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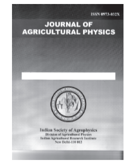

Research Article

Effect of Nutrient Management on Soil Organic Carbon Pools and Enzymes Activities under Groundnut in Acidic Soil

B.C. VERMA*[1], MANOJ KUMAR[2], B.U. CHOUDHURY[3], S. HAZARIKA[3], L.J. BORDOLOI[4], T. RAMESH[3], P. MOIRANGTHEM[3] AND RAMKRUSHNA G.I.[5]

[1]*Central Rainfed Upland Rice Research Station (CRURRS), (ICAR-NRRI), Hazaribagh, India*
[2]*ICAR Research Complex for Eastern Region, RCM, Darbhanga, India*
[3]*ICAR Research Complex for NEH Region, Umiam, India*
[4]*ICAR Research Complex for NEH Region, Nagaland Centre, India*
[5]*ICAR-Central Institute for Cotton Research, Nagpur, India*

ABSTRACT

Soil quality or health is governed by different soil attributes among them soil organic carbon (SOC) is central element, which is also very important for sustainable production system. To find out the impact of different nutrient management on SOC pools and soil enzymes, the results from a five year field experiment under groundnut in acidic soil is presented here. To achieve the objective, the soil samples from two depths (0-15 and 15-30 cm) were collected under different nutrient management practices for subsequent analysis of SOC pools and soil enzymes activities. Result from the experiment revealed that integrated nutrient management (INM) (50% NPK + Vermicompost @ 5t ha^{-1} + Lime @ 5q ha^{-1}) significantly improved the SOC pools over the other nutrient management. Soil enzymes activities were also higher in the INM. Across the nutrient management, surface soil (0-15cm) contain higher SOC pools and enzyme activities than sub surface (15-30 cm). Soil organic carbon pools and soil enzyme activities were significantly correlated (*$*P<0.05$, $**P<0.01$*) with each other and the microbial biomass carbon (MBC) was more closely correlated with the soil enzymes than the SOC and TOC (total organic carbon). It was concluded that integrated nutrient management along with lime application in acidic soil, improved the SOC pools as well as enhance the enzymes activities also, hence it may be a good options to improve the soil quality of acidic soil for future sustainability.

Key words: Acid soil, Groundnut, Integrated nutrient management, Soil enzymes, Soil organic carbon pools

Introduction

Acid soil is mostly characterized by the limited soil fertility and nutrient imbalance (toxicity of Al and Fe, deficiency or unavailability of phosphorus, low basic cations like calcium and magnesium etc), reduced microbial activity etc. In North Eastern Hill Region of India, most of the soils are acidic in nature, hence, to maintain the soil fertility, soil quality or health and to enhance the soil productivity, proper nutrient management is very much crucial for these low productive soils (Manoj-Kumar *et al*., 2012). Soil quality or health (soil fertility as well as productivity) are the functions of different soil attributes; however, it is primarily depends on soil organic matter (SOM) or soil organic carbon (SOC), which is the central key attributes (Mawlong *et al.,* 2020). Maintenance or improvement of SOM or SOC is very important as it influences most of the soil properties and carbon storage which is very much

*Corresponding author,
Email: bibhash.ssac@gmail.com

required for the long-term productivity and sustainability of any agricultural system (Haynes, 2005; Tian *et al*., 2013).

Total organic carbon (TOC) which comprises total amount of organic carbon present in soil and composed of several fractions vary from recalcitrant to labile or even more labile. The quality and quantity of organic carbon present in soil is very important for determination of carbon cycle, carbon mineralization, nutrient transformation and its availability etc and overall soil health and quality. It is reported that soil management (tillage, water, nutrient management etc.) has the significant impact on the organic carbon and its fractions (Mandal *et al*., 2008; Verma *et al.,* 2010). Active component of organic carbon contains soil microorganism and carbon associated with them, which is called soil microbial biomass carbon (MBC) controlling decomposition of organic matter and nutrient transformations (Melero *et al*., 2006; Wu *et al.,* 2011). Microbial biomass carbon and microbial activity closely associated with SOC and influenced by nutrient management options (Ross and Tate, 1993; Verma *et al.,* 2017). It is very important in maintaining soil functions because it is the main source of soil enzymes which regulate soil transformation processes (Landgraf and Klose, 2002). Soil microbial activity is generally measured with the help of soil enzymes which play key role in the biochemical transformations. Like SOC pools, activities of soil enzymes are also affected by different soil management options (Waldrop *et al*., 2004; Wang, 2013). Among the different enzymes present in soil, dehydrogenase activity is better correlated with the microbial population and activity and also provides the good information related to microbial dynamics (diversity and activity) (Verma *et al.,* 2017). Phosphatase enzymes which are a broad group of enzymes help in catalysing hydrolysis of phosphorus (P) compound and govern P cycle and help in P transformations in soil (Makoi and Ndakidemi, 2008). Soil enzymes activities reflect the real picture of soil microbial activity and also considered as important indicator of soil health and quality. However, the synergistic relationship between different SOC pools and enzymes activity at different soil depth of is still not clear under groundnut particularly in the acidic soil of north eastern India. We think that, nutrient management had a significant effect on SOC pools and enzymes activities under Groundnut, Hence the present work was undertaken to examine the changes in soil organic carbon pools and enzymes activities at two depth of soil under groundnut in the acidic soil under different nutrient management options.

Material and Methods

In 2011, a field experiment was initiated with different nutrient management practices (inorganic, organic and integrated) under groundnut in the Soil Science experimental farm of ICAR Research Complex for NEH Region, Umiam, Meghalaya. The experimental site is located at 25°41′ N latitude, 91°55′ E longitude at mid altitude (970 m amsl). The initial properties of the experimental site are presented in Table 1. The experiment was laid out in randomized block design (RBD) with six treatments (Table 2) and three replications.

Table 1. Initial soil properties of the experimental plot

Texture	Sandy loam
pH (1:2.5)	4.5
Soil organic carbon (SOC)	1.18%
Available nitrogen	208 kg ha^{-1}
Available phosphorus	7.1 kg ha^{-1}
Available potassium	134 kg ha^{-1}

After five years of experiment, soil samples were collected from two depths (surface 0-15 cm and sub surface 15-30 cm) before the harvest of crop. For determination of microbial biomass carbon (MBC) and activity of soil enzymes (dehydrogenase and acid phosphatase) moist soil samples were kept in the deep freeze. Remaining part of soil samples were air dried, passed through a 2.0 mm sieve for the determination of SOC and TOC. Total organic carbon was determined using TOC analyzer (Elementar Vario TOC Select, Langenselbold, Germany). For determination of TOC, soil samples were fed into the analyzer at designated slots and carbon in the sample was converted into CO_2. Amount of CO_2 formed will provide the carbon content in soil. Soil organic carbon (SOC) content was determined by wet oxidation method of Walkley and Black (1934).

Table 2. Details of nutrient management practices applied in the experiment

Treatments	Details
T_1	Control
T_2	100% NPK (20:60:40 N: P_2O_5: K_2O Kg ha^{-1})
T_3	50% NPK + Lime @ 5q ha^{-1}
T_4	50% NPK + Vermicopost @ 5t ha^{-1}
T_5	50% NPK + Vermicopost @ 5t ha^{-1} + Lime @ 5q ha^{-1}
T_6	FYM + Weed Compost + Vermi Compost @ 2.5 t ha^{-1} (1:1:1)

Inorganic (T_2, T_3), Integrated (T_4, T_5) and Organic (T_6)

Soil microbial biomass carbon was determined by chloroform-fumigation-extraction method (Brookes and Joergensen, 2006). Dehydrogenase activity which provides the idea of microbial activity and respiration was determined as per the method described by Casida *et al.* (1964). Soil sample (10 g) was mixed with 0.1 g $CaCO_3$ and then the mixture was divided into three culture tubes with 3 g each. To each tube, 0.5 ml of 3% 2,3,5-triphenyl-tetrazolium-chloride (TTC) and 1.25 ml of distilled water were added and mixed thoroughly by gentle tapering and incubated at 37°C for 24 hours. After 24 hours of incubation, the soil suspension was filtered through funnel equipped with absorbent cotton. Methanol was used to extract the soil suspension until the cotton plug's colour became white and the final volume was made upto 50 ml. Intensity of reddish colour was measured by using spectrophotometer at 485 nm. Acid phosphatase activity was determined through procedure described by Tabatabai and Bremner (1969). For this purpose, 1 g soil sample was taken in a flask and 4 ml of Modified Universal Buffer (MUB, pH 6.5), 0.25 ml of toluene and 1 ml of disodium p-nitrophenyl phosphate hexahydrate (p-NPP) were added and incubated at 37°C for 1 hour. After incubation, 1 ml of 0.5 M $CaCl_2$ and 4 ml of 0.5 M NaOH were added to the soil suspension and filtered. Intensity of yellow colour was measured in the filtrate at 400 nm using spectrophotometer. Analysis of variance (ANOVA) was followed to find the effect of different nutrient managements and depth on soil organic carbon pools and soil enzymes activity as outlined by Snedecor and Cochran (1967). Further, correlation study was carried out to access the relationships among the SOC pools and soil enzymes.

Results and Discussion

Soil organic carbon pools

The effect of nutrient management on soil organic carbon pool is significant and it was found that application of Vermicompost @ 5t ha^{-1} for consecutive five years significantly improved the TOC from 2.15 % to 2.41 % (Table 3), however the improvement is even more in organic treatment (T_6) (2.48%), which are statistically at par. The improvement in TOC in integrated and organic nutrient management is due to the addition of organic matter or organic carbon directly in the soil over a period of time. It was reported in several studies that addition of organic manure improved the TOC content in soil (Melero *et al.*, 2006; Verma *et al.*, 2010; Ghosh *et al.*, 2010). It was also reported that, nutrient management practices even within a period of three to seven years affects the TOC significantly (Sanchez *et al.,* 2004; Bastia *et al.*, 2013). In case of SOC, highest SOC was recorded in organic treatments T_6 (1.83%) followed by integrated (T_5 and T_4) and inorganic treatments (T_2 and T_3). The lowest was observed in T_1 (control). This may be also due to the addition of more amount of carbon in soil under organic treatment followed by integrated nutrient management. Addition of organic matter might increases the oxidizable carbon *i.e.* SOC. Verma *et al.* (2014a) and Ortas and Lal (2014) also reported significantly higher SOC concentration in organically treated plots than inorganic treated plots and control. Integrated nutrient management also enhance the SOC due to better crop growth and more root biomass production which add carbon to soil (Rudrappa *et al.*, 2006; Yi *et al.*, 2009). Proportion of SOC over TOC significantly improved with the addition of

Table 3. Soil organic carbon fractions, their proportion and enzyme activities affected by nutrient management

Treatment	Parameter							
	TOC (%)	SOC (%)	MBC (mg kg^{-1})	DHA (ug $TPFg^{-1}$ h^{-1})	PTA (mg phenol $kg^{-1}hr^{-1}$)	SOC/TOC (%)	MBC/SOC (%)	MBC/TOC (%)
T_1	2.15^{c}	1.24^{d}	284^{d}	5.59^{d}	186^{e}	57.7^{b}	2.27^{c}	1.32^{d}
T_2	2.37^{ab}	1.36^{c}	343^{c}	6.18^{c}	237^{d}	57.6^{b}	2.49^{abc}	1.44^{cd}
T_3	2.34^{b}	1.35^{c}	369^{c}	6.12^{c}	263^{c}	57.7^{b}	2.72^{a}	1.57^{bc}
T_4	2.40^{ab}	1.70^{b}	405^{b}	7.13^{b}	320^{b}	70.6^{a}	2.36^{bc}	1.68^{b}
T_5	2.41^{ab}	1.71^{b}	466^{a}	7.32^{b}	348^{a}	70.8^{a}	2.72^{a}	1.93^{a}
T_6	2.48^{a}	1.83^{a}	479^{a}	7.67^{a}	365^{a}	74.1^{a}	2.60^{ab}	1.94^{a}

* the values within a column followed by common letter are not significantly different by DMRT at *P= 0.05*

TOC: Total organic carbon; SOC: Soil organic carbon; MBC: Microbial biomass carbon; DHA: Dehydrogenase activity; PTA: Acid Phosphatase activity

vermicompost as in case of organic as well as integrated nutrient source. The addition of organic matter increases the SOC more rapidly as compared the TOC, hence, more SOC/TOC in integrated and organic treatments were observed. It was also reported that, recovery of organic carbon varied due to different nutrient management options (Verma *et al.,* 2014b). Soil depth also significantly affects the TOC and SOC content in soil and they are reduced from 2.41 to 2.30% and 1.64 to 1.42%, respectively (Table 4). Reduction of organic carbon at lower depth was due to higher accumulation of organic matter at the surface than the subsurface. These results were in agreement with the findings of Majumder *et al.* (2008) and Lawrence *et al.* (2015).

There was significant impact of nutrient management on the MBC (Table 3) and the highest MBC was observed in T_6 (479 mg kg^{-1})) in organic plot and it was at par with the T_5 where vermicompost was applied with lime along with the 50% of fertilizers. Lowest MBC was recorded in control (284 mg kg^{-1}). More amount of MBC in organic and integrated plot was because of the fact that organic plots provide more amount of carbon as food source and integrated nutrient management where lime was applied with other nutrient sources which also provided favourable micro environment and food source for the microbial growth. This favourable soil condition help in increasing the microbial population leads to higher MBC. Several studies confirm the higher MBC in organic and integrated nutrient management treatments (Xu *et al*., 2008; Ghosh *et al.,* 2010; Verma *et al*., 2014a). Relative proportion of MBC over TOC and SOC showed that with the application of lime and vermicpompost, MBC improves significantly and rate of change is more in comparison to SOC and TOC (Table 3). The highest proportion of MBC over TOC was recorded in T_6

Table 4. Soil organic carbon fractions, their proportion and enzyme activities affected by soil depth

Depth (cm)	Parameter							
	TOC (%)	SOC (%)	MBC (mg kg^{-1})	DHA (ug $TPFg^{-1}$ h^{-1})	PTA (mg phenol kg^{-1} hr^{-1})	SOC/TOC (%)	MBC/SOC (%)	MBC/TOC (%)
0-15	2.41^{a}	1.64^{a}	470^{a}	8.56^{a}	347^{a}	67.7^{a}	2.88^{a}	1.94^{a}
15- 30	2.30^{b}	1.42^{b}	312^{b}	4.78^{b}	226^{b}	61.7^{b}	2.17^{b}	1.35^{b}

* the values within a column followed by common letter are not significantly different by DMRT at *P= 0.05*

TOC: Total organic carbon; SOC: Soil organic carbon; MBC: Microbial biomass carbon; DHA: Dehydrogenase activity; PTA: Acid Phosphatase activity which is at par with T_5 and highest proportion of MBC over SOC was observed in the T_5 which is at par with the T_2, T_3 and T_6. Proportion of MBC to TOC varied from 1.32 to 1.94 % and MBC to SOC from 2.27 to 2.72%. It revealed that very small fraction of carbon was associated with microbial biomass. Several researchers also reported that MBC varied from 1-5% of soil carbon content (Powlson, 1994; Verma *et al.,* 2017). Soil depth also affects the MBC content (Table 4) and surface soil contains higher MBC (470 mg kg^{-1})) as compare to subsurface one (312 mg kg^{-1}). Higher MBC at surface is due to higher microbial activity because of high organic matter or carbon in the surface soil. Fang and Moncrieff (2005) also reported higher microbial C content in top 8 cm layer.

Soil enzymes

Soil enzymes (dehydrogenase and acid phosphates) activities are significantly affected by the nutrient management practices. The activity of both the enzymes followed more or less similar trend as of organic carbon pools. On an average, maximum soil enzymes activity was observed in T_6 (Organic plot) followed by the integrated, inorganic and control plots (Table 3). This might be due to high microbial biomass carbon and organic substrate which leads to high microbial activity and enzymes' activity. Several worker reported that in organic and integrated nutrient plots, more substrate availability increases the microbial population and biomass and also enhance the microbial activity and soil enzymes activity (Saha *et al.,* 200; Basak *et al.*, 2013). Soil depth also significantly affects the soil enzymes (dehydrogenase and acid phosphates) activity and it was significantly higher in the surface soil as compared to sub surface (Table 4). The more enzymes activities in surface soil might be due to more microbial activity as compared to sub surface soil. This result was supported by the findings of other researchers, where they reported that soil enzymes are most abundant and active in the upper most layers of non-disturbed soils (Taylor *et al.*, 2002; Ekenler and Tabatabai, 2003). It was also reported by several researchers that microbial activity was roughly 4-fold higher in surface than in subsurface soil (Ekenler and Tabatabai, 2003; Xiang *et al.*, 2008).

Correlation between SOC pools and soil enzymes activity

The soil organic carbon fractions (TOC and SOC) were significantly correlated (0.72**) with each other ($P \leq 0.01$) indicating the existence of a dynamic equilibrium (Table 5). Labile pool of carbon (MBC) is also significantly correlated with the TOC (0.66**) and SOC (0.83**). This proves the existence of equilibrium among the pools of SOC. Majumder *et al*. (2008), Verma *et al*. (2010, 2017) also reported a significant positive correlation among the SOC pools. Soil enzymes dehydrogenase and acid phosphatase, were significantly correlated with SOC fractions (Table 5). The reason of high correlation of soil enzymes with the SOC pools is that, enzyme activity is a microbial process and soil carbon acts as a source of food and energy for them. This indicated that high organic carbon levels provide a favourable environment for accumulation, synthesis and stimulation of soil enzymes. This observation was well supported by the finding of Wang *et al.* (2013) and Verma *et al.* (2010; 2017).

Table 5. Correlation coefficients of soil organic carbon fractions with the soil enzymes activities

	SOC	TOC	MBC	DHA	PTA
SOC	1				
TOC	0.72**	1			
MBC	0.83**	0.66**	1		
DHA	0.71**	0.61**	0.90**	1	
PTA	0.89**	0.75**	0.95**	0.89**	1

**Correlation is significant at the 0.01 level (2-tailed).
TOC: Total organic carbon; SOC: Soil organic carbon; MBC: Microbial biomass carbon; DHA: Dehydrogenase activity; PTA: Acid Phosphatase activity

Conclusions

Present study confirms that integrated nutrient management along with lime application in acid soil significantly improve the soil organic carbon pools and soil enzymes activity. Soil enzymes activities are significantly related with the organic carbon fractions. Surface soil had more amounts of organic carbon and its pools as well as enzymes activity over the sub surface soil. This experiment showed that integrated nutrient management practices (combination of inorganic and organic source of nutrients along with lime) had positive effect on soil organic carbon pools and enzymes activity in this acid soil, hence this may be adopted for improvement of soil fertility, productivity and overall soil quality.

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