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# Short Term Effect of Vermicompost on Soil Chemical Properties under Maize (*Zea mays* L.) Field in Northern Ethiopia

**Solomon Mebrahtom [a*]**

[a] *Tigray Agricultural Research Institute, Shire Soil Research Center, Shire, Tigray, Ethiopia.*

***Author's contribution***

*The sole author designed, analysed, interpreted and prepared the manuscript.*

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## ABSTRACT

**Aim:** The application of vermicompost (VC) to improve soil chemical properties in area that have low soil fertility status is crucial. Thus, the present study was initiated to determine impact of vermicompost on selected soil physicochemical properties.
**Study Design:** The experiment had 7 treatments arranged in a Randomized Complete Block Design (RCBD) with five replications.
**Place and Duration of the Study:** Hence, a field experiment was carried out in 2018 main cropping season at farmer's field at Adiha village in Kolla Tembien district, Tigray, Ethiopia.
**Methodology:** The treatments were 5 levels of VC (0, 2.5, 5, 7.5 and 10 t ha-1), the recommended rate of N and P (46 N and 46 P2O5 kg ha-1), compost at rate of 10 t ha-1 and control. Surface soil samples were collected before planting and after maize harvesting at a depth of 0-30 cm to analyze selected soil chemical properties such as pH, extractable electric conductivity (ECe), cation exchange capacity (CEC), total nitrogen (TN), available P and exchangeable bases (K, Mg, Ca, and Na). Likewise, vermicompost and compost nutrient contents were also analyzed to know their nutrient composition.
**Results:** Soil analysis results before sowing revealed that most of the soil chemical properties were rated as low. However, vermicompost application significantly ($P \le 0.05$) improved the soil chemical properties. The studied soil chemical properties such as OC (1.33%), TN (0.13%), CEC (17.2 Cmol

**Corresponding author: E-mail: Solomon.mebrahtom08@gmail.com, solomon28@tari.gov.et;*

(+) kg-1), and available P (6 .38 mg kg-1) showed an improvement at VC 10 t ha-1rate as compared to the control which was respectively 0.65%, 0.04%, 7.4 Cmol(+)kg-1 and 2.45 mg kg-1.
**Conclusion:** A significant (P≤0.05) increase in OC, TN and available P was observed with increased vermicompost rate under cultivated land.

*Keywords: CEC; compost; maize; organic carbon; RCBD.*

## 1. INTRODUCTION

Land degradation, including soil erosion, deforestation and desertification, represents another major obstacle to agricultural production. Unsustainable agricultural practices, excessive grazing and inadequate land management lead to the degradation of fertile soils, reducing their productivity and agricultural potential [1]. Furthermore, deforestation to expand agriculture further exacerbates the loss of valuable land resources [2].

The soils of most African countries are regularly degraded by erosion. Loss of about 50 tons of soil per hectare per year, corresponding to 20 billion tons of N, 2 billion tons of P and 41 billion tons of K per year [3]. Soil fertility in sub-Saharan Africa is decreasing due to land degradation due to population growth, lack of attention to integrated soil fertility management (ISFM), inadequate plant nutrients, poor agricultural practices and long-term drought, and irregular rainfall patterns which are also leading to a decline in soil fertility in southern Africa the Sahara with low yields [4-7].

“In Ethiopia, agricultural cultivation involves the removal of nutrients (N, P, K, etc.) from the soil through agricultural products (food, fiber and wood) and crop residues. Consequently, nutrient deficiency leads to a decline in soil fertility when the supply of inorganic or organic nutrients is insufficient” [8–10]. “Likewise, declining soil fertility is a major constraint to yield limitation of smallholder farmers in Ethiopia due to shorter fallow periods, lower levels and the imbalanced use of organic and inorganic fertilizers, removal of crop residues and lack of adequate soil conservation practices” [11–14].

“The soil-level bottleneck such as organic matter depletion, soil biota depletion, nutrient depletion, limited biomass cover, soil compaction, soil erosion, soil salinity/sodicity, acidity, water logging, low moisture availability and physical soil degradation have a negative impact on physical, chemical and biological conditions of the soil and its fertility are common in Ethiopia” [15,16]. “Possible measures are therefore soil fertility management, such as the application of organic and mineral fertilizers, crop rotation, catch crops, crop residue management, and physical protection of soil and water” [17].

“Vermicompost, made from livestock manure, potato waste, sugarcane residue and sunflower residue, resulted in significantly higher plant yields. Therefore, the nutrient content of vermicompost was always higher than that of normal compost” [18]. Many studies have shown that the use of manure provides yields comparable or even superior to those of inorganic fertilizers [19].

“Application of different organic fertilizers favorably influences the soil physical, chemical and biological environment such as available nitrogen over the inorganic alone applied plots. Among different organic N sources, the application 75 per cent vermicompost was found superior in improving soil health over the treatments with inorganic fertilizers” [20].

“The organic carbon content of vermicompost (15.2%) was much lower than that of FYM (37.4%), while the N content of vermicompost (1.40%) was much higher than that of FYM (0.9%)” [21]. Furthermore, [22] reported that “vermicompost prepared from mustard residues and sugarcane waste using *Eisenia fetida* resulted in a significant increase in mineral nitrogen content and microbial activity”. “The use of vermicompost alone or with chemical fertilizers reduces bulk density, increases soil porosity and water holding capacity, but increases soil pH and organic carbon content” [23]. “Likewise, higher levels of available soil N were observed in plots that received 5 t/ha of vermicompost. It also improved the pH of soil towards neutrality” [24]. “The use of organic fertilizers such as VC and FYM progressively reduces the bulk density of the soil” [25,26].

After applying vermicompost in two consecutive growing seasons, there was a significant decrease in soil density and a significant increase in pH and total organic carbon. Taken together, these changes in soil properties improve air and water availability, thereby promoting seedling emergence and root growth [27]. Thus, Mekelle University, with the help of AgriFoSe2030, recently introduced VC as an option for soil fertility management in Kolla Tembien District, located in the central part of Tigray Regional State. However, no study has been conducted so far on the influence of VC on the chemical properties of soils at the field level, especially in the study area. Therefore, this study was initiated to determine the effects of VC on soil properties under maize field.

## 2. MATERIALS AND METHODS

### 2.1 Description of the Study Area

The experimental study was conducted at Adiha village located in Kolla Tembein district, central zone of Tigray, Ethiopia (Fig. 1). The village is geographically located at 30 kilometers North east of Abyi - Adi town, and 95 kilometers north of Mekelle city (capital of Tigray Region) (Office of Agriculture and Rural Development (OoARD) [28], at a GPS location of 13º45'0.4''N and 38º 6' 5.8''E.

Most of the population lives in rural areas and earns their living through agricultural production. The main cereals grown in the study area are maize (*Zea mays L.*), sorghum (*Sorghum bicolor L.*), teff (*Eragrostis tef (Zucc.))* and millet (*Eleusine coracana L.*).). Likewise, farmers in the district are involved in rearing animals such as oxen, goats, sheep, donkeys, mules, camels, bee colonies and others [28]. The geology of the study area is Adigrat sandstone [29]. Soil type of the experimental trial has a Reference Soil Group (RSG) of Petric Calcisols [30].

### 2.2 Experimental Design

The experimental study has seven (7) treatments with five replications namely: five levels of vermicompost (0, 2.5 t ha$^{-1}$, 5 t ha$^{-1}$, 7.5 t ha$^{-1}$ and 10 t ha$^{-1}$), recommended rate of NP (100kg ha-1 urea and 100 kg ha-1 TSP) used by the

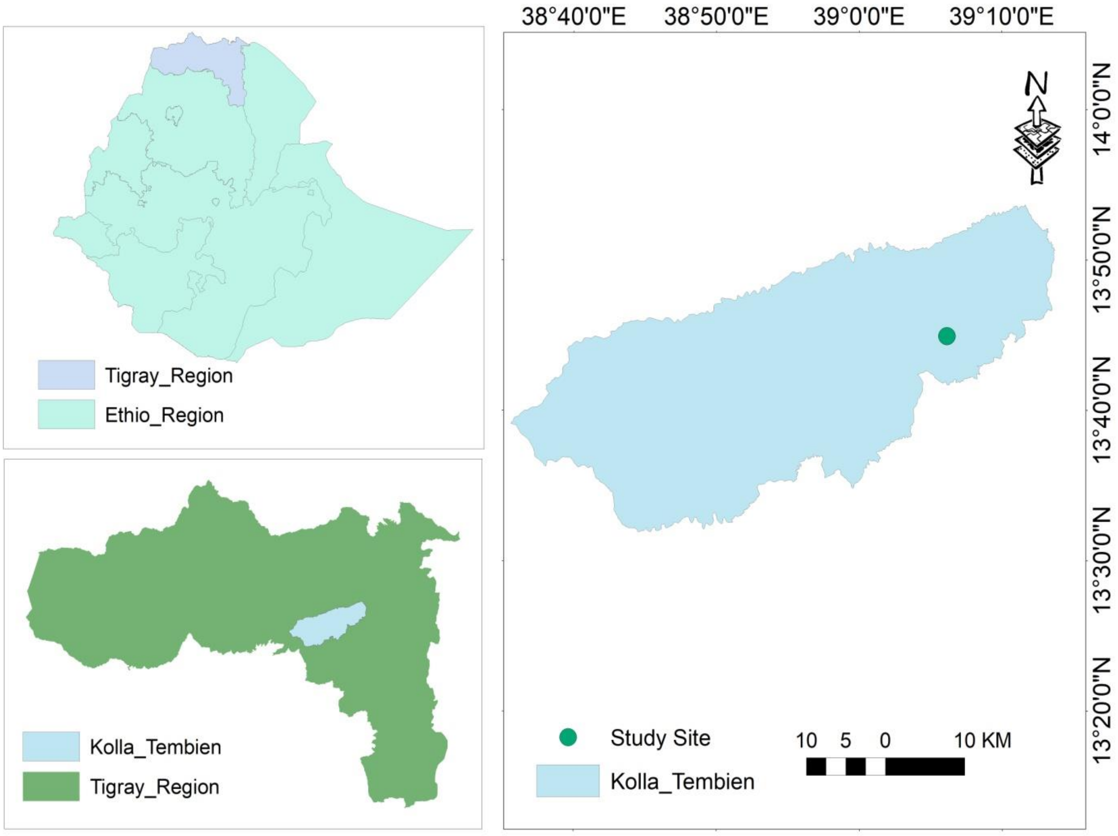


**Fig. 1. Location map of the study area**

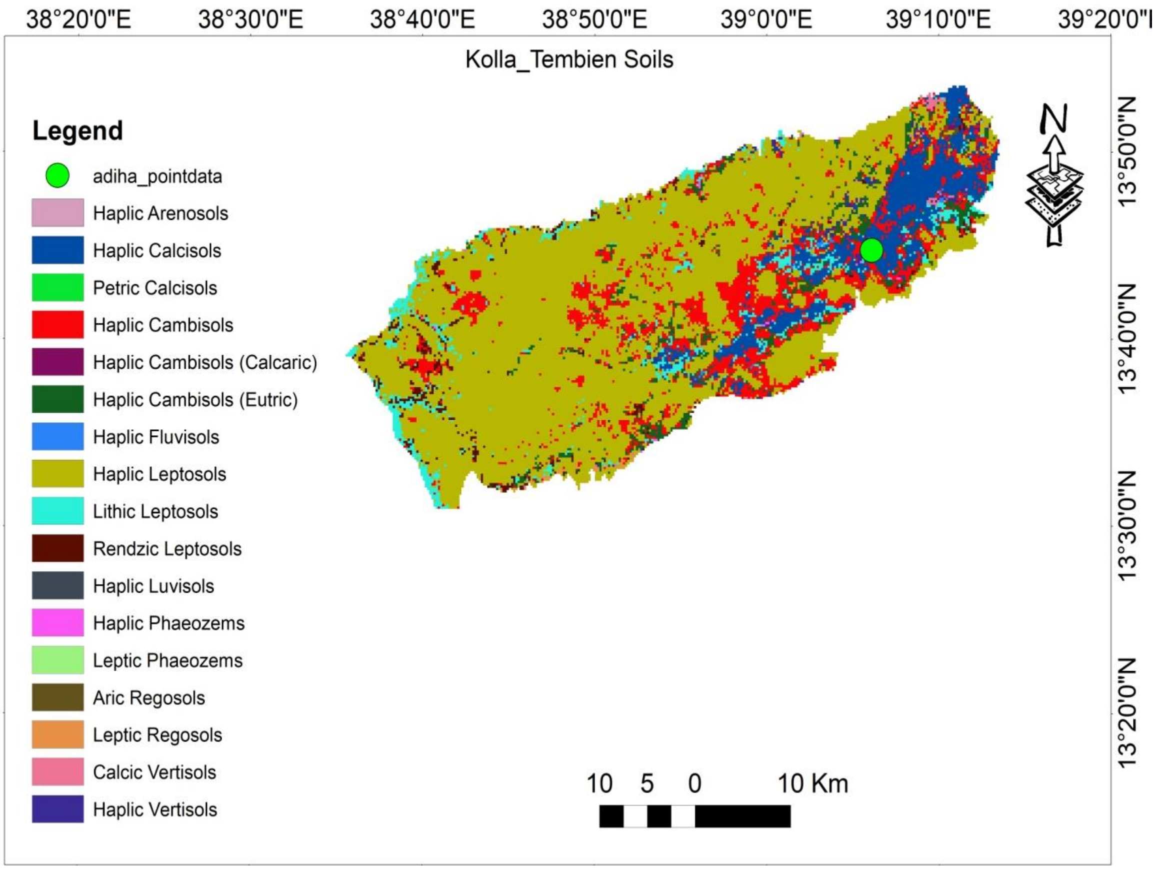


**Fig. 2. Soil type of Kolla Tembien District [30]**

farmers in the study area and compost at rate of 10 t $ha^{-1}$. The seven treatments were laid out in randomized complete block design. The total area used for the trial was 35 m×25.75 m (901.25 $m^2$), whereas the plot size was 3.75 m × 4 m (15 $m^2$). The spacing between plots and blocks were 1 m and 1.5 m, respectively.

## 2.3 Soil, Compost and Vermicompost Sampling and Analysis

Before planting, a composite soil sample (disturbed, for analysis of chemical properties) was collected from the entire study area to a depth of 0–30 cm. After harvest, 35 composite (disturbed) soil samples were collected from each subplot and pooled with the respective plots. The composite soil samples were air- dried, ground, passed through a 2 mm sieve, and prepared for analysis of soil chemical properties. One composite vermi-compost and compost produced by farmer's using locally available organic waste materials (cow dung, straw of crops, food waste like Lettuce and cabbage) were also taken for the same purpose.

**Table 1. Soil parameter, method analysis and reference used in the experiment**

| Soil parameters | Method of analysis | Reference |
|---|---|---|
| pH | 1:2.5 soil to water suspension | [31] |
| EC | 1:2.5 soil to water suspension | [32] |
| Organic carbon | Wet oxidation method | [33] |
| Total nitrogen | Kjedahl method | [34] |
| Available P | Olsen method | [35] |
| CEC | Ammonium Acetate method | [36] |
| Exchangeable K and Na | Flame photometer | [37] |
| Exchangeable Ca and Mg | Titration method | [38] |

**Table 2. Initial chemical properties of vermicompost, compost and soil**

| Parameters | | | | Rating | Reference |
|---|---|---|---|---|---|
| | VC | C | Soil | | |
| pH | 7.31 | 7.1 | 7.32 | Slightly acidic to neutral | [39,40] |
| ECe (ds $m^{-1}$) | 1.28 | 1.33 | 1.7 | Low salinity | [41] |
| Organic Carbon (%) | 23.01 | 22.14 | 0.65 | Low | [40] |
| Total N (%) | 1.64 | 1.04 | 0.041 | Low | [42] |
| Total P (mg $kg^{-1}$) | 0.83 | 0.54 | - | - | [35] |
| Total K (mg $kg^{-1}$) | 1.08 | 1.24 | - | - | |
| CEC (cmol(+) $kg^{-1}$) | - | - | 7.61 | Low | [43] |
| Ava. P(mg $kg^{-1}$) | - | - | 2.45 | Low | [35] |
| Exchangeable Ca (cmol(+) $kg^{-1}$) | - | - | 2.8 | Low | [44] |
| Exchangeable Mg (cmol(+) $kg^{-1}$) | - | - | 1.0 | Low | [44] |
| Exchangeable K (cmol(+) $kg^{-1}$) | - | - | 0.12 | Low | [44] |
| Exchangeable Na (cmol(+) $kg^{-1}$) | - | - | 0.17 | Low | [44] |

## 2.4 Data Analysis

The collected after harvesting soil data were subjected to statistical analysis like analysis of variance. Analysis of variance (ANOVA) was performed using SAS version 9.1 [45]. Significant difference between and among treatments means were assessed using the least significant difference (LSD) at 0.05 level of probability [46].

## 3. RESULTS AND DISCUSSION

## 3.1 Effect of Vermicompost on Selected Soil Chemical properties

### 3.1.1 Soil reaction

The pH values were not significantly affected by VC dose and fertilizer type (P > 0.05) (Table 3). However, the result varied numerically between treatments, namely the maximum pH value (7.63) was obtained from plots treated with a high dose of vermicompost, while the minimum pH (7.3) was obtained from plots treated with 10 t ha$^{-1}$ compost (Table 3). This could be due to the addition of basic cations to the soil, which hinders the action of exchangeable acids at the site of soil exchange [26,47].

### 3.1.2 Extractable electrical conductivity

ECe values were not significantly (P>0.05) affected by the rates of VC and fertilizer types (Table 3). However, they had numerical difference within the treatments i.e. the maximum ECe value (1.7 ds m$^{-1}$) was obtained from plots treated with recommended NP and no fertilizer; while the minimum ECe value (1.6 ds m$^{-1}$) was from the plot treated by 10 t ha$^{-1}$ VC (Table 3). This is in accordance with the findings of [48] which revealed that application of compost and vermicompost could lower ECe than inorganic fertilizer. “This is possibly due to unlike chemical fertilizers, organic fertilizers release nutrients more gradually as a result of degradation process and their cheated effect” [49].

### 3.1.3 Organic carbon

Soil organic carbon (SOC) content was significantly (P ≤ 0.05) affected by VC doses and fertilizer type (Table 3). The SOC value increased as the VC rate increased. Therefore, the highest SOC content (1.33%) was obtained with the highest VC dose and with the lowest dose (0.66%) came from the recommended NP-treated plots (Table 3). This is consistent with the results of [50], who reported that the use of vermicompost at a dose of 10 t ha-1 significantly increased the organic carbon content of the soil. However, the high dose (10 t ha-1) at a dose of 7.5 t ha-1 VC and composting at a dose of 10 t ha$^{-1}$were not significant.

### 3.1.4 Total N

Total N values were significantly (P≤0.05) affected by the rates of VC (Table 3). Total N increased as the rate of VC increased. Hence, the maximum total N content of the soil (0.13%) was obtained from the high VC dose, whereas the lowest (0.042%) was from the recommended NP and unfertilized plots. This is in orthodoxy with the findings of [51-52] that revealed application of vermicompost to soils resulted in higher total N concentration in the soil and plant compared to the control. The increment in total N with addition of organic amendments (VC) to soil is caused by high release of total N content of vermicompost in the high dose of VC than control [53].

### 3.1.5 Cation Exchange Capacity (CEC)

The CEC was significantly (P≤0.05) influenced by the rates of VC (Table 4). CEC showed a slight increase as the rate of VC increased. Thus, the highest CEC of the soil (17.2 cmol (+) $kg^{-1}$) was obtained from the plots treated with high dose of Vermicompost, whereas the lowest (7.6 cmol (+) $kg^{-1}$) was from unfertilized plots. This might have resulted from the humic acids contained in both vermicompost and compost which they bind cations as they contain carboxylic acid groups, which can in turn bind positively, charged multivalent ions [54].

### 3.1.6 Exchangeable bases

Exchangeable bases showed significant difference (P≤0.05) upon application of different rates of VC (Table 4). The highest (8.1 cmol (+) kg-1) exchangeable Ca was obtained from plots

**Table 3. Effect of vermicompost on selected soil physico-chemical properties**

| Treatment | pH | ECe (mmhos/cm) | OC (%) | TN (%) |
|---|---|---|---|---|
| Control | 7.40 | 1.71 | $0.66^{c}$ | $0.042^{ed}$ |
| 46 N kg $ha^{-1}$ + 46 $P_2O_5$ kg $ha^{-1}$ | 7.35 | 1.72 | $0.63^{c}$ | $0.038^{e}$ |
| 10 t $ha^{-1}$ Compost | 7.32 | 1.69 | $1.22^{ab}$ | $0.072^{bc}$ |
| 2.5 t $ha^{-1}$ VC | 7.38 | 1.69 | $0.99^{b}$ | $0.06^{cd}$ |
| 5 t $ha^{-1}$ VC | 7.44 | 1.67 | $1.01^{b}$ | $0.08^{bc}$ |
| 7.5 t $ha^{-1}$ VC | 7.57 | 1.67 | $1.27^{a}$ | $0.09^{b}$ |
| 10 t $ha^{-1}$ VC | 7.63 | 1.66 | $1.33^{a}$ | $0.13^{a}$ |
| Mean | 7.44 | 1.69 | 1.01 | 0.07 |
| LSD (P≤0.05) | NS | NS | 0.25 | 0.02 |
| CV | 3.99 | 11.57 | 12.01 | 14.71 |

*Means followed by the same letters are not significantly different (P≤0.05) according to Tukey Test; B.D= bulk density, SMC = Soil moisture content, pH= Power of hydrogen, ECe = Extractable electrical conductivity, OC = Organic carbon, TN = Total nitrogen, N = nitrogen; $P_2O_5$ = Di phosphate Penta Oxide t= tone; ha= hectare; CV= Coefficient of variation;*

**Table 4. Effect of vermicompost on selected soil chemical properties**

| Treatment | | Exchangeable base (cmol(+) $kg^{-1}$) | | | | |
|---|---|---|---|---|---|---|
| | CEC (cmol(+) $kg^{-1}$) | Ca | Mg | Na | K | AvaP (mg $kg^{-1}$) |
| Control | $7.60^{d}$ | $2.60^{e}$ | $1.00^{d}$ | $0.14^{f}$ | $0.10^{e}$ | $2.43^{e}$ |
| 46 N kg $ha^{-1}$ + 46 $P_2O_5$ kg $ha^{-1}$ | $7.90^{d}$ | $3.16^{d}$ | $1.10^{d}$ | $0.21^{e}$ | $0.21^{d}$ | $2.46^{e}$ |
| 10 t $ha^{-1}$ C | $11.52^{c}$ | $4.40^{c}$ | $1.80^{c}$ | $0.33^{d}$ | $0.31^{c}$ | $3.28^{d}$ |
| 2.5 t $ha^{-1}$ VC | $10.50^{c}$ | $4.08^{c}$ | $1.28^{d}$ | $0.22^{e}$ | $0.24^{d}$ | $3.08^{d}$ |
| 5 t $ha^{-1}$ VC | $13.50^{b}$ | $5.80^{b}$ | $2.78^{b}$ | $0.41^{c}$ | $0.41^{b}$ | $3.92^{c}$ |
| 7.5 t $ha^{-1}$ VC | $16.60^{a}$ | $7.58^{a}$ | $3.24^{a}$ | $0.45^{b}$ | $0.42^{ab}$ | $5.61^{b}$ |
| 10 t $ha^{-1}$ VC | $17.20^{a}$ | $8.10^{a}$ | $3.46^{a}$ | $0.47^{a}$ | $0.46^{a}$ | $6.38^{a}$ |
| Mean | 12.12 | 5.11 | 2.10 | 0.32 | 0.31 | 3.88 |
| LSD (P≤0.05) | 1.97 | 0.55 | 0.36 | 0.02 | 0.04 | 0.48 |
| CV | 8.09 | 5.33 | 8.47 | 2.33 | 6.89 | 6.17 |

*Means followed by the same letters are not significantly different (P≤0.05) according to Tukey Test; Av. P = Available phosphorus, CEC = Cation exchange capacity, Ca= calcium, Mg= magnesium, K= potassium, Na= sodium, $P_2O_5$ = Di phosphate Penta Oxide t= tone; ha= hectare; CV= Coefficient of variation;*

treated by 10 t $ha^{-1}$ VC, whereas the lowest (2.6 cmol (+) $kg^{-1}$) was from unfertilized plots. An increase in exchangeable Ca content of soil might happened due to organic amendments improve soil cation exchange capacity (CEC) through humus formation and increased concentrations of Ca. Similarly, the highest (3.5 cmol (+) $kg^{-1}$) exchangeable Mg was obtained from plots which received 10 t $ha^{-1}$ VC, while the lowest (1.0 cmol (+) $kg^{-1}$) was from control. This could be due to storage and availability of Mg closely related to CEC [51,55].

The maximum value of exchangeable Na (0.47 cmol(+) kg-1) and K (0.46 cmol(+) kg-1) were obtained from plots which received the highest dose of VC; whereas, minimum values (0.14 cmol(+) kg-1) and (0.10 cmol(+) kg-1) for the respective nutrients were from unfertilized plots. This might occur when organic material like VC is added to soils at high dose so that it improves organic matter content; they also supply soils with nutrients including exchangeable K and Na [55-57]. In harmony to this result, [50] revealed that application of VC at high dose significantly increased exchangeable base of post-harvest soil than the lowest rate and nil treatment.

#### 3.1.7 Soil available P

Soil available P of the post-harvest soil was significantly (P≤0.05) influenced by the rates of VC (Table 4). Available P showed a slight increment as the rate of VC increased. The highest (6.38 mg $kg^{-1}$) available P was obtained from plots treated with 10 t $ha^{-1}$ VC, while the lowest (2.43 mg $kg^{-1}$) was from control/check. This corresponds with the findings of [51-52] who revealed that application of VC at high dose significantly increased available P. This might have happened when organic material like VC add to soils at high dose can improve organic matter status, there by supply soil with nutrient of available P [56-57].

## 4. CONCLUSIONS

The findings from this study showed that the initial soil reaction ranged from slightly acidic to neutral; ECe value is rated as low soil salinity. Most of the chemical properties like OC content, TN, av.P, CEC and exchangeable bases were also rated as low. However, application of vermicompost at different rates significantly affected most of the studied soil parameters. Hence, VC improves the degraded soil and that have initially low soil nutrient through improving the structure of the soil, porosity of soil and improving soil nutrient. Vermicompost had also significantly affected soil chemical properties. A significant increase in OC, TN and available P was observed with increased vermicompost rate. Thus, the highest CEC, OC, TN and available P were recorded from plots which received the highest VC dose; while the lowest values were recorded from unfertilized plots and recommended NP.

## DATA AVAILABILITY

Data used to support the findings of this study are available from the corresponding author upon reasonable request of the publisher or other stakeholders.

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## COMPETING INTERESTS

Author has declared that no competing interests exist.

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