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Effect of phosphorus levels on soil carbon fractions in acid soil

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ABSTRACT

A pot experiment carried out to understand the effect of phosphorous (P) application on different soil carbon fraction in acidic soil at the research farm of College of PG Studies in Agricultural Sciences (CPGS-AS), CAU (I) revealed that the microbial carbon fraction (MBC) and particulate organic matter (POM) were increased with the application of phosphorous. About 16.67% soil organic carbon (SOC), 19.09% oxidizable organic carbon fraction 1 (OOC1), 23.46% oxidizable organic carbon fraction 2 (OOC2) and 16.67% oxidizable organic carbon fraction 3 (OOC3) were decreased with application of T_5(NPK @ 80:100:40 kg ha^{-1}) over T_0(NPK @ 80:0:40 kg ha^{-1}). Dissolved organic carbon (DOC) was decreasing 16.73% with application of T_5(NPK @ 80:100:40 kg ha^{-1}) over T_0(NPK @ 80:0:40 kg ha^{-1}). However, 5% hot water extractable carbohydrates (HWC) and 2.4% water extractable carbohydrates (WC) were increased with application of T_5(NPK @ 80:100:40 kg ha^{-1}) over T_0. The SOC, OOC2, OOC3 at 30 DAS and OOC3 at crop maturity were decreasing. The SOC and OOC2 at crop maturity were finally gained its content at crop maturity. The POM, DOC, MBC and WC were lower at crop maturity than those at 30 DAS.

Key words: Available phosphorous, land use, soil organic carbon, topography, Umiam

INTRODUCTION

Considerable amount of nutrients loses from the soil every year in North Eastern Hill (NEH) region of India due to hilly terrain (77% hilly), very high rainfall (>2000 mm per annum) and shifting cultivation practice which also contribute for the development of soil acidity. Soil organic carbon (SOC) is an index of soil fertility, capacity of a soil to supply nitrogen (N), phosphorous (P), sulfur (S) and trace metals to plants (Pan et al., 2009), however, the SOC decomposition might inhibit or decrease with nutrient limitation and C:N:P ratio (Zhu et al. 2018). Microbial activities would be increased with nutrients sufficiently meet microbial C:N:P ratio requirements and SOC mineralization stimulated (Wei et al. 2017, 2019). Soil microorganisms determine the magnitude and direction of SOC mineralization (Yuan et al., 2016; Li et al., 2018). The change in SOC mineralization rate might enhance the utilization of labile resources by microorganisms (Fontaine et al., 2003). The soil management has a significant impact on soil carbon (C) fractions and N turn over and also has an effect on P dynamics. Labile soil organic carbon fractions like dissolved organic carbon (DOC), microbial biomass C (MBC), and particulate organic carbon (POC) are the fine indicators of soil quality which influence soil function and are sensitive to change in soil management practices (Xu et al., 2011; Nayak et al., 2012). The labile fraction consists of material in transition between fresh plant residues and stabilized organic matter. On the other hand, stabilized fraction of SOM is composed of organic materials that are highly resistant to microbial decomposition (Haynes, 2005). Labile fractions are the potential indicator of soil quality changes due to management practices (e.g. tillage, fertilizer and manure applications) (Marriott and Wander, 2006; Yoo et al., 2006; Sharifi et al., 2008). Measurement of labile fractions is required for a better assessment of the effects of management on soil properties (Iovieno et al., 2009) and improved understanding of labile organic matter fractions will provide valuable information for establishing sustainable fertilizer management systems to maintain and enhance soil quality. The labile fractions are microbial biomass carbon (MBC), oxidizable organic carbon (OOC), dissolved organic carbon (DOC), particulate organic carbon (POC), hot water extractable carbohydrates (HWC), water extractable carbohydrates (WC).

The soil organic carbon (SOC) content and phosphorous (P) availability in the acid soil is very much reduced because P bounded to humic substances forming a resistant P fraction and also P fix with clay, Fe, and Al contents in acid soil. Soil microorganisms help in P transformation and release from the microbial biomass, solubilisation of inorganic P and mineralization of organic P. The addition of organic materials including manures, crop residues and composts could improve soil P availability and SOC and its fractions (Bhattacharyya et al., 2011). Keeping this in view, an experiment was planned to study the effect of different P levels on the different soil carbon fractions in acid soils.

MATERIALS AND METHODS

Description of study sites

The bulk soil samples for the pot experiment were collected from College of PG Studies in Agricultural Sciences (CPGS-AS) research farm and the experiment was conducted at poly-house of the CPGS that lies between 91° 18′ to 92° 18′ E longitude and 25° 40′ to 26° 20′ N latitude with an altitude of 950 m above sea level. The experimental site falls under subtropical humid climate with high rainfall and cold winter. Monsoon normally sets in the first fortnight of June and remaining active till October with 1000-4000 mm mean annual rainfall and high humidity (above 80%). The maximum temperature rises up to 35°C in the months of July-August and minimum falls down to 5-6°C during the first week of January. The average annual rainfall of the study sites were 2349 mm; mostly confined to May to November and mean daily temperature varied from 2.58°C in January to 32.58°C in August (Choudhury et al. 2012).

Experimental details

The pot experiment was conducted in Completely Randomized Design with five replications and six treatments (Table 1) and French bean was taken as the test crop. Thirty numbers of cylindrical pots having 26 cm height with 25 cm diameter at top and 18 cm diameter at bottom were used in the experiment. Each pot was filled up with 7 kg of dried 2mm sieved soil treated with different treatments. The sources of nitrogen, phosphorous, potassium will be Urea, SSP and MOP respectively. Total amount of phosphorous and potassium as per the treatments were applied at the time of sowing. Nitrogen was applied in three split doses i.e. 50% of RDF at time of sowing, 25% of remaining 50% RDF at 30 DAS, and another 25% at 60 DAS.

Table 1. The treatment details of the experiment

Experimental design	Treatment details
Completely Randomized Design (CRD)	1) T_0- NPK @ 80:0:40 kg ha^{-1}
	2) T_1 - NPK @ 80:20:40 kg ha^{-1}
	3) T_2 - NPK @ 80:40:40 kg ha^{-1}
	4) T_3 - NPK @ 80:60:40 kg ha^{-1}
	5) T_4 - NPK @ 80:80:40 kg ha^{-1}
	6) T_5- NPK @ 80:100:40 kg ha^{-1}

Soil sample collection and processing

The samples were air dried, grinded and passed through a 0.5 mm sieve for determination of organic carbon fractions (Table 2) and immediately stored at 20ºC for analysis of DOC, HWC and MBC (Singh and Lal, 2005). The initial properties of soil were 1.77% SOC, 0.55% OOC1, 1.27% OOC2, 1.77% OOC3, 1.50% POM, 305.73 (μg g^{-1}) MBC, 730.82 (μg g^{-1}) DOC, 74.17 (μg g^{-1}) HWC and 39.73 (μg g^{-1}) WC. The very-labile (OOC1), labile (OOC2) and less-labile (OOC3) fraction of soil carbon were determined using 12N H_2SO_4, 18N H_2SO_4 and 24N H_2SO_4.

Table 2. The parameters and methods for soil organic carbon fractions analysis

Sl. No	Parameter	Method
1.	Oxidisable organic carbon	Modified wet oxidation method (Chan et al., 2001)
2.	Particulate organic matter (POM)	Size-base procedure using sodium hexametaphosphate (Gregorich and Beare, 2008)
3.	Microbial biomass carbon (MBC)	Chloroform fumigation and K_2SO_4 extraction method (Brookes and Joergensen, 2006)
4	Dissolved organic carbon (DOC)	1M KCl extraction followed by 0.45µm polycarbonate filtration method (Zsolinay, 1996 and Mc Dowell et al., 2006)
5.	Hot water extractable carbohydrate	Phenol method (Safarik and Santruckova, 1992)
6.	Water extractable carbohydrate	Phenol method (Safarik and Santruckova, 1992)

RESULTS AND DISCUSSION

Effect of phosphorus levels on different soil carbon fractions at 30 DAS

The soil organic carbon (SOC) content was decreased with mineralization with application of phosphorous (P) and soil microbes obtained energy through the catabolism of soil available C to acquire their necessary nutrients (Sinsabaugh et al., 2013; Sistla and Schimel, 2012) resulting higher microbial carbon fraction (MBC) (Table 3). Fertilization significantly affected microbial community structure (Zhang et al., 2016). The microbial decomposition rate of SOC might depend upon the nutrient limitation and C:N:P ratio (Zhu et al., 2018) (i.e. averaged C:N:P ratio 287:17:1 for soil nutrients and 42:6:1 for soil microbial biomass (Xu et al., 2013)). Microbial activities would be increased with sufficient microbial C:N:P ratio in the nutrients and SOC mineralization stimulated (Wei et al., 2017, 2019). The SOC mineralization increased exponentially with dissolved organic C (DOC):NH4+-N, DOC:Olsen P and microbial biomass (MB)C:MBN ratios (Wei et al., 2020). However there was no significant difference of MBC and particulate organic matter (POM) among the different treatments at 30 days after sowing (DAS) of French bean crop (Table 3). The MBC and particulate organic matter (POM) mineralization in short time period might not be notice. Similar results were reported by (Manna et al., 2006; Lou Y et al., 2011). On contrary, Huang et al. (2009) and Luo et al., (2016) reported that fertilization enhanced particulate organic C (POC) contents.

The result was cleared that the content of SOC and oxidizable organic carbon (OOC) fractions at 30 DAS were significantly decreased with application of increasing doses of P. About 16.67% SOC, 19.09% OOC1, 23.46% OOC2 and 16.67% OOC3 were decreased with application of T_5(NPK @ 80:100:40 kg ha^{-1}) over T_0(NPK @ 80:0:40 kg ha^{-1}). This decrement might be due to microbial translocation, plant uptake and pedogenic process of soil. An optimum C:P ratio was mandatory for mineralization and immobilization of SOC to different C fractionation. The dissolved organic carbon (DOC) ranging from 809.98 to 674.44 µg g^{-1} was also found decreasing with application of increasing dose of P. Approximately 16.73% of DOC was decreasing with application of T_5(NPK @ 80:100:40 kg ha^{-1}) over T_0(NPK @ 80:0:40 kg ha^{-1}). DOC caused C flow and increase in available nutrients and stimulated SOC mineralization. Similarly, Luo et al., (2020) found that the fertilization was significantly decreased the water-soluble organic carbon (WSOC). Fertilization might increased the soil C:N ratio resulting in decreasing DOC. Luo et al., (2020) reported that fertilization increased C:N ratio.

However, the hot water extractable carbohydrates (HWC) and water extractable carbohydrates (WC) were increasing over the T_0. About 5% HWC and 2.4% WC were increased with application of T_5(NPK @ 80:100:40 kg ha^{-1}) over T_0.

Table 3. Effect of phosphorous levels on different soil carbon fractions at 30 DAS old french bean

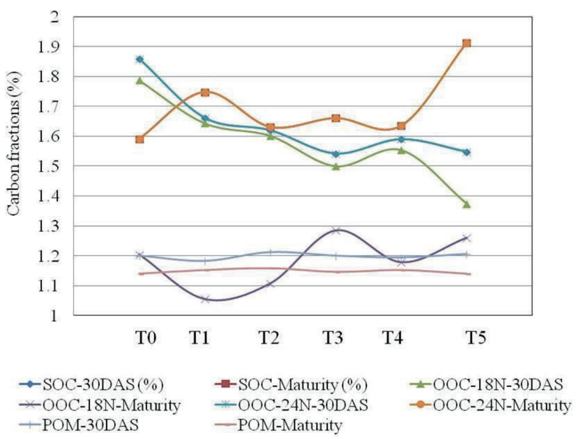
Treatment	SOC (%)	OOC1 with 12N H_2SO_4 (%) (very-labile)	OOC2 with 18N H_2SO_4 (%) (labile)	OOC3 with 24N H_2SO_4 (%) (less-labile)	MBC ($\mu g\ g^{-1}$)	POM (%)	DOC ($\mu g\ g^{-1}$)	HWC ($\mu g\ g^{-1}$)	WC ($\mu g\ g^{-1}$)
T_0	1.86	1.10	1.79	1.86	381.30	1.20	809.98	61.40	34.15
T_1	1.66	0.94	1.64	1.66	382.14	1.18	703.14	56.72	33.24
T_2	1.62	0.95	1.60	1.62	397.17	1.21	700.13	59.90	34.79
T_3	1.54	0.99	1.50	1.54	401.52	1.20	678.17	70.19	34.97
T_4	1.59	1.01	1.55	1.59	397.45	1.19	675.52	63.38	34.61
T_5	1.55	0.89	1.37	1.55	405.07	1.21	674.44	64.53	34.97
Sem±	0.02	0.03	0.03	0.02	0.02	0.02	15.24	2.54	0.41
CD5%	0.08	0.11	0.11	0.07	NS	NS	54.61	9.10	1.47

*OOC-oxidizable organic carbon fraction, MBC- soil microbial biomass carbon, POM- particulate organic matter, DOC- dissolved organic carbon, HWC- hot water extractable carbohydrates, WC- water extractable carbohydrates

Influence phosphorus levels on changing different soil carbon fractions from 30 DAS to crop maturity:

The Fig.1 was indicating the changes of different soil carbon fractions from 30 DAS till crop maturity. The figures of SOC, OOC2 and OOC3 at 30 DAS were noticed in decreasing and also OOC3 at crop maturity was also found decreased. This might be attributed to microbial utilization of such labile fractions of carbon as source of their energy. The SOC and OOC2 at crop maturity were observed depressions and finally gained its content at crop maturity. The POM at 30 DAS and crop maturity were maintained in uniform lined, however, POM at crop maturity was lower than the POM at 30 DAS.

The DOC and MBC at 30 DAS were found higher amount as compared to DOC and MBC at crop maturity. The HWC at 30 DAS and maturity were found not much changed with different P applications. The WC at 30 DAS was little bite higher amount than the WC at crop maturity.



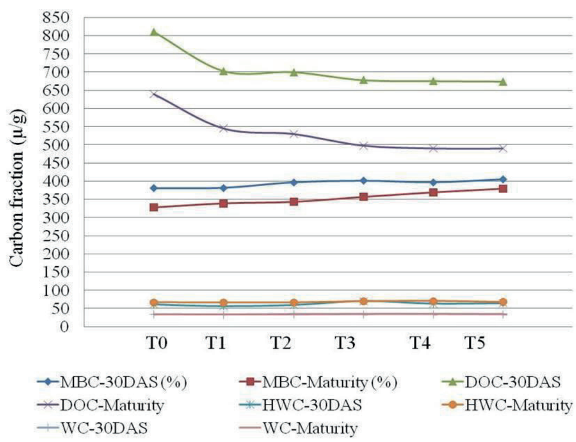


Fig. 1. Effect of phosphorus levels on changing different soil carbon fractions during crop (French bean) growing

CONCLUSION

Application of 100% recommended dose of P_2O_5 (i.e. NPK @ 80:100:40 kg ha^{-1}) in acidic soil was resulted in decreasing about 16.67%, 19.09%, 23.46%, 16.67%, 16.73% of SOC, oxidizable organic carbon fraction 1 (OOC1), OOC2, OOC3 and Dissolved organic carbon (DOC) respectively, however, increased MBC, POM, HWC (5%) and WC (2.4%). Therefore, it was concluded that the mineralization of labile carbon pools such as OOC1, OOC2 and OOC3, DOC were increased the phosphorous availability in acid soil.

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