# Acomparison between Effect Humic Acids Extracted with Sodium and Potassium Hydroxide from Different Animal Organic Manure on Soil Properties and the Growth and Yield of Beetroot

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## Abstract

Field experiment was conducted during the 2024-2025 winter season in the fields of the College of Agricultural Engineering Sciences - University of Baghdad - Al-Jadriya. The aim was to comparing effect of humic acids extracted with sodium hydroxide and potassium hydroxide from different animal organic fertilizers on soil properties in presence of sugar beet. The experiment included three factors: humic acid extracted with sodium hydroxide (B1), humic acid extracted with potassium hydroxide (B2), and three animal organic fertilizers used in extraction of humic acids: sheep manure (OM1), cow manure (OM2), and pigeon manure (OM3). Two concentrations of humic acids, 5% (C1) and 10% (C2), were added to the irrigation water in five applications ten days after plant emergence. Fourteen treatments were conducted, along with two control treatments (no humic fertilizer or mineral fertilizer) and one treatment with 100% of the recommended mineral fertilizer. The treatments were repeated three times, resulting in a total of 42 experimental units. The results showed that pigeon manure (OM3) significantly increased soil organic matter and cation exchange capacity (CEC). The experimental treatments had no significant effect on soil pH. Sheep manure (OM1) had a significant effect on electrical conductivity, while cow manure (OM2) had a significant effect on bulk density. The second concentration (10%) of extracted humic acids showed a significant effect on soil organic matter, cation exchange capacity, and bulk density compared to the first concentration (5%). Regarding the triple interaction B2OM3C2 yielded the highest concentration in soil organic matter, while the B2OM2C2 interaction yielded the highest concentration in soil pH. For electrical conductivity (EC), the B2OM1C2 interaction yielded the highest concentration, and for cation exchange capacity, the B1OM3C2 interaction yielded the highest value. Finally, for bulk density, the B1OM1C1, B1OM2C1, and B2OM2C1 interactions yielded the highest concentrations.

**Keywords: Organic fertilizers, Apparent density, CEC**

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# Introduction

With the rise of sustainable and organic farming, the need arose to use humic acids and organic fertilizers to increase soil organic carbon content, thereby enhancing aeration, improving soil structure, and increasing water retention capacity. Numerous studies in this field have addressed the organic content of humic acids (N, H, O, C) and E4/E6 (aromaticity), as well as their organic sulfur and phosphorus content (5). Commercial organic fertilizers contain 15-85% humic substances. Currently, there is no precise method for isolating and purifying humic substances (7).

Humic substances are complex, bioactive organic materials originating from the remains of microorganisms and plant and animal remains found in nature. Soil and humus are natural sources of these substances, which are high molecular weight organic materials with diverse and complex properties. Humic substances are generally classified into three types based on their solubility: humic and fulvic acids, which are soluble in basic solvents, and humin, which is residual and insoluble in both bases and acids. These substances contain Humic acids are classified into major functional groups, namely carboxylates, phenols, carbonyls, hydroxylates, amines, and amides. Based on their chemical properties, they are used in industry, agriculture, the environment, and biomedicine.

(6) found that humic acids affect on cell protoplasm and cell walls due to their hormonal effects, leading to faster cell division and growth, and consequently, increased plant height. The ability of humic substances to form chelating complexes with heavy metals such as cadmium is used to protect organisms from heavy metals and in ongoing medical research and studies.

Humic acids can be extracted using 0.1 *M* NaOH or 0.5 *M* KOH (10). Sodium hydroxide is characterized by its high sodium ion content, which can negatively impact soil properties in arid and semi-arid regions, unlike potassium hydroxide, which has a high potassium ion content, essential for plants. Beetroot (*Beta vulgaris*) belongs to the Chenopodiaceae family and contains a high percentage of betalains, the compound that gives beetroot its red color and is considered one of the strongest antioxidants. It has a sweet taste and is rich in vitamins and nutrients. It contains 90% water, 5% fiber, and 2% ash, in addition to sugars, organic and amino acids, vitamins, and elements. Beetroot is grown from seed in temperate climates. In Iraq, it thrives during the autumn, winter, and spring seasons, as it flourishes in temperatures up to 16°C. The current research aims to determine the effect of humic acid, extracted with sodium and potassium hydroxides from sheep, cattle, and pigeon manure, on soil organic matter, cation exchange capacity, bulk density, soil pH, and electrical conductivity in the presence of beetroot.

# Materials and Methods

A field experiment was conducted with the cultivation of sugar beet in the autumn season of 2024-2025 in the fields of the College of Agricultural Engineering Sciences - University of Baghdad in the Al-Jadriya area. The experimental treatments included three factors: the extraction of humic acids using 0.5 *N* NaOH, symbol B1, and 0.5 *N* KOH, symbol B2, and three animal organic fertilizers used in the extraction of humic acids, namely sheep manure, symbol OM1, cow manure, symbol OM2, and pigeon manure, symbol OM3. Humic acid was added at two concentrations: 5%, symbol C1, and 10%, symbol C2. Humic acid was added with the irrigation water ten days after the emergence of the plants and in five batches. 75% of the recommended mineral fertilizer for the treatments (200, 53, 100 kg N, P and K $ha^{-1}$) was added respectively (1). Phosphorus was added in the form of DAP fertilizer and potassium in the form of potassium sulfate in one batch next to and below the plants by 5 cm ten days after the emergence of the seedlings in the form of furrows. As for the remainder of the nitrogen, it was added with the irrigation water in the form of urea fertilizer 20 and 40 days after the emergence of the plants. The number of treatments was 12, in addition to two control treatments without adding any mineral fertilizer and humic acid, and a treatment adding 100% mineral recommendation. So the number of treatments became 14. The treatments were repeated 3 times, so the number of experimental units became 42 experimental units in bords with an area of 4 $m^2$. The number of lines was 6, with a distance of 30 cm between them, leaving 10 cm between the first and last lines and the outer borders of the panels. Soil properties were estimated before planting (Table 1) and at the end of the experiment, represented by OM, pH, EC, bulk density, and CEC. The optical density of humic and fulvic acids E4/E6 was analyzed (to estimate the level of humification in organic matter during decomposition) at wavelengths of 400 and 600 nm.

Humic acids (humic and fulvic) extracted from different animal organic materials were estimated using an HPLC instrument type 9100 YL at the Scientific Research Authority – Department of Environment and Water (Table 2), as reported in( 8, 2, 9). The properties of the organic fertilizers used in the study were estimated as reported in (15) (Table 3).

ISSN 2072-3857

## Table (1) Some Soil Properties Before Planting

| Unite | Value | Properties | |
|---|---|---|---|
| - | 7.8 | Soil Reaction pH 1:1 | |
| $dS\ m^{-1}$ | 1.28 | Electrical Conductivity EC1:1 | |
| $Cmol_+\ kg^{-1}$ Soil | 25.7 | cation Exchange Capacity CEC | |
| $g\ kg^{-1}$ Soil | 16.5 | Organic Matter | |
| | 220 | Carbonate Minerals | |
| $mmol\ L^{-1}$ | 3.5 | Calcium $Ca^{2+}$ | Soluble Positive Ions |
| | 2.0 | Magnesium $Mg^{2+}$ | |
| | 1.9 | Sodium $Na^{+}$ | |
| | 0.84 | Potassium $K^{+}$ | |
| | Nil | Carbonate $CO_3^{2-}$ | Soluble Negative Ions |
| | 2.8 | Bicarbonate $HCO_3^{-}$ | |
| | 2.4 | Sulfate $SO_4^{2-}$ | |
| | 6.4 | Chloride $Cl^{-}$ | |
| $mg\ kg^{-1}$ Soil | 21.6 | Nitrogen | Available Ions |
| | 12.8 | Phosphorus | |
| | 130.0 | Potassium | |
| $Mg\ m^{-3}$ | 1.47 | | Bulk Density |
| $g\ kg^{-1}$ | 450 | Sand | Particle Size distribution |
| | 180 | Clay | |
| | 370 | Silt | |
| Loam | | | Texture |

ISSN 2072-3857

## Table (2) Some Properties of Humic Acids

| Humic % | Fulvic % | E4/E6 | Potassium | Phosphorus | Nitrogen | Humic Acid |
|---|---|---|---|---|---|---|
| | | | % | | | |
| 40.9 | 24.6 | 10.7 | 0.22 | 0.17 | 0.1 | Sheep KOH |
| 41.8 | 22.3 | 2.50 | 0.20 | 0.19 | 0.1 | Sheep NaOH |
| 43.7 | 25.8 | 11.1 | 0.31 | 0.31 | 0.1 | Cattle KOH |
| 45.9 | 23.2 | 7.20 | 0.22 | 0.12 | 0.1 | Cattle NaOH |
| 37.8 | 21.9 | 6.20 | 0.70 | 0.39 | 0.2 | Pigeon KOH |
| 39.8 | 20.7 | 4.94 | 0.40 | 0.34 | 0.2 | Pigeon NaOH |

## Table (3) Properties of Organic Fertilizers Used in Humic Acid Extraction

| Unit | Organic Fertilizer | | | Properties |
|---|---|---|---|---|
| | Pigeons with Bedding OM3 | Cattle OM2 | Sheep OM1 | |
| - | 7.7 | 7.9 | 7.7 | pH 1:5 |
| $dS\ m^{-1}$ | 4.8 | 5.5 | 7.2 | EC 1:5 |
| % | 40.0 | 31.0 | 32.0 | Organic Carbon |
| | 69.0 | 53.4 | 55.2 | Organic Matter |

ISSN 2072-3857

| | | | | |
|---|---|---|---|---|
| % | 5.1 | 1.5 | 2.0 | Total Nitrogen |
| | 1.1 | 0.80 | 0.82 | Total Phosphorus |
| | 1.7 | 0.92 | 0.80 | Total Potassium |
| - | 7.8 | 20.7 | 16 | C/N |
| % | 500 | 230 | 260 | Water holding Capacity |

## Results and Discussion:

### 1- Effect of experimental treatments on soil organic matter (g $kg^{-1}$) after harvest.

Table (4) shows the effect of the study factors on soil organic matter (g $kg^{-1}$) after harvest. The table indicates no significant differences between the two humic acids extracted with sodium hydroxide and potassium hydroxide on the soil organic matter after harvest. However, the same table shows significant differences between the fertilizer sources used to extract the humic acids. The humic acid extracted from pigeon wastes using NaOH and KOH yielded the highest concentration 23.1 g $kg^{-1}$, followed by the humic acid extracted from cow wastes 17.9 g $kg^{-1}$, and finally the humic acid extracted from sheep wastes.

The table also shows significant differences between the 5% and 10% concentrations of the two humic acids extracted from the organic soil material after harvest. The second concentration, C2, yielded the highest concentration 20 g $kg^{-1}$, compared to the first concentration, which yielded 17.7 g $kg^{-1}$. The table also indicates no significant differences for binary interactions. However, the same table shows significant differences for ternary interactions, with the interaction B2OM3C2 yielding the highest concentration 26.3 g $kg^{-1}$, compared to the interaction B1OM1C1 at 13.7 g $kg^{-1}$. Furthermore, the ternary interaction had a significant effect compared to the recommendation of a complete mineral fertilizer (OM0R100) and the control treatment of no humic or mineral fertilizer (OM0R0). It appears that the organic matter in most treatments increased compared to before planting 16.5 g $kg^{-1}$ as a result of the addition of humic acids, despite the decomposition of the organic matter in the plant life cycle.

ISSN 2072-3857

**Table (4) Effect of experimental treatments on organic soil material (g $kg^{-1}$) after harvest**

| B * OM | | C | | OM | B |
|---|---|---|---|---|---|
| | | C2 | C1 | | |
| 15.1 | | 16.5 | 13.7 | OM1 | B1 |
| 17.0 | | 18.1 | 15.9 | OM2 | |
| 21.3 | | 21.8 | 20.9 | OM3 | |
| 16.2 | | 16.7 | 15.7 | OM1 | B2 |
| 18.8 | | 20.7 | 16.8 | OM2 | |
| 24.8 | | 26.3 | 23.3 | OM3 | |
| | | 13.60 | | OM0R100 | |
| | | 13.00 | | OM0R0 | |
| N.S | LSD 0.05 | 5.31 | | LSD 0.05 | |
| B * C | | | | | |
| Average B | | C2 | C1 | B | |
| 17.80 | | 18.80 | 16.80 | B1 | |
| 19.90 | | 21.20 | 18.60 | B2 | |
| N.S | LSD 0.05 | N.S | | LSD 0.05 | |
| OM * C | | | | | |
| Average OM | | C2 | C1 | OM | |
| 15.70 | | 16.60 | 14.70 | OM1 | |
| 17.90 | | 19.40 | 16.40 | OM2 | |
| 23.10 | | 24.00 | 22.10 | OM3 | |
| 2.640 | LSD 0.05 | N.S | | LSD 0.05 | |
| | | C2 | C1 | C | |
| | | 20 | 17.7 | Average C | |
| | | 2.160 | | LSD 0.05 | |

(13 ,3) confirmed that potassium hydroxide (KOH) yields higher humic material extraction due to its high affinity for dissolving the phenolic and carboxyl groups that make up humic compounds, leading to a significant increase in organic matter. This increase is also attributed to the chemical nature of pigeon wastes, which often have a low (C/N) ratio. This means that the organic matter contains a high nitrogen-to-carbon ratio, resulting in rapid decomposition of organic matter in the soil. (11) indicated that bird wastes are characterized by high nutrient concentrations, which increases organic matter and humus production during decomposition. Furthermore, increasing the concentration to 10% creates a more alkaline environment, thus releasing a greater quantity of humic acids. (4) confirmed that the concentration of the extracted humic solution affects the amount of organic matter released.

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## 2- Effect of experimental treatments on soil pH after harvest.

Table (5) shows the effect of experimental treatments on soil pH after harvest. The table shows no significant differences for the studied treatments and binary interactions in soil pH. However, the same table shows significant differences for ternary interactions, with the B2OM2C1 interaction yielding the highest value 7.87. The ternary interaction also showed significant differences compared to the recommended total mineral fertilizer OM0R100 and the control treatment (no fertilizer added) OM0R0. It appears that the soil pH decreased slightly as a result of the interaction of experimental treatments compared to the pre-planting value 7.8, due to the combined effects of source and concentration, as reported by (4).

**Table 5: Effect of experimental treatments on soil pH after harvest**

| B * OM | | C | | OM | B |
|---|---|---|---|---|---|
| | | C2 | C1 | | |
| 7.78 | | 7.80 | 7.77 | OM1 | B1 |
| 7.75 | | 7.77 | 7.73 | OM2 | |
| 7.65 | | 7.70 | 7.60 | OM3 | |
| 7.62 | | 7.60 | 7.63 | OM1 | B2 |
| 7.75 | | 7.63 | 7.87 | OM2 | |
| 7.68 | | 7.67 | 7.70 | OM3 | |
| | | 7.77 | | OM0R100 | |
| | | 7.80 | | OM0R0 | |
| N.S | LSD 0.05 | 0.192 | | LSD 0.05 | |
| B * C | | | | | |
| Average B | | C2 | C1 | B | |
| 7.73 | | 7.76 | 7.70 | B1 | |
| 7.68 | | 7.63 | 7.73 | B2 | |
| N.S | LSD 0.05 | N.S | | LSD 0.05 | |
| OM * C | | | | | |
| Average OM | | C2 | C1 | OM | |
| 7.70 | | 7.70 | 7.70 | OM1 | |
| 7.75 | | 7.70 | 7.80 | OM2 | |
| 7.67 | | 7.68 | 7.65 | OM3 | |
| N.S | LSD 0.05 | N.S | | LSD 0.05 | |
| | | C2 | C1 | C | |
| | | 7.694 | 7.717 | Average C | |
| | | N.S | | LSD 0.05 | |

(12 ,13)

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## 3- Effect of experimental treatments on soil electrical conductivity ($dSm^{-1}$) after harvest.

Table (6) shows the effect of experimental factors on the electrical conductivity of the soil ($dSm^{-1}$) after harvest. The table indicates significant differences between the two humic acids extracted with sodium hydroxide and potassium hydroxide. The humic acid extracted with potassium hydroxide yielded the highest concentration 1.06 $dS\ m^{-1}$, compared to 0.93 $dS\ m^{-1}$ with sodium hydroxide. The table also shows significant differences between the fertilizer sources used to extract the humic acids. The humic acid extracted from sheep manure yielded the highest concentration 1.12 $dSm^{-1}$, followed by the acid extracted from pigeon manure 0.97 $dSm^{-1}$, and finally the acid extracted from cow manure 0.90 $dS\ m^{-1}$. The concentrations did not have a significant effect on the electrical conductivity. The table also shows significant differences in the two-way interaction between the organic fertilizer sources used in humic acid extraction and their concentrations. The OM1C2 interaction yielded the highest concentration 1.37 $dSm^{-1}$. The interactions between the fertilizer source and the extraction solution, and between the concentration and the extraction solution, did not have a significant effect on electrical conductivity. The table also shows significant differences in the three-way interaction, with the B2OM1C2 interaction yielding the highest concentration 1.65 $dSm^{-1}$. The three-way interaction also showed a significant difference compared to the complete mineral fertilizer recommendation OM0R100 and the control treatment (no fertilizer added) OM0R0. It appears that the soil electrical conductivity after the application of the treatments and at harvest was generally lower than before planting (1.28 $dS\ m^{-1}$). This may be due to salt leaching caused by rain and irrigation.

**Table (6) Effect of experimental parameters on soil electrical conductivity ($dS\ m^{-1}$) after harvest**

| B * OM | | C | | OM | B |
|---|---|---|---|---|---|
| | | C2 | C1 | | |
| 0.99 | | 1.09 | 0.90 | OM1 | B1 |
| 0.88 | | 0.90 | 0.85 | OM2 | |
| 0.92 | | 0.85 | 0.99 | OM3 | |
| 1.24 | | 1.65 | 0.83 | OM1 | B2 |
| 0.93 | | 0.85 | 1.00 | OM2 | |
| 1.02 | | 0.93 | 1.11 | OM3 | |
| | | 0.98 | | OM0R100 | |
| | | 0.78 | | OM0R0 | |
| N.S | LSD 0.05 | 0.222 | | LSD 0.05 | |
| B * C | | | | | |

ISSN 2072-3857

| | | | | |
|---|---|---|---|---|
| Average B | | C2 | C1 | B |
| 0.93 | | 0.94 | 0.92 | B1 |
| 1.06 | | 1.15 | 0.98 | B2 |
| 0.097 | LSD 0.05 | N.S | | LSD 0.05 |
| OM * C | | | | |
| Average OM | | C2 | C1 | OM |
| 1.12 | | 1.37 | 0.87 | OM1 |
| 0.90 | | 0.88 | 0.93 | OM2 |
| 0.90 | | 0.89 | 1.05 | OM3 |
| 0.119 | LSD 0.05 | 0.168 | | LSD 0.05 |
| | | C2 | C1 | C |
| | | 1.04 | 0.95 | Average C |
| | | N.S | | LSD 0.05 |

The humic acid extracted with potassium hydroxide from sheep manure and the second concentration gave the highest electrical conductivity. This may be due to the increased concentration of dissolved ions resulting from the decomposition of organic compounds in the manure (6 ,13) table (3). Also, the basic decomposition of complex organic compounds into simpler and ionic forms enhances the electrical conductivity of the solution.

## 4- Effect of experimental treatments on soil bulk density (Mg $m^{-3}$) after harvest.

Table (7) shows the effect of experimental treatments on soil bulk density (Mg $m^{-3}$) after harvest. The table indicates a significant difference between the two humic acids extracted with sodium hydroxide and potassium hydroxide. The humic acid extracted with sodium hydroxide gave the highest reading 1.41 Mg $m^{-3}$, while the humic acid extracted with potassium hydroxide gave the lowest reading 1.38 Mg $m^{-3}$. The table also shows a significant difference between the sources of organic fertilizers used in extracting the humic acids. The humic acid extracted from cow manure gave the highest concentration 1.41 Mg $m^{-3}$, followed by the acid extracted from sheep manure 1.39 Mg $m^{-3}$, and finally the acid extracted from pigeon manure 1.38 Mg $m^{-3}$. The table also showed a significant difference in the concentrations of humic acids. The first concentration (5%) yielded the highest reading 1.41 Mg $m^{-3}$, while the second concentration (10%) yielded 1.37 Mg $m^{-3}$. The table also revealed significant differences in the three-factor interaction, with B1OM1C1, B1OM2C1, and B2OM2C1 all yielding the highest concentration of 1.43 µg $m^{-3}$. Furthermore, the three-factor interaction showed a significant difference compared to the complete mineral fertilizer recommendation

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(OM0R100) and the control treatment (no fertilizer added) (OM0R0). The results indicate that the soil bulk density before planting was 1.47 Mg $m^{-3}$ and decreased due to the addition of humic acids and the increased activity of plant roots.

**Table (7) Effect of experimental treatments on bulk density of soil (Mg $m^{-3}$) after harvest**

| B * OM | | C | | OM | B |
|---|---|---|---|---|---|
| | | C2 | C1 | | |
| 1.42 | | 1.41 | 1.43 | OM1 | B1 |
| 1.41 | | 1.39 | 1.43 | OM2 | |
| 1.40 | | 1.39 | 1.41 | OM3 | |
| 1.35 | | 1.31 | 1.39 | OM1 | B2 |
| 1.42 | | 1.40 | 1.43 | OM2 | |
| 1.37 | | 1.33 | 1.40 | OM3 | |
| | | 1.44 | | OM0R100 | |
| | | 1.46 | | OM0R0 | |
| N.S | LSD 0.05 | 0.05 | | LSD 0.05 | |
| B * C | | | | | |
| Average B | | C2 | C1 | B | |
| 1.41 | | 1.39 | 1.42 | B1 | |
| 1.38 | | 1.35 | 1.41 | B2 | |
| 0.019 | LSD 0.05 | N.S | | LSD 0.05 | |
| OM * C | | | | | |
| Average OM | | C2 | C1 | OM | |
| 1.39 | | 1.36 | 1.41 | OM1 | |
| 1.41 | | 1.40 | 1.43 | OM2 | |
| 1.38 | | 1.36 | 1.40 | OM3 | |
| 0.024 | LSD 0.05 | N.S | | LSD 0.05 | |
| C1 | | | | | |
| | | C2 | C1 | C | |
| | | 1.3717 | 1.4139 | Average C | |
| | | 0.019 | | LSD 0.05 | |

(6 ,13)

## 5- Effect of experimental treatments on the cation exchange capacity (CEC) $Cmol_+ Kg^{-1}$ soil after harvest.

Table (8) shows a significant difference between the two humic acids extracted with sodium hydroxide and potassium hydroxide in the cation exchange capacity of the soil after harvest. The humic acid extracted with sodium hydroxide gave the highest reading 27.52 $Cmol_+ Kg^{-1}$ soil, followed by the humic acid extracted with potassium hydroxide 26.36 $Cmol_+ Kg^{-1}$ soil. The table also shows significant differences between

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the sources of organic fertilizers used in extracting the humic acids. The humic acid extracted from pigeon wastes gave the highest concentration 27.68 $Cmol_{+}$ $Kg^{-1}$ soil, followed by the humic acid extracted from cow wastes 27.12 $Cmol_{+}$ $Kg^{-1}$ soil, and then the acid extracted from sheep wastes 26.01 $Cmol_{+}$ $Kg^{-1}$ soil. There is also a significant difference between the two concentrations of extracted humic acids. The second concentration (10%) yielded 27.67 cmol + $kg^{-1}$, while the first concentration (5%) yielded 26.21 cmol + $kg^{-1}$. The table also shows significant differences in the triple interactions, with the B1OM3C2 interaction yielding the highest reading 29.97 $cmol_{+}$ $kg^{-1}$. Furthermore, the triple interaction showed a significant difference compared to the complete mineral fertilizer recommendation (OM0R100) and the control treatment (no fertilizer added) (OM0R0).

**Table (8) Effect of experimental treatments on the cation exchange capacity of soil $Cmol_{+}$ $kg^{-1}$ soil after harvest**

| B * OM | C | | OM | B |
|---|---|---|---|---|
| | C2 | C1 | | |
| 26.50 | 26.37 | 26.63 | OM1 | B1 |
| 27.57 | 28.83 | 26.30 | OM2 | |
| 28.50 | 29.97 | 27.03 | OM3 | |
| 25.52 | 26.03 | 25.00 | OM1 | B2 |
| 26.68 | 27.27 | 26.10 | OM2 | |
| 26.87 | 27.57 | 26.17 | OM3 | |
| | 25.80 | | OM0R100 | |
| | 24.03 | | OM0R0 | |
| LSD 0.05 | 1.64 | | LSD 0.05 | |
| B * C | | | | |
| Average B | C2 | C1 | B | |
| 27.52 | 28.39 | 26.66 | B1 | |
| 26.36 | 26.96 | 25.76 | B2 | |
| LSD 0.05 | N.S | | LSD 0.05 | |
| OM * C | | | | |
| Average OM | C2 | C1 | OM | |
| 26.01 | 26.20 | 25.82 | OM1 | |
| 27.12 | 28.05 | 26.20 | OM2 | |
| 27.68 | 28.77 | 26.60 | OM3 | |
| LSD 0.05 | N.S | | LSD 0.05 | |
| C1 | | | | |
| | C2 | C1 | C | |
| | 27.67 | 26.21 | Average C | |
| | 0.675 | | LSD 0.05 | |

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Due to direct relationship between organic matter and cation exchange capacity we observe that the second concentration of humic acid extracted from pigeon wastes yielded the highest reading. (4) indicated that materials with high nitrogen content (pigeon wastes) produce humic acids with a higher CEC. Similarly, the second concentration (C2) yields the highest percentage of released humic acids, positively impacting the CEC. (14) stated that the average molecular weight results in the highest CEC value. The results show that the CEC of the experimental treatments increased compared to the pre-planting level (25.7 $Cmol_{+}\ kg^{-1}$), which may be attributed to soil enrichment with organic matter.

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