with increase in storage. Among the treatments, significant difference was also observed with 15% AvCC-treated carrots having minimum decrease compared to uncoated peeled carrots. The minimum microbial load was found in 15% AvCC-treated carrots (7.08 and 6.42 log cfu/g) at room and refrigerated conditions respectively.

Thus, the results showed that 15% AvCC treatment is better than 10% AvCC and 5% AvCC in enhancing the shelf life of peeled carrots. There were significant changes in TSS, total sugars, total carotenoids and microbial composition during storage, indicating that the peeled carrots coated with 15% AvCC could be kept wholesome till 12 and 24 days under room and refrigerated conditions respectively.

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Effect of ultra graphite application on morphological and physico-chemical properties of red soil

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We assess the effect of ultra graphite on red 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 morpho- and physico-chemical changes of red soil samples with and without ultra graphite. FTIR, SEM, EDAX and soil analysis data support the fact that ultra graphite application significantly influences soil carbon, soil physico-chemical properties and exchange capacity of coarse-textured red soil.

Keywords: Morphological and physico-chemical properties, red soil, soil quality, ultra graphite.

RESTORATION of soil quality through soil organic carbon (SOC) management has remained the major concern for tropical soils[1]. Soil organic matter (SOM) plays an essential

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role in nutrient cycling and support to develop good 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 important soil chemical properties for crop growth and development. Water holding capacity (WHC) and soil bulk density (SBD) are fundamental soil physical properties playing a vital role in crop production and productivity[2]. The dynamics of above soil physical properties are mainly controlled 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 them[3].

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 microflora, 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.

In Tamil Nadu (TN), India, red soil occupies 60% of the area and is distributed in all the districts of the state. Most of the red soils are low in organic carbon and available nutrients, and display poor soil physical properties such as low WHC, poor soil structure, and surface and subsurface crusting. The poor soil physical properties and low organic carbon directly influence the soil microbial load. They severely affect crop production under changing climate.

SOC build-up in red 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 soft enough to form a blotch 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 ultra graphite (UG) powder (highly purified graphite powder with fixed carbon >98% and particle size of 2–2000 μm) application on soil organic carbon and cation exchange capacity and their interaction.

The present study was conducted using UG powder mixed with red 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.

The study was conducted in Madukkur, Thanjavur district of TN. It is located at an altitude of 59 m amsl, and lying between 10°15′–11°2′N and 78°10′–79°5′E. The mean maximum and minimum temperatures vary between 32.2°C and 21.2°C (Figure 1). The highest temperature ever recorded is 37.4°C and the lowest is 24.7°C. On an average, the district receives 938 mm of rainfall in a year – 273.3 mm rainfall from the southwest monsoon (June–September) followed by high rainfall of 394.8 mm from the northeast monsoon (October–December).

Red 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 procedures. Table 1 shows the nutrient concentrations and physico-chemical parameters of red soil sample. The pH and electrical conductivity 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 × SOC.

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 red soil CEC was calculated using the relation

$$\text{CEC (centi-mol}^{+}\text{/kg)} = \text{Exchangeable } (Ca^{++} + Mg^{++} + K^{+}) \times \text{factor value (1.0)}.$$

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 uisng a camera. In the recent times, the image is being recorded in digital format.

FTIR spectra clearly indicated the presence of UG in the studied soil and it was confirmed by vibrated peaks of organic molecules in IR spectra. Overtones and combination bands in FTIR due to organic matter effect from the stretching of various functional groups such as N–H (3423 cm^{-1})[9–11]. Application of ultra graphite in

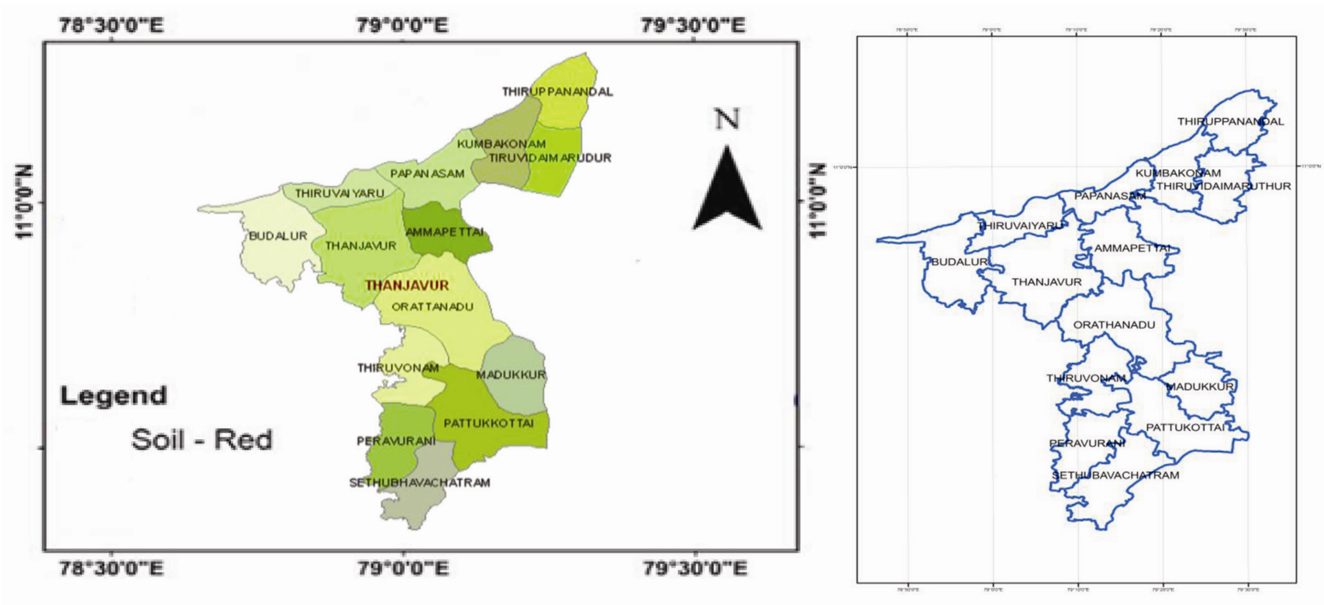

Figure 1. Map of study area.

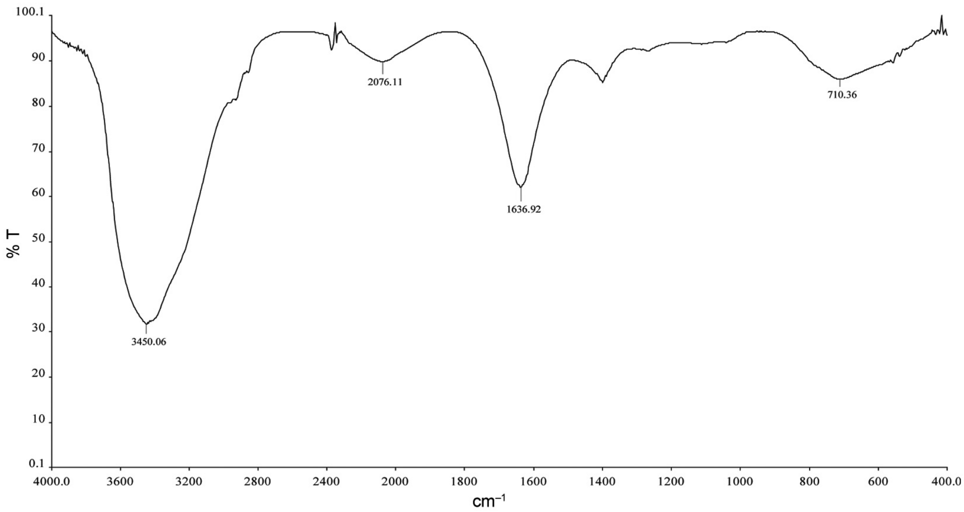

Figure 2. FTIR spectrum of red soil after addition of graphite.

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

Wave number (cm^{-1})	Bond type	Functional group (cm^{-1})
3423	N–H (stretch)	Amines
2087	C≡C	Alkynes
1648	N–H (bend)	Amines
1029	C–N (stretch)	Aliphatic amines

combination with Cohex positively influenced the organic carbon and cation activity of red soil. It was clearly evidenced from FTIR spectra (Figure 2). The band at 1648 cm^{-1} indicates the presence of N–H bending of the amines, whereas the band at 1029 cm^{-1} represents C–N of aliphatic amines which strongly confirm the presence of amine of Cohex compound. Additionally, the weak band at 714 cm^{-1} may be due to C–C bending, which supports the presence of graphite in the soil sample.

The scanning electron microscope (SEM) images in Figure 3 indicate that the mean diameter of graphite powder is about 10 µm and that the shape is irregular. Also, mean diameter of red soil and graphite powder-added red soil is about 2 µm.

SEM image of red soil clearly shows that it has more of macro particles and macrospores, which are directly responsible for low WHC and aeration. SEM image of UG mixed red soil shows smaller particle size and more number of micropores. This may due to the small particle size of graphite powder. The fine particles of graphite

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

Soil parameters		CEC	BEC			
			Ca	Mg	Na	K
CEC	Pearson correlation	1	0.898	0.987	0.991	0.997
	Sigma (two-tailed)		0.038	0.002	0.001	0.001
	N	5	5	5	5	5

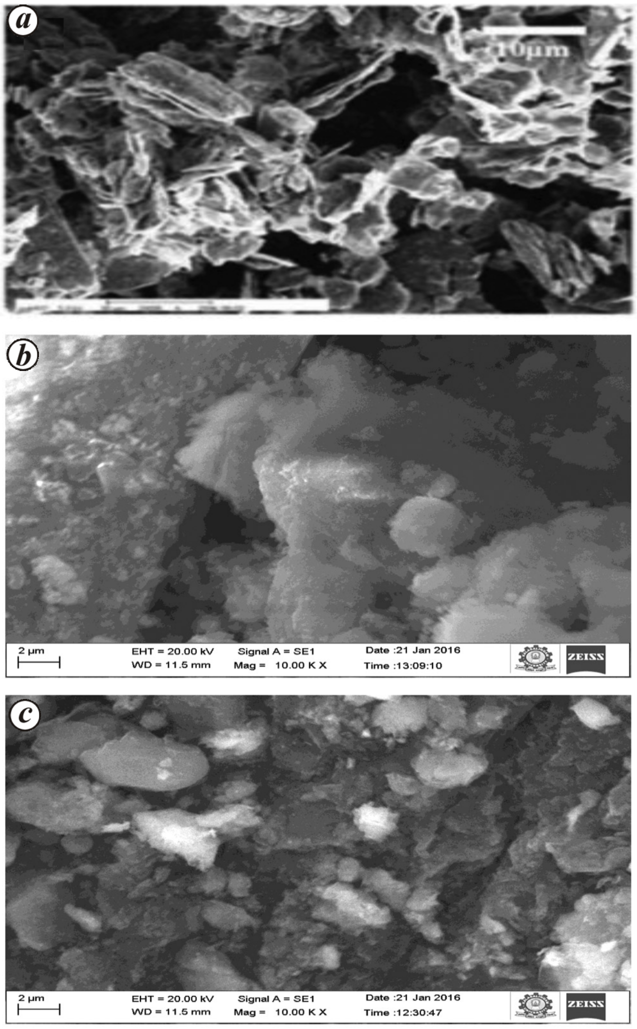

Figure 3. SEM images of (***a***) graphite powder, (***b***) red soil sample and (***c***) graphite-added red soil sample.

enter into the cavity of the macropores and reduce the pore size, which ultimately increases the microspores in the soil. Graphite mixed with red soil also increases the WHC and aeration status of the soil, which is mainly due to the presence of more micro pores in the UG applied red soil. CEC of graphite-added red soil samples is significant ($P \leq 0.05$) and positively correlated with porosity ($R_{red} = 0.983$) and WHC ($R_{red} = 0.993$). WHC and aeration are the prime factors that influence nutrient availability and microbial load of soils.

UG addition in different ratios slightly increased the soil pH from 7.12 to 7.15 from the original value of 7.06. Electrical conductivity data shows irregular trend and SBD reduced from 1.70 to 1.60 Mg/m^3. Application of UG positively influenced the porosity of the red soil. The porosity varied from 44% to 49% and WHC increased to the tune of 35–39% in varied ratio of 5–25% of UG application. CEC and base exchange capacity (BEC) vary significantly under UG treated soil. Higher CEC (19.95 cmol$^+$/kg) and BEC (9.20–Ca, 8.30–Mg, 3.04–Na, 0.31–K) are recorded under UG against the control. According to the Pearson correlation coefficient, CEC of the graphite-added red soil is significant ($P \leq 0.05$) and positively correlated with SOC ($R_{red} = 0.974$) and BEC of studied soil sample (Table 2). EDS data also support the fact that UG has more Ca, Mg, Na than other cations. The addition of UG in red soil, which has low base exchange shows positive response and increases the soil CEC. CEC of the graphite-added red soil samples is not significant ($P \geq 0.05$) but positively correlated ($R_{red} = 0.050$) with pH of soil samples. CEC of graphite-added red soil samples is significant ($P \leq 0.05$) and negatively correlated with EC ($R_{red} = -0.942$) and bulk density ($R_{red} = -0.937$) of soil samples. CEC of the graphite added red soil samples is not significant ($P \geq 0.05$) and negatively correlated ($R_{red} = -0.504$) with particle density of soil samples.

EDX clearly reveals that application of graphite powder in red soil influences oxygen dynamics in the studied soil (Figure 4). The oxygen content is 17.7% in soil, but graphite-mixed soil shows 33.2% oxygen, which is mainly due to the porosity changes of UG and accumulation of more oxygen (Table 3). Iron content also shows positive changes and addition of UG increases the iron content by 1.5% 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 0.4%, 0.15% and 0.01% 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 57.5% to 25.7%, which is 31.8% lower than red 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 red soil. The increased microbes required more

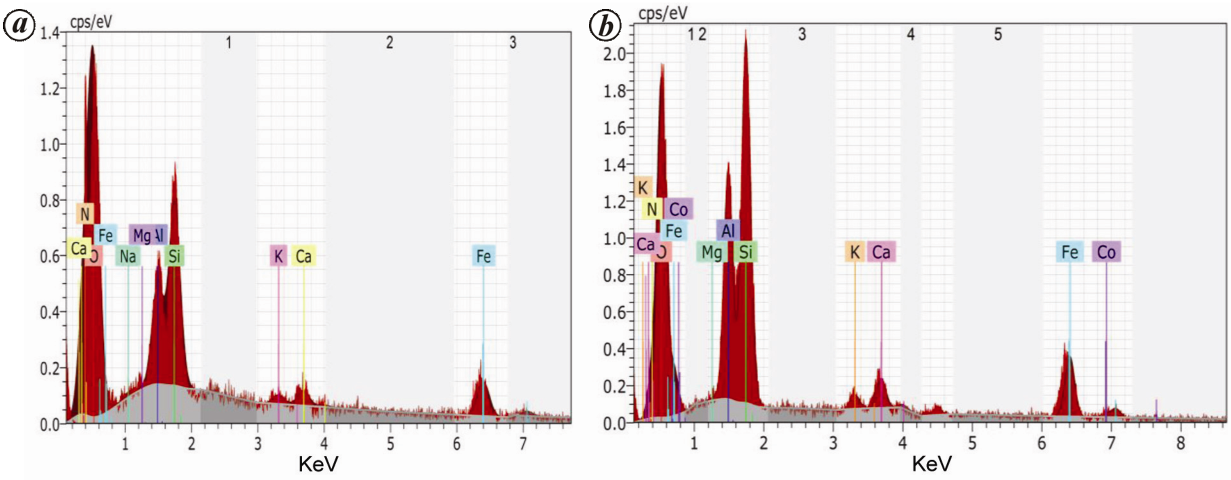

Figure 4. EDX images of (***a***) red soil sample and (***b***) graphite powder-added soil sample.

Table 3. Elemental composition of red soil and ultra graphite-added red soil

Elements	Red soil (%)	Graphite powder-added red soil (%)
Oxygen	17.7	33.2
Silicon	8.28	16.9
Aluminium	5.74	11.5
Iron	7.76	9.27
Calcium	1.42	1.86
Nitrogen	57.5	25.7
Potassium	0.76	0.91
Magnesium	0.10	0.11

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.

Application of UG in the coarse-textured red soil augumented the SOC and positively influenced soil morphological and physico-chemical properties. SEM images showed smaller particle size and more number of micropores in UG-mixed red soil. It increased the CEC and influenced oxygen, nitrogen, aluminium and iron contents in the red 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 UG dose for different crops under changing climate.

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