis

Samples were analyzed individually for Soil type etc it revealed to be sandy, clay, loam, with pH ranged between 8.5 to 9.06. Electric conductivity (Ec), Phosphate (P) and potassium (K) are ranged between 0.60 – 0.96 (dSm⁻¹); 21.2 – 46.4 (kg ha⁻¹) and 167 -258 (kg ha⁻¹) respectively. TC ranged between 8.9 - 11.9 g kg⁻¹, SOC ranged between 7.4 - 9.19 g kg⁻¹ and TN ranged from 0.82-1.12 g kg⁻¹ (See Graph 2, 1 and Table 1 respectively). Pool I and II together known as the labile pool, which ranged from 3.6 to 4.5 g kg⁻¹ and pool III and IV constitute together the recalcitrant/refractory pool, which ranged from 3.2 to 3.8 g kg⁻¹(See Graph 1).

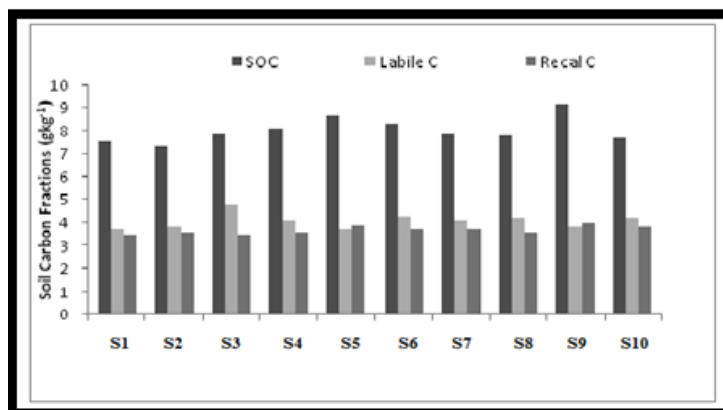


Figure 1. Soil carbon analysis

Table 1. Soil Analysis data

Sample	Soil organic C Pools (g kg ⁻¹)					Total nitrogen (g kg ⁻¹)
	Very labile (Pool I)	Labile (Pool II)	Labile (Pool I + Pool II)	Labile (Pool III)	Labile (Pool IV)	
S1	0.18	0.19	0.37	0.35	0.938	0.83
S2	0.2	0.18	0.38	0.36	0.892	0.82
S3	0.25	0.23	0.48	0.35	1.04	1.03
S4	0.2	0.21	0.41	0.36	0.940	1
S5	0.16	0.21	0.37	0.39	1.02	0.89
S6	0.23	0.2	0.43	0.37	0.934	0.95
S7	0.22	0.19	0.41	0.37	1.19	1.12
S8	0.23	0.19	0.42	0.36	1.01	0.9
S9	0.21	0.17	0.38	0.4	0.923	0.9
S10	0.24	0.18	0.42	0.38	1.13	1.02

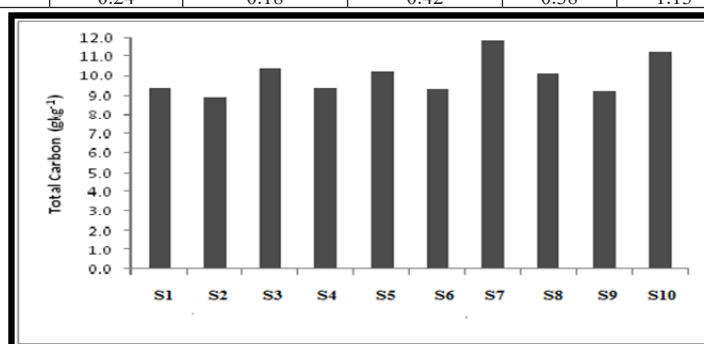


Figure 2. Total Carbon Analysis

The comparative analysis of physico-chemical properties of sodic soil as influenced by organic amendments

The highest decrease in soil pH, EC and ESP were observed in FYM and VC (T8) treated

Table 2. Chemical properties of sodic soil as influenced by organic amendments in sodic soil. Values are in means and range. Values in parenthesis represent % increase (+) or decrease (-) with respect to pre-harvest values.

	Pre harvest	9.04	1.05	21.7	184
T1		9.03 (-0.11)	0.95 (-9.5)	22.5 (+3.69)	182.6 (-0.76)
		9.01-9.06	0.95-0.96	21.2 -23.8	174-185
T2		9.03 (-0.11)	0.94 (-10.4)	24.4 (+12.4)	189 (+2.72)
		9.00-9.05	0.90-0.95	23.3-25.7	167-196
T3		8.64 (-4.42)	0.75 (-28.5)	33.6 (+54.8)	205.3 (+11.5)
		8.62-8.66	0.70-0.79	25.5-39.7	188-218
T4		8.64 (-4.42)	0.71 (-32.3)	35.3 (+62.6)	214.6 (+16.6)
		8.62-8.68	0.70-0.73	27.4-42.8	187-233
T5		8.72 (-3.50)	0.77 (-26.6)	30.6 (+41.0)	196.3 (+6.68)
		8.71-8.74	0.77-0.78	23.7-34.6	178-216
T6		8.55 (-5.42)	0.65 (-38.0)	36.8 (+69.5)	225 (+22.2)
		8.55-8.66	0.64-0.66	27.4-39.3	199-140
T7		8.53 (-5.64)	0.64 (-39.0)	38.1 (+75.5)	231.6 (+25.8)
		8.52-8.55	0.63-0.65	26.8-49.4	195-258
T8		8.50 (-5.97)	0.61 (-41.9)	38.7 (+78.3)	238.3 (+29.5)
		8.50-8.51	0.60-0.62	28.6-46.4	197-248

T1=control; T2=NPK; T3=FYM (farm yard manure); T4=VC (Vermicompost); T5=NPK+VC; T6=FYM+VC (1:1); T7=FYM+VC (1:2); T8 =FYM+VC (2:1)

plots respectively. The soil nutrients N, P, K and SOC contents were higher in organically amendments sodic soils than soils amended with chemical fertilizers (T3; NPK amended soil) and control soil. The highest soil nutrients were observed in FYM and VC treated plots (T8). The increased values were N (2.62% - 33.2%), P (3.69% – 78.3%), K (2.72% - 29.5%) and OC % (16%-152%) in comparison to pre harvest values. Various physico-chemical properties of used organic amendments such as FYM and VC were also analyzed and given in Table 2. It further indicates that organically amended soil have a potential to reduce the sodicity and enhance fertility. Further FYM and VC in 2:1 can act as boosting element to improve soil structure by facilitating the growth of microbial population and in turn carbon assimilation.

Discussion

Labile organic carbon has been proved to be sensitive indicators of changes in SOC pool due to changes in agricultural management practices (Ghosh et al., 2013). The soil organic carbon pool and the total amount of labile carbon fraction has direct control over physiochemical and biological properties of the soil system and also influences self organization capacity of soil (Addiscott, 1995; Blair and Crocker, 2000;). In 1995 in a report the Carbon lability was defined as the ratio of labile C to non-labile C (Blair et al., 1995).

Changes in labile C pools occur within a short period (one to two years) and this labile pool can be used to assess land management effects. Walkley Black C (WBC) or oxidizable soil organic C mostly represents the entire labile C pool and some portion of long-lived C pools, which takes longer to change, due to land management effects (Six et al., 1999). Hence, several workers reported that the KMnO_4 - oxidizable SOC or labile carbon is a more sensitive SOC indicator compared with total SOC or WBC (Moharana et al., 2012; Liu et al., 2014). This fraction of carbon is a crucial part of global carbon cycle. In the present analysis it is indicative of its complex dynamics. In the other observation of organic amendment the pH may reduce primarily due to high production of CO_2 and

organic acids in soil followed by solubilisations of CaCO_3 and even neutralization of sodicity is reported (Shiamma et al., 2012) .

Conclusion

Thus, quantification of soil carbon (C) cycling which is influenced by management practices is necessary for determining carbon sequestration dynamics as hypothesised is justified.

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