Soil Physicochemical Properties Variation in Black Soil after the Long-term Application of Different Organic Amendments

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Authors’ contributions

This work was carried out in collaboration among all authors. Author JW supervised the study, designed the study, conceptualization, fund and resources acquisition. Author YOK wrote the protocol, data curation and validation and also wrote the first draft of the manuscript. Author XC managed the software and formal analysis. Author AS performed the statistical analysis and data curation. Author SGA managed the literature searches and final editing and review of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This research aimed to assess how the physicochemical properties of black soil respond to different organic amendments after 10 years of application.

Study Design: The experiment was established in 2010 and followed a randomized block design consisting of 24 plots (5 m × 5 m) 25 m² with eight treatments in three replicates.

Place and Duration of Study: The study site was located at the Jilin Agricultural University Research Farm, Northeast China (43°48’ N, 125°23’ E; km).

Methodology: The treatments for the study included an annual input of chemical fertilizer and organic amendments at the surface of the soil. The treatments were: Control (CK), chicken manure...
1. INTRODUCTION

Due to the increase in the human population, there have been several ways to protect natural resources and also use them in a manner that will ensure sustainability. Soil happens to be one of the important resources that need to be used sustainably. This is because it forms the basic material that supports plant life [1]. In order to be able to feed the increasing population, soils are subjected to huge stress ranging from fertilizer application, use of machinery, etc [2]. The effects of these stress are usually manifested through the physicochemical properties of the soil. The fertility and productivity of the soil usually depend on these physical and chemical properties.

According to Cooperband [3], the soil is made up of four primary components: mineral matter, air, water, and organic matter whereby each component plays a special function in the soil. However, soil organic matter is generally considered to be a line that combines the biological, chemical and physical properties of soil to promote soil fertility. It is related to many soil functions such as water retention and drainage, nutrient cycling, disease control, erosion control and pollution restoration [3]. Intensive agricultural systems have degraded soils by decreasing soil organic matter which in turn reduces soil fertility and increases soil erosion [4]. Several techniques have been developed to enhance soil organic matter since it plays a very important role in enhancing the properties of the soil. Soil physicochemical properties are highly dependent on the quantity and quality of organic matter in the soil [5,6]. For the past decades, soil organic amendment has been used to circumvent the loss of the organic matter in the soil since it has been proven to be an effective method for improving soil organic matter content [6]. It has been shown in previous studies that the use of organic materials as organic fertilizers serves as an effective way to manage agricultural waste which also improves the chemical, physical, and biological properties of the soil to promote the growth of plants [3,7,8].

Soil physicochemical properties form an important aspect of the soil since it determines the suitability of the soil for its planned use [9]. Also, the productivity and health of soil usually depend on its physicochemical properties [10]. The study site was set up in 2010 and the soil type is black soil. The black soil is characterized by its high fertility hence serves as the most important grain production area in China [11]. Amidst the high fertility of the soil, studies have reported that intensive agricultural production has led to a depletion of the black soil [8,12] however no study has been conducted to ascertain how the physicochemical properties of the black soil are affected by organic amendments application. The physical and chemical properties of soils are important indicators for assessing soil quality [13].
Therefore, understanding the beneficial relationship between soil organic amendments and the physicochemical properties of the black soil is very imperative in this era of soil degradation. This knowledge will, therefore, help practitioners and farmers to understand the appropriate organic amendment that will improve the productivity and health of their farm soils. We hypothesize that the application of organic amendments can improve soil physicochemical properties. The aim of this study is to determine how different organic amendment application affects the physicochemical properties of the soil.

2. MATERIALS AND METHODS

2.1 Study Site

The study site was located at the Jilin Agricultural University Research Farm, Northeast China (43°48′N, 125°23′E; km). The soil in the area was classified as Udic Mollisol according to the international soil taxonomy classification. The area has a typical continental temperate monsoon climate and the cumulative temperature (≥10°C) is about 2950–3500°-days (C). The average precipitation is about 500–600 mm per year.

2.2 Experimental Design

The experiment was established in 2010 and followed a randomized block design consisting of 24 plots (5 m × 5 m) 25 m2 with eight treatments in three replicates. The treatments for the study included an annual application of chemical fertilizer and organic amendments at the surface layer of the soil (0–20 cm). Table 1 shows the chemical composition of the seven organic amendments used in this study. The treatments were: control (CK), chicken manure (JM), fodder grass (FG), mushroom (MS), maize straw (MZ), tree leaf (TL), pig manure (PM) and cow manure (CM). Chemical fertilizers were added at the rate of 165 kg of N, 82.5 kg of P and 82.5 kg of K ha−1 per year. Application rates of organic materials were adjusted to similar amounts of organic matter (2000 kg ha−1).

2.3 Soil Sampling

In June 2019, soil samples were taken from each of the amended fields. In each field, three sampling points were randomly selected. Soil samples were collected from the 0–20 cm depth using a core sampler then taken to the laboratory for soil physicochemical properties analysis.

2.4 Soil Laboratory Analysis

Soil compaction was evaluated using the bulk density of soil samples. The bulk density of the soil samples was analyzed on undisturbed samples which were collected using the core sampling method as described by [14]. Using this method, soils were sampled or collected by drilling the core sampler into the soil. The core samples collected were oven-dried and the bulk densities were calculated by dividing the masses of the oven-dry soils by their respective volumes. The volumes will be determined by the volume of the core sampler used for the sampling.

Bulk density (BD) of the soil was calculated as:

\[
\text{BD} = \frac{\text{mass of oven dry soil (g)}}{\text{volume (cm}^3\text{)}}
\]

Soil porosity was determined from soil particle density and bulk density using the Army, U.S. [15] equation shown below:

\[
\text{Porosity (pt)} = 1 - \frac{\text{bulk density (pb)}}{\text{particle density (pd)}} \times 100\%
\]

where particle density was estimated to be 2.66 g/cm3.

The soil water characteristics curve was determined using the pressure plate extractor, where about 7 data points were acquired from the air-entry value (suction) and the remaining water content in the soil [16].

<table>
<thead>
<tr>
<th>Organic amendment</th>
<th>pH</th>
<th>Organic matter/ (g kg−1)</th>
<th>Total N/ (g kg−1)</th>
<th>Total P/ (g kg−1)</th>
<th>Total K/ (g kg−1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize straw</td>
<td>6.42</td>
<td>493</td>
<td>8.33</td>
<td>1.12</td>
<td>12.34</td>
</tr>
<tr>
<td>Fodder grass</td>
<td>6.69</td>
<td>343.60</td>
<td>15.29</td>
<td>2.74</td>
<td>10.82</td>
</tr>
<tr>
<td>Mushroom</td>
<td>7.09</td>
<td>248.79</td>
<td>11.27</td>
<td>1.78</td>
<td>7.26</td>
</tr>
<tr>
<td>Chicken manure</td>
<td>8.03</td>
<td>240.11</td>
<td>17.07</td>
<td>8.79</td>
<td>14.09</td>
</tr>
<tr>
<td>Cow manure</td>
<td>7.27</td>
<td>302</td>
<td>13.9</td>
<td>3.60</td>
<td>8.32</td>
</tr>
<tr>
<td>Pig manure</td>
<td>7.63</td>
<td>268.91</td>
<td>21.18</td>
<td>8.79</td>
<td>14.09</td>
</tr>
<tr>
<td>Tree leaf</td>
<td>6.14</td>
<td>371</td>
<td>9.91</td>
<td>1.02</td>
<td>4.05</td>
</tr>
</tbody>
</table>

Table 1. Chemical properties of the organic amendments used in this experiment
The soil particle size distribution was determined following the hydrometer method [17]. Soil aggregate stability was determined by two methods; wet sieving and dry sieving methods [18,19]. In the dry sieving method, 500 g of soil was placed on topmost of a nest of seven flat sieves of mesh sizes 10, 7, 5, 3, 2, 1, 0.5, 0.25 and shaken for 5 min. The shaking and vibratory movement of the sieves was achieved mechanically using a dry-sieving machine having two rotors rated 0.18kW each, 1450r/min and vibration distance of <5 mm (soil dry pellet analyzer, model DM185, Chinese model). Prior to sieving, the nest of sieves together with a collection pan of the same size was placed beneath the nested sieve and held in place with a tight lid over the topmost sieve, to prevent no loss of soil particles during the sieving.

\[ \text{MWDd} = \sum_{i=1}^{n} x_i d_i \]

Where MWDd = Mean-Weight Diameter of dry aggregates (mm), \( x_i \) = Mean Diameter of each size fraction (mm), di = proportion of total sample weight occurring in the corresponding size fraction.

In the wet sieving method, soil samples were separated into size fractions by hovering the nest of sieves (up and down movement) in a pool of water [18,20]. In this procedure, 50 g of soil from the different treatments was placed on the uppermost nest of the six flat sieves with sizes 5, 3, 2, 1, 0.50 and 0.25 mm. The sieves were lifted and lowered in the water at an amplitude of 4 cm, and there were 35 of such oscillations per min. Prewetting was done by allowing the base of the topmost sieve to slightly touch the water level, such that the wetting was through sorption. Thereafter, the sieves were completely plunged in water for 5 min, followed by manual oscillation for 1 min. Soil aggregates that were resistant to breaking (water-stable aggregates, WSAs) remained on the sieves. The aggregates were oven-dried at 105°C for 16.5 h to determine their weights.

\[ \text{WSA} = \sum_{i=1}^{n} x_i w_i \]

Where WSA = weight of water-stable aggregates, \( x_i \) = each size fraction, \( n \) = the number of the different size fractions, \( w_i \) = [weight of a given size fraction/total weight of soil (50 g)]*100%.

Soil pH and electrical conductivity (EC) were determined by using a pH meter and EC meter respectively. Soil total nitrogen (TN) and soil organic carbon (SOC) were respectively determined using the Kjeldahl method [21] and the K2Cr2O7 external heating method [22].

2.5 Statistical Analysis

Data on soil physicochemical properties under the different organic amendments were collected. The data were subjected to statistical analysis using ANOVA (Analysis of Variance). Duncan’s new multiple range tests were used for multiple comparisons to compare treatment means to test their significance in variation. All data analysis was done using Microsoft Excel 13.0 and SPSS 17.0. Results were presented in tables and graphs.

3. RESULTS AND DISCUSSION

Table 2 shows the effect of the different treatments on bulk density, porosity, electrical conductivity, pH, soil particle size distribution (percentage of clay, sand, and silt), total nitrogen and Soil Organic Carbon (SOC).

3.1 Soil Bulk Density and Soil Porosity Variation under the Different Organic Amendments

The results showed that the application of organic amendments reduced the bulk density (BD) of the soil compared with the control. Among the organic amended fields, the BD of treatments JM, FG, TL, MZ and MS were lower but had no significant difference between them (\( P < .05 \)). The highest BD was recorded in the control and the lowest was recorded in treatment FG. Some research works have proved that soil physical fertility is mainly improved by the addition of organic amendments which increases aggregate stability and decreases soil bulk density [23,24]. Hence Akgül and Özdemir [25] suggested that due to the importance of bulk density it can serve as a suitable indicator of soil quality assessment. The findings of this study showed that the amended fields recorded the lowest bulk densities compared with the control which had no organic amendment. The lower bulk density values recorded in the amended fields can mainly be attributed to the increased organic matter content in the soil. This is due to the fact that the addition of organic amendments improves the organic matter content of the soil thereby resulting in a reduction of the bulk density of the soil. This observation was consistent with the findings of Gardner et al. [26], Wang et al. [26] and Tejada et al. [27] who all
reported a decrease in soil bulk density after the application of organic amendments.

Due to the inverse proportional relationship between bulk density and porosity, in most studies, a decrease in bulk density caused a rise in porosity [28,29,30]. Similar results were recorded for soil porosity, where the lowest porosity was observed in the control and the highest was observed in treatment FG. Also, the porosity of treatments JM, FG, TL, MZ, and MS were higher but had no significant difference between them (P < .05). In this study, the addition of organic amendments significantly increased the porosity of the soil. This could be attributed to the lower intrinsic density of organic material compared to mineral soils, which reduces the dry bulk density of soils receiving organic amendments thereby increasing the total porosity of the soil [28]. This result was consistent with past studies such as Pagliai and Vittori [31] and Péres et al. [32], who also reported similar findings.

### 3.2 Effects of Different Organic Amendments on Soil Water Characteristics

Fig. 1 shows how the different organic amendments affected the water retention curves of the soils. At higher suctions, the highest water content was recorded in TL (44%) whiles the lowest was recorded in CK (18%). Throughout the incubation period, the water content reduced with an increase in suction however at 200 kPa, the water content increased for all the treatments with the exception of treatment PM. After 200 kPa, the water content subsequently reduced when the suction range was increased (Fig. 1). The soil-water characteristic curve helps to determine the infiltration rate of the soil and its ability to store and release water for plants' use [33]. The high water content in the organic amended fields at higher suction potentials can be attributed to the potential ability of the organic materials to improve aggregates stability, increase the porosity of the soil and decrease the bulk density thereby creating more pores for water storage [34]. Previous studies have reported that, various factors including the pore size distribution, organic matter content, and the soil bulk density influence the soil water retention characteristics [35,36,37].

### 3.3 Soil Particle Size Distribution under the Different Organic Amendments

The soil particle size distribution varied significantly comparing the other treatments to CK (P < .05) however in all the fields, the textural class was clay-loam. The soil particle size distribution was highly dominated by silt and clay for the organic amended area with % sand being the lowest. An opposite trend was observed for the control whereby the % sand was higher with low % silt and clay. The % silt and clay in the organic amended fields were between 31.40-40.11% and 34.07-39.1% respectively, which was higher than that of the control while the %sand in the control was 35.76% which was also higher than the organic amended fields. Aydinalp [38] and Ghiberto et al. [39] have reported that generally, the particle size distribution of mollisols follows an ascending order of sand, clay, and silt. Thus, usually, the %silt and clay are higher than sand. High silt or clay content and low sand content are characteristic of the soil matrix of Mollisols. In the current study, the particle size distribution among the various treatments did not vary from that of a typical mollisol and the textural class for all the treatments was clay-loam. This is because soil particle size distribution forms one of the properties of soil which takes a long time to change with soil management practices [40]. The high silt and clay content in the organic amended fields could be a result of the high organic matter content in mollisols which causes clay and silt particles to bind to organic matter due to their mineralogy and surface charge properties [41,42]. The high clay and silt contents of the organic amended soils are also attributed to the high CEC with the organic matter found in the amendments [38].

### 3.4 Variation of Aggregate Stability under the Different Organic Amendments

From the results in Table 3, the different organic amendments affected soil aggregate stability differently. The water-stable aggregates for the organic material treatments were significantly higher compared with CK, with the exception of treatment PM which was higher than CK but had no significant difference (P < .05). The highest water-stable aggregates were recorded in MS while the lowest was recorded in CK. For the dry aggregate stability, although the recorded values for all the treatments ranged between 91-92.3%, however, the dry aggregate stability for the organic material treatments were significantly higher compared with CK (P < .05). In all, the organic material treatments improved the dry aggregate stability and water-stable aggregates by 0.21-1.1767% and 2.26-19.84% respectively. The MWDd and WSA values varied significantly
### Table 2. Summary of results

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Bulk density (g/cm³)</th>
<th>Porosity (%)</th>
<th>Electrical conductivity (mS/cm)</th>
<th>pH</th>
<th>% Clay</th>
<th>% Sand</th>
<th>% Silt</th>
<th>Total N g kg⁻¹</th>
<th>SOC g kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>1.55±0.01</td>
<td>41.66±0.45</td>
<td>0.12±0.00</td>
<td>5.70±0.01</td>
<td>31.00±0.90</td>
<td>35.76±1.02</td>
<td>33.23±0.42</td>
<td>0.73±0.00</td>
<td>19.84±0.33</td>
</tr>
<tr>
<td>PM</td>
<td>1.38±0.02</td>
<td>47.96±0.83</td>
<td>0.14±0.00</td>
<td>5.75±0.00</td>
<td>38.94±0.80</td>
<td>29.65±0.78</td>
<td>31.40±0.58</td>
<td>1.10±0.04</td>
<td>21.11±0.82</td>
</tr>
<tr>
<td>JM</td>
<td>1.28±0.02</td>
<td>51.65±0.75</td>
<td>0.13±0.00</td>
<td>5.76±0.01</td>
<td>37.97±0.75</td>
<td>28.34±1.06</td>
<td>33.67±1.21</td>
<td>1.13±0.10</td>
<td>20.10±0.43</td>
</tr>
<tr>
<td>MZ</td>
<td>1.28±0.01</td>
<td>51.54±0.59</td>
<td>0.13±0.00</td>
<td>5.73±0.01</td>
<td>34.07±0.62</td>
<td>30.73±0.77</td>
<td>35.20±1.05</td>
<td>0.86±0.01</td>
<td>22.63±0.55</td>
</tr>
<tr>
<td>MS</td>
<td>1.30±0.02</td>
<td>50.51±0.83</td>
<td>0.13±0.00</td>
<td>5.75±0.01</td>
<td>38.32±1.23</td>
<td>25.92±0.14</td>
<td>35.32±1.02</td>
<td>0.75±0.01</td>
<td>21.36±0.33</td>
</tr>
<tr>
<td>FG</td>
<td>1.27±0.00</td>
<td>52.24±0.33</td>
<td>0.15±0.00</td>
<td>5.75±0.01</td>
<td>37.41±0.63</td>
<td>23.55±0.48</td>
<td>39.03±0.23</td>
<td>0.94±0.03</td>
<td>22.25±0.25</td>
</tr>
<tr>
<td>CM</td>
<td>1.47±0.01</td>
<td>44.66±0.61</td>
<td>0.15±0.00</td>
<td>5.80±0.01</td>
<td>39.11±0.60</td>
<td>28.59±0.83</td>
<td>32.90±0.81</td>
<td>0.98±0.01</td>
<td>21.36±0.33</td>
</tr>
<tr>
<td>TL</td>
<td>1.32±0.01</td>
<td>50.31±0.46</td>
<td>0.13±0.00</td>
<td>5.70±0.00</td>
<td>36.96±0.80</td>
<td>22.92±1.00</td>
<td>40.11±0.24</td>
<td>0.98±0.03</td>
<td>23.51±0.21</td>
</tr>
</tbody>
</table>

Note: Values present are means and ±standard error. Different treatments in the same column followed by the same superscript are not significantly different (P = .05)
compared with the control. This was not consistent with the findings of Obalum et al. [43] where compost application and tillage did not influence the dry aggregate stability. The MWDd values for all the treatments ranged between 91-92.3% which generally implies that organic materials application was unlikely to influence wind erosion in the black soil since the soil aggregates from the different treatments were dominated by large particles (details not shown). However, the application of different organic materials significantly affected the soil dry aggregate stability. In addition, the high percentage of water-stable aggregates in the organic material treatments might be due to the increase in organic matter content which accelerated important microbial activities in the soil to improve aggregation [44]. Several studies such as Diacono and Montemurro [24], Annabi et al. [45], and Wang et al. [46] posited that the application of organic materials significantly improved soil aggregate stability.

3.5 The Variation of Soil pH and Electrical Conductivity under the Different Organic Amendments

Compared to the control, the pH of all the treatments varied significantly with the exception of treatment TL ($P < .05$). Among all the treatments the highest pH was recorded in the manure amended fields especially in treatment CM and the lowest was recorded in CK. This was due to the liming and buffering effect of CACO3 in cow manure [47,48]. Moreover, the nature of amendments affects the pH, thus if the applied amendment has a low pH, it will affect the pH of the soil and vice versa [49]. The high pH in the organic amended fields could have been due to any of the under mentioned mechanisms or combinations; proton consumption during the removal of carboxyl groups from the organic acids anions which occur during decomposition [50], proton consumption by functional groups associated with the organic materials [51] and the release of hydroxide ions from local anaerobic microsites during reduction reactions [52]. Similar results were reported by several authors [29,47,48]. Several studies have reported that the application of manure moves soil pH towards neutrality in alkaline and acidic soils thereby improving nutrient availability especially for phosphorus and other micronutrients [53,54]. This move towards neutrality favors plant growth and other beneficial microbial processes. Therefore, solid manure should be regarded not only as a source of nutrients but also as a beneficial soil conditioner [55].

Compared to CK, the EC of all the treatments varied significantly however, the EC of treatments MZ, JM and TL did not vary significantly compared with CK ($P < .05$). Among all the treatments highest EC was recorded in treatment CM and FG and the lowest was recorded in CK. Soil electrical conductivity (EC) is known to correlate with other soil properties including soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, and subsoil characteristics to directly affect crop productivity [56]. In the present study, the highest EC was observed in the amended fields. This may be due to the presence of saline ions in the organic amendments that were applied. The solubilization and mineralization processes that occur after the application of the organic amendments release soluble mineral nutrients that contain salt [57]. A similar result was reported by [34], who stated that there was an increase in soil EC after the application of biosolids. Also, manures are believed to contain salts due to the feed additives given to the livestock hence can increase soil EC when applied as a fertilizer [58].

3.6 Total Nitrogen and SOC under the Different Organic Amendments

Comparing all the treatments to CK the TN and SOC of all the treatments were significantly different ($P < .05$). Among all the treatments, the lowest TN and SOC were recorded in the control (CK) while the highest TN and SOC were recorded in JM and TL respectively. Among the organic amended fields, the TN and SOC of the treatments were significantly different with the exception of CM and TL which had no significant difference in TN content ($P < .05$). The application of organic amendments increased SOC content which is important for improving soil environment and promoting SOC storage [59]. The increase in SOC in the organic amended fields was attributed to the enhanced organic matter content with the addition of organic amendments. This enhances the soil structure to reduce the microbial degradation of organic materials [60]. Among the organic amendment treated fields, TL recorded the highest SOC due to the higher lignin and polyphenols contents and higher lignin/N ratios in TL which reduces the rates of decomposition thereby increasing SOC accumulation in the soil [61]. Several studies
such as Fan et al. [8], Hu et al., [61] and Wu et al., [62] have reported similar results. TN also increased after the application of organic amendments compared with the control. This may be due to the initial high contents of nitrogen in the organic amendments. Similar results were reported by Frederickson et al. [63] and Oo et al. [30].

4. CONCLUSION

After studying the long-term effects of the organic amendment application on the physicochemical properties of soil, the results of this study showed that treatments that involved the application of organic materials significantly improved the physicochemical properties of the soil. This was mainly attributed to improved organic matter content. From the study, the different organic amendments had different effects on the physicochemical properties of the black soil. Comparatively, treatment FG highly improved most of the soil physicochemical properties tested in this study (BD, porosity, EC, and texture). As such, we recommend treatment FG as an effective treatment for ameliorating degraded soils in order to improve their quality and physicochemical properties. The findings of this study can help farmers, practitioners and managers to select appropriate organic amendments that will help to ameliorate degraded agricultural soil to promote socio-economic development. Further long term studies that go beyond 10 years can be carried on.

Fig. 1. Effects of organic amendments applications on soil water retention curves

Table 3. Aggregate stability analysis under the different organic amendments

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Wet aggregate stability % (WSA)</th>
<th>Dry aggregate stability % (MWDd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>61.1000⁰⁰ ±1.33551</td>
<td>91.0400⁰⁰ ±0.02022</td>
</tr>
<tr>
<td>PM</td>
<td>63.3600⁰⁰ ±1.12907</td>
<td>92.2167⁰⁰ ±0.15295</td>
</tr>
<tr>
<td>JM</td>
<td>70.6467⁰⁰ ±0.57877</td>
<td>91.2633⁰⁰ ±0.07670</td>
</tr>
<tr>
<td>MZ</td>
<td>70.5200⁰⁰ ±1.40627</td>
<td>91.6810⁰⁰ ±0.04073</td>
</tr>
<tr>
<td>MS</td>
<td>80.9467⁰⁰ ±1.50388</td>
<td>91.2503⁰⁰ ±0.12919</td>
</tr>
<tr>
<td>FG</td>
<td>70.6133⁰⁰ ±1.19048</td>
<td>91.5050⁰⁰ ±0.13211</td>
</tr>
<tr>
<td>CM</td>
<td>76.5200⁰⁰ ±3.31888</td>
<td>91.5783⁰⁰ ±0.04812</td>
</tr>
<tr>
<td>TL</td>
<td>75.2200⁰⁰ ±1.81960</td>
<td>91.2650⁰⁰ ±0.07461</td>
</tr>
</tbody>
</table>

Note: Different treatments in the same column followed by the same superscript are not significantly different (P < .05). Numbers in parentheses are standard errors of the means.
out to know the long term effects of organic materials on soil properties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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