ACTA SCIENTIFIC AGRICULTURE (ISSN: 2581-365X)

Volume 2 Issue 12 December 2018

Research Article

Morphological and Physico-Chemical Analysis of Graphite Affected Black soil

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Received: September 18, 2018; **Published:** November 26, 2018

Abstract

We analyze the effect of graphite powder on Black soil collected from Cauvery delta region, Tamil Nadu, India. Soil samples were collected from the top 15 cm depth from the experimental site using conventional soil tillage technology. We provide a detailed comparison of the morphological and physico-chemical changes of black soil samples with and without addition of graphite powder. FTIR, SEM, EDAX and soil analysis data support the fact that graphite powder application significantly influences soil physico-chemical properties and soil carbon, exchange capacity of fine-textured black soil.

Keywords: Black Soil; Morphological and Physico - Chemical Properties; Soil Quality; Graphite Powder

Introduction

Restoration of soil quality through soil organic carbon (SOC) management has remained the major concern for tropical soils [1]. Soil organic matter plays an important role in nutrient cycling and can support to improve the soil structure. Ideal soil has more organic matter, sufficient mineral nutrients, good soil aeration and higher water holding capacity and enabling better crop growth and development. Soil pH, cation exchange capacity (CEC) and nutrient availability are significant soil chemical properties for crop growth and development. Water holding capacity (WHC) and soil bulk density (SBD) are fundamental soil physical properties playing an essential role in crop production and productivity [2-6]. The dynamics of above soil physical properties are mainly inhibited by organic matter, mineral matter and porosity of soil. Numerous studies have been conducted to understand the relationship between SBD and SOM content of soil and obtain a strong positive relationship between them3. SOM is the most important soil component, which enhances the soil quality by improving soil structure, WHC and nutrient availability. Organic matter is the prime habitat for a large number and variety of soil fauna and micro flora, which play a critical role in the health and productivity of soils. SOM is highly susceptible to changes in land use and management, soil temperature and moisture [12].

In Tamil Nadu, India, black soil occupies 72% of the area and is distributed in all the districts of the state. Most of the black soils are temperate in organic carbon and available nutrients and display moderate soil physical properties such as low WHC, moderate soil structure, and surface and subsurface crusting. This black soil physical properties and organic carbon directly influence the soil microbial load. They severely affect crop production under changing climate. SOC build-up in soil is essential to sustain crop protection and reduce soil degradation under vulnerable climate. In this context, use of graphite power as soil amendment for increasing organic carbon is recommended. Carbon is present in two well-known allotropes - diamond and graphite. Diamond is the basic structural element and hardest material, whereas graphite is adequate to form a splotch on paper. Graphite is the most thermodynamically stable structure and is stable against rapid decomposition. So, application of graphite powder may increase the organic carbon and related soil properties. Generally, graphite powder is being used as a lubricant in the mechanical devices of planter. To increase crop yield through better seed planting is the basic practice in Africa and Kenya and mid-west of Europe. Designing the seed by adding graphite and talc powder is practiced for increasing the size of seed. This study explores the influence of graphite powder application on soil organic carbon and cation exchange capacity and their interaction. The present study was conducted using graphite powder mixed with black soil in different ratios in order to assess the soil carbon build-up, changes in soil physical and chemical properties, and their positive and negative interaction under laboratory conditions [12].

Materials and Methods

The study was conducted in padalur, Perambalur district of TN. It is located at an altitude of 133.3m amsl, and lying between 11°14'00.59" N and 78°52'59.85" E. The changes of temperatures between 32°C and 24°C respectively. The highest recorded temperature is 36 and the lowest is 23°C. On an average, the district gets 861 mm of rainfall in a year. Perambalur receives 270 mm rainfall from South West monsoon (June - September) and 464 mm heavy rain fall from North East Monsoon (October - December). Black soil sample (size approx. 2 mm) of about 2 kg was collected and allowed to dry in air for 14 h. It was analysed for physical, chemical and physico chemical properties using standard methods. Table 1 indicates the soil nutrient concentrations of black soil sample and physico chemical parameters of the sample. The pH and EC of soil samples were determined in 1: 2.5 soil and water suspension. The SOM was obtained from estimated SOC using the conversion equation SOM = 1.53 X SOC.

S. No.	Wave Number (cm^{-1})	Bond Type	Functional Groups (cm^{-1})
1	3401.96	N-H (Stretch)	amines
2	2373.01	−C≡C−	alkynes
3	2344.97	−C≡C−	alkynes
4	1637.38	N-H(Bend)	amines
5	1400.78	C-H(Bend)	alkanes

Table 1: FTIR spectrum of Black soil after the addition of graphite powder.

To determine the soil physical properties such as bulk density, porosity and particle density, the Keen- Rackzowski box method was employed [5,6]. Soil nutrients such as calcium and magnesium, and CEC were determined using Cohex method; sodium, potassium using flame photometer, and SOC using Walkley and Black method [7,8]. The Black soil CEC was estimated, CEC (Cmol +/Kg) = Exchangeable (Ca^{2+} + Mg^{2+} + Na^{2+} + K) X 1.0 (Factor value).

A cathode-ray tube (CRT) was used as a display unit. The scan speed of the electron probe can be transformed in various steps, A fast scan speed is used for observations and a slow scan speed is used for acquisition or saving of images. The soil is exposed to a narrow electron beam from an electron gun, which rapidly scans the surface of the specimen. This causes the release of secondary electrons and other types of radiations from the specimen surface. The intensity of these secondary electrons depends upon the shape and the chemical composition of the irradiated object. These electrons are collected by a detector, which generates electronic signals. These signals are scanned and produce an image on a CRT. Earlier, the SEM image appearing on the CRT was photographed using a camera. In the recent times, the image is being recorded in digital format.

Figure 1

Result and Discussions

FTIR analysis

FTIR spectra clearly indicated the presence of graphite powder in the collected soil and it was confirmed by vibrated peaks of organic molecules in IR spectra. Combination bands and in FTIR spectra due to the OM results from the stretching of various functional groups such as N-H (3401 cm^{-1}) [9-11]. Application of graphite powder in combination with Cohex positively influenced the organic carbon and cation activity of Black soil. It was clearly evidenced from FTIR spectra (Figure 2). The band at 2373 cm^{-1} and 2344 cm^{-1} denotes the presence of c≡c of the alkynes, whereas the band at 1029 cm^{-1} Bending represents the N-H amines which strongly denotes the presence of amine of Cohex compound.

Additionally, the band at 1400 cm^{-1} may be due to C-H bending, which supports the presence of graphite in the soil sample.

Figure 2

SEM analysis

The scanning electron microscope images in figure 3 represents the mean diameter of graphite powder is 10 µm and that the shape is irregular. Also, mean diameter of Black soil and graphite powder added black soil is 3 µm. SEM image of Black soil clearly shows that it has more of macro particles and macrospores, which are directly responsible for low WHC and aeration. SEM image of graphite powder mixed Black soil shows smaller particle size and a greater number of micro pores. This may due to the small particle size of graphite powder. The fine particles of graphite enter into the cavity of the macro pores and reduce the pore size, which ultimately increases the microspores in the soil. Graphite mixed with Black soil also increases the WHC and aeration status of the soil, which is mainly due to the presence of more micro pores in the graphite powder applied black soil. CEC of graphite powder added black soil samples is significant ($P \leq 0.05$) and positively correlated with porosity (R_{black} = 0.942) and WHC (R_{black} = 0.986). WHC and aeration are the prime factors that influence nutrient availability and microbial load of soils. Graphite powder addition in different ratios slightly increased the soil pH from 7.60 to 8.02 from the original value of 7.06. Electrical conductivity data shows irregular trend and BD reduced from 1.45 to 1.39 Mg/m^3. Application of graphite powder positively influenced the porosity of the Black soil. The porosity varied from 24% to 35% and WHC increased to the tune of 51-60% in varied ratio of 5-25% of graphite powder application. CEC and basic exchange capacity (BEC) vary significantly under graphite powder treated soil. Higher CEC (35.10 Cmol+/kg) and BEC (17.5-Ca, 15.5-Mg, 3.90-Na, 0.56-K) are recorded under graphite powder against the control.

Figure 3: SEM images of (a) graphite powder, (b) Black soil sample and (c) graphite-added Black soil sample.

Statistical analysis

The Pearson correlation analysis represents the CEC of the graphite-added Black soil is significant ($P \leq 0.05$) which is positively correlated with SOC ($R_{black} = 0.962$) and BEC of studied soil sample (Table 2). EDS data also support the fact that graphite powder mixed black soil has more Ca, Mg, Na than other cations.

Soil parameters	Correlation	BEC			
	Pearson Correlation Sigma (2-ailed)	Ca	Mg	Na	K
CEC		0.979	0.953	0.991	0.976
		0.004	0.012	0.001	0.004
	N	5	5	5	5

Table 2: Correlation of cation exchange capacity (CEC) and base exchange capacity (BEC).

The addition of graphite powder in black soil, which has low base exchange shows positive response and increases the soil CEC. CEC of the graphite-added black soil samples is not significant ($P \geq 0.05$) but which is negatively correlated ($R_{black} = - 0.011$) with pH of soil samples. CEC of graphite-added black soil samples is significant ($P \leq 0.05$) which is negatively correlated with EC (Rblack = -0.941) and bulk density ($R_{black} = -0.991$) of soil samples. CEC of the graphite added black soil samples is significant ($P \leq 0.05$), negatively correlated (Rblack = -0.948) with particle density of soil samples.

EDX analysis

EDX clearly reveals that application of graphite powder in black soil influences oxygen dynamics in the studied soil (Figure 4). The oxygen content is 31% in soil, but graphite powder - mixed soil shows 44.99% oxygen, which is mainly due to the porosity changes of graphite powder and accumulation of more oxygen (Table 3). Iron content also shows positive black soil changes and addition of graphite powder increases the iron content from 8.13% to 11.95% in the soil. Calcium, potassium and magnesium are important basic cations influencing CEC of the soil. Graphite powder application significantly increases the calcium, potassium and magnesium contents to the tune of 3.11%, 2.12% and 0.66% in the soil. This is mainly responsible for higher CEC of graphite powder applied soil. In contrast to the other elements, nitrogen content reduces from 31.26% to 25.67%, which is 5.59% lower than black soil. This reduction is mainly due to the high microbial immobilization of nitrogen in the graphite powder-mixed soil. Graphite has higher carbon content, which acts as food material and favours microbial growth in black soil. The increased microbes required more.

Nitrogen for sustaining growth, for that they utilized nitrogen from the soil to meet their demands and deplete the soil nitrogen from the original level.

Figure 4: EDX images of (a) Black soil sample and (b) graphite powder-added Black soil sample.

Elements	Black soil	Graphite Powder added Black soil
Oxygen	31	44.99
Silicon	18.75	27.36
Aluminium	6.64	9.32
Iron	8.13	11.95
Calcium	2.06	3.11
Nitogen	31.26	25.67
Potassium	1.89	2.12
Magnesium	0.25	0.66

Table 3: Elemental composition of Black soil and graphite powder added Black soil.

Conclusion

Application of graphite in the Fine-textured black soil augmented the SOC and positively influenced soil morphological and Physico-Chemical properties. SEM images showed smaller particle size and a greater number of micro pores in graphite powder mixed black soil. It increased the CEC and influenced oxygen, nitrogen, silicon, aluminium and iron contents in the black soil. The method has been tested under laboratory conditions and found to be cost-effective. However, it needs to be tested in field conditions in different types of soil to optimize the graphite powder dose for different crops under changing climate.

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