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RESEARCH ARTICLE

Effect of NPS and Vermicompost A Addition on the Physico-Chemical Properties of the Soil under (*Zea* Mays) at the Bako Agricultural Research Center in Western Oromia, Ethiopia

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Abstract

The main chemical, physical, and biological limitations on soil production in western Ethiopia include low soil fertility, nutrient unavailability, and acidity. Therefore, the purpose of the study was to evaluate how specific physico-chemical properties of soil were influenced by the combined application of vermicompost and NPS fertilizer rates at Bako Agricultural Research Center. Four vermicompost levels (0, 2.32, 3.48, and 4.64 tons ha^{-1}) and four NPS fertilizer levels (0, 50, 75, and 100 kg ha^{-1}) were combined in a factorial manner were laid out in Randomized Complete Block Design (RCBD) with three replications. The study's findings demonstrated that while bulk density decreased below the control due to different levels of organic fertilizer application, all treatments applied increased soil moisture and total porosity relative to the control or NPS fertilizer alone. The results showed that the combination of vermicompost and NPS fertilizer rates significantly affected organic carbon, organic matter, total nitrogen, basic cations (Ca^{2+}, Mg^{2+}, K^{+}), and available phosphorous. Nevertheless, the experiment indicated the integration of organic and inorganic fertilizers to enhance nutrient availability by maintaining soil fertility and health because the pH of the soil was significantly influenced by the primary effects of vermicompost levels ($P \leq 0.01$).

Keywords: Fertility; Depletion; NPS; Vermicompost; Improvement

Introduction

Nutrient depletion in Ethiopia has been accelerated by improper management of soil fertility and land use shifts, primarily from natural vegetation to cultivated areas. A reduction of the physical, chemical, and biological characteristics of the soil was the outcome of intensive and continuous farming of land with inadequate soil fertility management techniques. The country's declining agricultural output and food scarcity are made worse by these changes in the soil's properties. (Habtamu). According to this perspective, the main causes of the nation's declining soil fertility include nutrient input levels or absence, crop residue management issues, continuous cultivation, nutrient removal through erosion, and a lack of crop rotation programs (Aleminew and Alemayehu).

The fertility and productivity of soils are crucial factors in guaranteeing food security for the growing global population [1]. To maintain the productivity of the soil and balance the nutrient outflow from agricultural land, it is, therefore, necessary to improve soil fertility by adding nutrients in the form of fertilizer and managing it properly. Hence, soil fertility and plant nutrition are two closely related topics that focus on the types and availability of nutrients in soils, as well as their mobility, uptake by plants, and utilization by plants (Grant and Flaten,2022).

Among the main obstacles to crop development in Ethiopia are low soil fertility, acidity-induced nutrient unavailability, and high amounts of agricultural inputs [2]. Acid soil production is restricted by the toxic levels of manganese (Mn) and aluminum (Al), as well as by the lack of nutrients like phosphorus (P), calcium (Ca), magnesium (Mg), and molybdenum (Mo) [3]. Due to its high exchangeable aluminum content, Al lowers P uptake by fixing P. [4]. Applying organic fertilizer can improve soil aeration, reduce acidity, promote greater microbial activity, increase soil organic matter, CEC, and P availability, and significantly raise crop yields [5]. Maintaining increased soil production has become more successful recently when organic and mineral fertilizers are used in combination [6].

The physical, chemical, and biological activities of soil are enhanced by organic fertilizer; but, because of their relatively low nutrient content, a greater amount is needed. All of the nutrients required for plants to grow are included in inorganic fertilizers (Jemal Nora et al.). However, the degradation, acidity, and pollution of the environment caused by the continued application of inorganic fertilizers alone results in soil organic matter (Bhatt, Labanya, and Joshi). Thus, by combining the application of inorganic and organic materials, the integrated nutrient management system is an alternative strategy for the sustainable and economical management of soil fertility that raises soil fertility and productivity without harming the environment. Farmers have observed that using both organic and inorganic fertilizers improves the physical, chemical, and biological qualities of the soil while also increasing yield and maintaining productivity [7]. It is one of the best practices for plant nutrient management to optimize the social, economic, and environmental benefits of crop production [8].

Integrated soil fertility management is a strategy used in sustainable agriculture systems to promote land production while preserving or improving soil fertility. It makes the best use of naturally occurring soil nutrient stocks, locally accessible soil amendments, and mineral fertilizers (Jemal Nura et al.). Utilizing organic materials, mineral fertilizers, and soil amendments in combination to replenish soil nutrient pools and boost the effectiveness of external inputs is known as integrated soil fertility management (Chala and Gurmu, 2016). Nowadays the price of fertilizer has been escalating so much to the levels that farmers cannot afford the costs to supply the required amount of nutrients. Several researchers have demonstrated the beneficial effects of combined organic materials and inorganic fertilizers mitigating deficiency of several macro- and micro-nutrients [9]. In addition, many research findings have been obtained in many parts of the country (Chimdi *et al.*, 2012). Fertilizers, both organic and artificial, are essential for maintaining soil fertility and increasing crop production. Thus, soil fertility is a well-known issue that restricts crop yield throughout the western region of the country, including Gobu Sayo and Bako Tibe.

However, the adoption of vermicompost application along with inorganic fertilizers for improving soil fertility is poor in the study area. To encourage farmers to use integrated vermicompost and inorganic fertilizers for improving soil fertility as well as reducing climate change impacts, investigation of their effects on soil is vital. Nevertheless, soil and crop-specific recommendations on the combined application of vermicompost and inorganic fertilizer (NPS) are lacking for the study area. Therefore, due to a lack of information particularly on the effect of vermicompost and inorganic fertilizer application rates in the Bako area, this research was initiated with objectives to assess the effect of NPS fertilizer and vermicompost on selected soil physical and chemical properties.

Materials and Methods

Description of the Study Area

Location

The study was conducted at Bako Agricultural Research Center (BARC) in the Gobu Sayo district during the 2022 cropping season. The research center is located at a height of 1650 meters above sea level in the Oromia Regional National State, between 9°12'35" - 9°7'30" N is the number and 37°58' 25" - 37o 13' 40" E longitude. as well as 258 kilometers west of Addis Ababa, 8 kilometers from Bako, the closest town, and 4 kilometers from the highway that goes to Nekemte Town in western Ethiopia. (Figure 1).

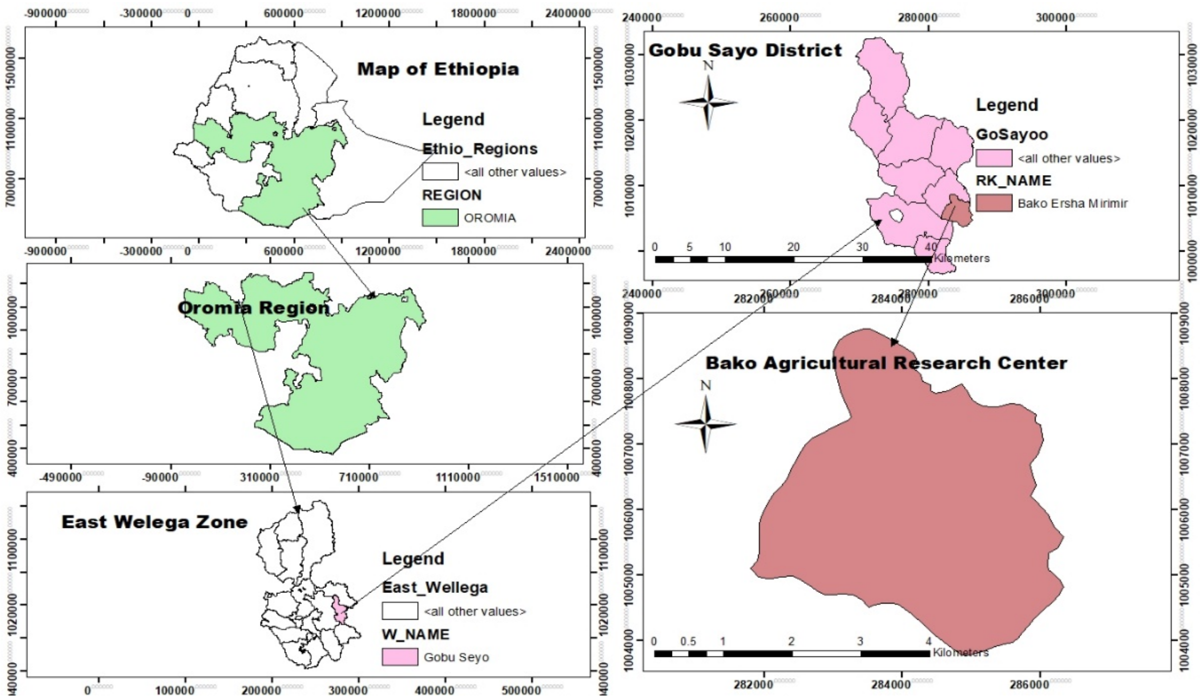

Figure 1: Location map of study Area.

Experimental Materials

The NPS fertilizer containing (19% N, 38% P_2O_5, and 7% S) was used as sources of nitrogen, phosphorus, and sulfur. Vermicompost prepared from soybean residue and farmyard manure at Bako Agricultural Research Center was used for this study. The soya bean straw and cow dung were mixed 1:2 ratio respectively. The Vermicompost had been prepared from soya bean straw and cattle manure at Bako Agricultural Research Center, using red earthworms (Eisenia fetida). The vermicompost used in the experiment was selected based on its nutrient content information obtained from the laboratory analytical results.

Treatments and Experimental Design

Vermicompost rates (0, 50, 75, and 100%) and NPS (0, 50, 75, and 100 kg NPS ha^{-1}) were the treatment levels. The experiment contained 16 treatments.

Soil Sampling and Sample Preparation

Soil sampling before application of fertilizers

Using the given auger, samples were collected across the diagonal of each block from the top soil surface (0–30 cm deep). The fifteen samples were completely mixed in the field right away following sampling, and then a 1 kg composite and the homogenized sample were taken and placed in the plastic bag along with the label.

Soil sampling after application

Following harvesting, soil samples were taken from every experimental field plot. Samples were obtained from the middle three rows of the plots where vermicompost and fertilizer were applied. Following collection, the samples were well combined in the field, and one kilogram of homogenized material was removed from each of the 48 plots and placed in a plastic bag with a label. After that, the sample's physico-chemical characteristics were examined.

With the help of the room's airflow, the soil samples were spread out over a sample bag and dried. To analyze the chosen soil parameters, the air-dried soil samples were first ground with a mortar and pestle and then sieved through a 2 mm diameter sieve. Soil samples were screened through a 0.5 mm sieve for measurement of total nitrogen and organic carbon content.

Analysis of Selected Soil Physical and Chemical Properties

At Bako Agricultural Research Center, soil samples taken from the study area were examined. After following the procedure, the Bouyoucos hydrometer method was used to examine the texture (size distribution) of soil particles. described by [10]. Using the soil textural triangle, soil textural classes were determined by comparing the percentages of sand, silt, and clay separations as described by [11]. The undisturbed soil samples that the core sampler took were used to calculate the bulk density of the soil using the methodology outlined by [12]. Based on the bulk density and particle density measurements, total porosity was determined using the technique described by [12].

$$Total\ porosity\ f(\%) = (1 - \frac{pb}{ps}) * 100 (3.1)$$

Where ρb is bulk density (g cm^{-3}), ρs is the average particle density of about 2.65 g cm^{-3} [13], and f is total porosity in percentage. Soil moisture content was determined using a gravimetric method as described by [14].

The pH of the soil was measured potentiometrically using a pH meter with a combination glass electrode in a soil-water ratio of 1:2.5 to determine the soil reaction, as stated by [15]. Organic carbon was determined using the wet oxidation method [16]. The soil's organic matter (OM) content was determined under normal conditions using potassium dichromate in sulfuric acid solution, by multiplying the percentage of OC by 1.724. The Kjeldahl method was used for determining the soil's total nitrogen concentration. [17] using sulfuric acid to oxidize materials to change N compounds into NH4+, or ammonium sulfate. Because the soil in this study's site is acidic, the Bray II method was used to measure the amount of available phosphorus. Hydrochloric acid (0.03M NH4F + 0.10M HCl) and ammonium fluoride were used as the extraction solutions. A UV-visible spectrophotometer was used to measure the amount of available phosphorus that was extracted using this method. The leachate of a 1M ammonium acetate (NH4OAc) solution at pH 7.0 was used to determine the exchangeable bases (Ca, Mg, Na, and K) in the soil. While CEC was determined after leaching by NH4OAc extracted soil samples with 10% NaCl solution by ammonium acetate method, exchangeable Ca and Mg in the ammonium acetate leachate were measured by the EDTA titrimetric method and exchangeable K by flame photometer. The turbid metric method was utilized to determine the available sulfur.

Chemical Properties of Vermicompost Used in an Experiment

Vermicompost's chemical characteristics, including pH, organic carbon content, total nitrogen, available phosphorus, potassium, total calcium, and total magnesium, are shown in Table 1. The compost's pH (1:2.5 H2O) was 8.2, meaning that it is nonacidic in reaction. Additionally, the compost's total nitrogen concentration was 1.98 and its mean organic carbon content was 32.22. The very medium carbon-to-nitrogen ratio of 16.27 (Table 1) in the vermicompost shows that the compost decomposed well, and that nitrogen may be released into the soil for plant uptake.

Table 1: Chemical composition of vermicompost prepared from soybean straw and cattle manure

Parameter	Result	Rating	References
pH (1:2.5) H2O	8.2	Slight Alkaline	Benton (2003)
%OC	32.22	High	Tekalign (1991)
%TN	1.98	Very high	Tekalign (1991)
Avail. P (mg kg-1)	1.39	Low	Cottenie (1980)
Avail. S (mg kg-1)	1.29	Medium	Havlin et al. (1999)
Exch. Ca (cmol kg-1)	11.91	High	FAO (2006)
Exch. Mg (cmol kg-1)	12.7	High	FAO (2006)
Exch. K cmol kg-1)	3.94	High	FAO (2006)
CEC cmol kg-1)	50.32	Very high	Murphy (2007)

%OC=organic carbon; TN=total nitrogen; Av.P=available phosphorus; exch. K exchangeable Potassium, exch. Mg exchangeable, exch. Ca exchangeable Calcium.

Data Analysis

Using the R programming language (version 4.3.1), a two-way analysis of variance was performed on all the parameters that were gathered. The Fisher's protected Least Significant Difference (LSD) test was used to compare the means at a 5% level of significance whenever the effects of the treatments were determined to be significant.

Results and Discussion

Selected Properties of Soil of the Experimental Site

Physical Properties

According to (Table 2) results of the soil particle size distribution investigation, the percentage of sand was 7%, whereas the percentages of silt and clay were 16 and 77%, respectively. Consequently, the soil textural triangle indicates that clay is the textural class of the soil (Stevens, 1983). An inherent characteristic of soil called texture shows whether or not it is suitable for growing crops and other purposes. Clay soils can contain water and retain nutrients well. According to [18]. The bulk density that was measured, 1.43 g/cm3, was less than the critical threshold of 1.40 g/cm3, which is the point at which root penetration occurs in plant growth. For clay soil, crop root growth is expected to be severely constrained above this number [19].

Table 2: Physical properties of soil of the experimental site

Physical properties	Results	Ratings
Clay%	77	clayey as per textural triangle classification
Silt%	16	
Sand%	7	
Porosity (%)	46	Moderate as per FAO, (2006)
Bulk density (g cm^{-3})	1.43	Moderate as per Barauah and Barthakulh (1997)

Chemical Properties

Being the primary soil variable, pH represents the general chemical status of the soil and affects a wide variety of chemical, physical, and biological activities in the soil (Emamu, 2021). The soil has a pH of 5.13, which is very acidic [19]. A pH range of 6.0 to 7.5 is preferred by the majority of plants and soil organisms [21].

Soil organic carbon is an essential indicator of soil fertility status [22]. According to the soil organic carbon rating the organic carbon in the soil of the experimental site was 1.23%, which is in the moderate range. Furthermore, the total nitrogen in the soil of the study area was 0.13%, which was low [23].

As indicated by Bray II, the experimental site's soil had 5.02 ppm of extractable available phosphorus, which is slightly below the required amount of 8 ppm for the majority of Ethiopian soils [24] and in the low range as per rating by [25] for available soil Phosphorus. The available sulfur content of the soil (0.38 ppm) is in the low range. Similarly, the cation exchange capacity of the soil of the experimental site (14.8 cmol(+)kg^{-1}) was rated as moderate according to the rating by [26] (Table 3). Overall, the soil analysis results indicate that the experimental site's soil had a low level of fertility. The low amounts of total nitrogen, available phosphorus, and available sulfur that were observed may have resulted from continuous crop production with little in the way of inorganic fertilizer input, as well as from a lack of application of organic matter or soil incorporation of crop residue. The low contents of total N, available S, and available P observed in the soil of the study area are in agreement with the results reported by [24].

Table 3: Chemical properties of soil of the experimental site

Parameter	Results	Ratings	References
pH(1:2.5)H2O	5.13	Strongly acid	Benton (2003)
%OC	1.23	Moderate	Debele (1982)
%TN	0.13	Low	Murphy(1986)
Avail. P mg kg^{-1}	5.02	medium	Cottenie (1980)
Avail. S mg kg^{-1}	0.38	Very Low	Hariram and Dwivedi,(1994)
Exch. Ca	2.8	Low	FAO (2006)
Exch. Mg	3.45	High	FAO (2006)
Exch. K	0.45	Medium	FAO (2006)
CEC	14.8	Moderat	Hazelton and Murphy (2007)

where,Organic Carbon(%OC) , Total Nitrogen, Available Phosphorus(Av.P), Echeangeable (K).Exchangeable (Mg), Exchangeable Calcium(-Ca), Av.S= Available Sulphur(Av.S), and Cation Exchange Capacity(CEC)

Effect of Vermicompost and NPS Fertilizer on Selected Soil Properties After

Soil physical properties

Bulk density

The analysis of variance showed that the interaction effects of vermicompost and NPS were significant on the bulk density of the soil ($P \leq 0.05$). The lowest bulk density value (1.28 $g.cm^{-3}$) was recorded for the soil of plots treated with 100 % of the recommended rate (4.64t VC ha^{-1}) and 75 kg NPS ha^{-1}. However, the control treatment had the highest bulk density value (1. 45$g.cm^{-3}$). (Table 13) indicates a significant negative relationship ($r = -0.67^{**}$) between soil organic matter and bulk density, which suggests that the influence of vermicompost on bulk density may be the reason for the lowest bulk density values among the other treatments when compared to the control Agreeing with this, [27] reported lower bulk density values when organic matter was applied to the soil. Similarly, [28] also reported the inverse relationship between soil bulk density and organic matter content.

Table 4: Interaction effects of NPS and vermicompost on soil bulk density (g cm^{-3})

Parameter	Results	Ratings	References
pH(1:2.5)H2O	5.13	Strongly acid	Benton (2003)
%OC	1.23	Moderate	Debele (1982)
%TN	0.13	Low	Murphy(1986)
Avail. P mg kg^{-1}	5.02	medium	Cottenie (1980)
Avail. S mg kg^{-1}	0.38	Very Low	Hariram and Dwivedi,(1994)
Exch. Ca	2.8	Low	FAO (2006)
Exch. Mg	3.45	High	FAO (2006)
Exch. K	0.45	Medium	FAO (2006)
CEC	14.8	Moderat	Hazelton and Murphy (2007)

Means with the same factor and column followed by the same letter are not significantly different at a 5% level of significance, CV: Coefficient of variation, LSD: least significant difference.

Total Porosity

The analysis of variance showed that the interaction effects of vermicompost and NPS were statistically highly significant on the total porosity of the soil ($P \leq 0.01$). The soil of the plots treated with 100% of the prescribed rate (4.64 t ha^{-1}) and 75 kg NPS ha^{-1} showed the maximum total porosity value (51.46%), whereas the control plots had the lowest value (42.79%) (Table 5). The maximum total porosity values observed for 4.64 t VC ha^{-1} and 75 kg NPS ha^{-1} corresponded with increased levels of organic matter content and decreased bulk density values. This suggests that increasing rates of vermicompost application reduced soil bulk density and subsequently increased total porosity. In line with this, (Emamu and Wakgari) reported that low organic matter content and high bulk density as causes of the low total porosity of soil. This is further supported by [29] who reported increased soil organic matter due to the application of organic fertilizer, which led to a decrease in bulk density and, ultimately, an increase in soil porosity.

Table 5: Interaction effects of vermicompost and NPS on porosity (%)

	VC, % of the recommended rate (4.64 t ha-1)			
NPS(kg ha-1)	0	50	75	100
0	42.79f	46.90cde	47.75bcde	49.54abc
50	45.38ef	47.24cde	47.75bcde	49.92abc
75	46.0de	47.35bcde	48.04abcde	51.46a
100	45.65def	47.37bcde	48.72abcd	50.41ab
LSD (5%)	3.12			
CV (%)	3.97			

Means with the same factor and column followed by the same letter are not significantly different at a 5% level of significance, CV: Coefficient of variation, LSD: A least significant difference.

Moisture Content

The analysis of variance showed that the interaction effects of vermicompost and NPS were statistically highly significant on soil moisture content ($P \leq 0.01$).The second significant element of soil physical properties is soil moisture content, which varies from 18.39% to 24.94% depending on the NPS and vermicompost rates (Table 6). The soil of the plots treated with 100% of the recommended amount (4.64 t ha^{-1}) and 75 kg NPS ha^{-1} showed the highest percentage of soil moisture content (25.94%), while the soil of the control plots showed the lowest values (18.39%). Over control, all of the treatments (a combination of VC and NPS) increased soil moisture. This might be because vermicompost, which has a high water-retaining capacity, has been added to the soil. Similarly, [30] stated that the continuing use of organic fertilizer has increased the soil's moisture content.

Table 6: Interaction effect of NPS and vermicompost on soil moisture (%)

	VC, % of the recommended rate (4.64 t ha-1)			
NPS(kg ha-1)	0	50	75	100
0	18.39f	21.29de	21.44de	23.88b
50	20.03e	20.83de	21.91cd	22.07cd
75	20.54de	21.18de	21.37de	25.94a
100	20.87de	21.44de	22.93bc	24.04b
LSD (5%)	1.34			
CV (%)	3.72			

A 5% level of significance indicates that means with the same factor and column followed by the same letter are not substantially different; CV is for the coefficient of variation; LSD stands for least significant difference.

Soil Chemical Properties

Soil Reaction (Ph)

The main effects of NPS and the interaction effect of vermicompost on soil pH were not statistically significant, while only the main effect of vermicompost on soil pH showed a significant difference at ($P < 0.05$). The results concerning how vermicompost affects the pH of the soil are shown in (Table 7). The lowest soil pH (5.25) was noticed for the control plots, whilst the highest soil pH (5.73) was identified for the plots treated with 100% of the recommended rate of vermicompost (4.64 t VC ha^{-1}) and 75% of the recommended rate of vermicompost (3.48 t VC ha^{-1}). According to(Thomas and Hargrove, 1984) recommended rating, the pH values of the soil after the application of different amounts of vermicompost are between highly and mildly acidic.

The neutralizing effect of the vermicompost pH (8.2) value may be the cause of the soil's relative increase in pH as compared to the control plots (zero rates of vermicompost). This could be confirmed by a significant and positive correlation (r=0.58**) (Table 13) of soil pH with organic carbon contents of the respective plots that were treated by different rates of vermicompost. Similarly, [31] reported an increase in pH as a result of the application of different levels of compost to the soil.

Table 7: The main effect of vermicompost on soil pH

VC, % of the recommended rate (4.64 t ha-1)	Soil pH.
0%	5.25c
50%	5.43bc
75%	5.61ab
100%	5.73a
LSD (5%) CV (%)	0.19 4.5

Means with the same factor and column followed by the same letter are not significantly different at a 5% level of significance, CV: Coefficient of variation, LSD: least significant difference.

Organic Carbon

The analysis of variance showed that the interaction effects of vermicompost and NPS were statistically significant on soil organic carbon contents ($P \leq 0.01$) The fertility and health of soil depend heavily on soil organic carbon or the carbon held in soil organic matter. After applying varying rates of modifications, it ranged from 1.33 to 2.51% (Table 8). These values are found in the low to high range based on the ratings suggested by Debele (1982). The highest value of soil organic carbon (2.51%) was recorded for the soil of plots treated with 100 % of the recommended rate of vermicompost (4.64 t VC ha $^{-1}$) and 100 kg NPS ha^{-1} followed by 75 %recommended rate (3.48 t VC ha^{-1}) VC and 100 kg NPS ha^{-1} while, the lowest value of soil organic carbon (1.33 %) was recorded for the soil of the control plots. Soil organic carbon content increased with vermicompost and NPS levels. As reported by [32] soil organic carbon content increased with increased rates of fertilizer application.

Table 8: Interaction effects of vermicompost and NPS on organic carbon

	VC, % of the recommended rate (4.64 t ha-1)			
NPS(kg ha-1)	0	50	75	100
0	1.33f	1.78d	2.24b	2.44a
50	1.43f	1.97c	2.24b	2.44a
75	1.62e	2.08c	2.44a	2.47a
100	1.66de	2.08c	2.36ab	2.51a
LSD (5%)	0.13			
CV (%)	3.2			

Means with the same factor and column followed by the same letter are not significantly different at a 5% level of significance, CV: Coefficient of variation, LSD: least significant difference.

Total Nitrogen

The analysis of variance showed that the interaction effects of vermicompost and NPS were statistically highly significant ($P \leq 0.01$) on the total nitrogen contents of the soil. After applying various quantities of amendments, the total nitrogen a crucial nutrient factor influencing crop yield was between 0.11 and 0.26% (Table 9). These values are in the medium and high range based on Murphy's recommended ratings (1968). The soil of the plots treated with 100% of the recommended rate of vermicompost (4.64 t ha -1) and 100 kg NPS ha-1 was the highest value of total nitrogen (0.216%), followed by the soil of the plots treated with 100% of VC and 75 kg NPS ha-1 (0.213%), and the soil of the control plots was the lowest value of total nitrogen (0.11%). The highest total nitrogen recorded for the soil of plots treated with 100 % of the recommended rate of vermicompost (4.64 t ha $^{-1}$) and 100 kg NPS ha^{-1} might be attributed to N released from vermicompost through mineralization and N supplied to soil from the NPS. Because vermicompost and NPS fertilizer were applied, the amount of organic carbon in the soil increased which increased total nitrogen. As reported by [33] by applying organic fertilizers, the total nitrogen content of the soil can be increased.

Table 9: Interaction effects of vermicompost and NPS on total nitrogen

	VC, % of the recommended rate (4.64 t ha-1)			
NPS(kg ha-1)	0	50	75	100
0	0.11h	0.13f	0.19d	0.2cd
50	0.12h	0.17e	0.19d	0.21abc
75	0.13g	0.18e	0.2cd	0.213ab
100	0.14fg	0.18e	0.2bcd	0.216a
LSD (5%)	0.01			
CV (%)	3.9			

Means with the same factor and column followed by the same letter are not significantly different at a 5% level of significance, CV: Coefficient of variation, LSD: least significant difference.

Available Phosphorus

The analysis of variance showed that the interaction effects of vermicompost and NPS were statistically highly significant on available phosphorus ($P \leq 0.01$). Phosphorus is the most common component in tropical soils that inhibits plant growth, behind nitrogen. The rate at which plants absorb phosphate ions is influenced by their concentration in the soil solutions. The soil's available P concentration varied from 10.17 to 5.11 mg kg-^{1} after the application of NPS and vermicompost (Table 10), lying between the medium and high range according to Cottenie's recommended rating (1980). The maximum available phosphorus (10.17 ppm) was recorded for the soil of plots treated with 100% of the recommended rate of vermicompost (4.64 t ha^{-1}) and 100 kg NPS ha^{-1} and the minimum (5.11 ppm) was recorded for the soil of the control plots. The highest detected amount of available phosphorus in the soil of plots treated with 100 kg NPS ha^{-1} and 100% of the approved rate of vermicompost (4.64 t ha^{-1}) could be the result of NPS fertilizer supplying the soil with phosphorus which is released from vermicompost. This can be concluded from the observation that phosphorus and organic carbon have a positive and extremely significant relation (r=0.53**) in (Table 13). These results of finding agree with Inal *et al.*(2003) stated that after using NPS and vermicompost fertilizer, the amount of available P in the soil increases. Furthermore, Rick *et al.*, (2011) found that the amount of phosphorus available in the soil after harvesting increased twofold when farmyard manure (at 15 t ha^{-1}) and 66 kg ha^{-1} of phosphate were added

Table 10: Interaction effects of vermicompost and NPS on available phosphorous (mg kg^{-1})

	VC, % of the recommended rate (4.64 t ha-1)			
NPS (kg ha-1)	0	50	75	100
0	5.11e	5.67de	6.00cde	6.57cde
50	5.93cde	5.97cde	6.67cde	7.57bcd
75	5.96cde	6.06cde	8.0abc	9.28ab
100	7.31bcde	8.97ab	9.36ab	10.17a

LSD (5%)	1.85			
CV (%)	7.11			

Means with the same factor and column followed by the same letter are not significantly different at a 5% level of significance, CV: Coefficient of variation, LSD: A least significant difference.

Exchangeable Potassium

The interaction effect of both fertilizer and the main effect of vermicompost revealed significant differences at ($P \leq 0.05$After applying vermicompost and NPS fertilizers, the exchangeable potassium of the experimental site ranged from 0.63 to 1.57 cmol(+) kg^{-1}, which shifts from high to very high according to the rating by FAO (2006) (Table 11). The treatment that received 100 kg NPS ha-1 and 0 t VC ha-1 was the lowest value of exchangeable potassium (0.63 cmol (+) kg-1) while 100% of the stated rate vermicompost (4.64 t ha-1) and 100 kg NPS ha-1 fertilizer was the highest value (1.57 cmol (+) kg-1). Potassium released from vermicompost into soil is the cause of the increase in exchangeable potassium. The higher potassium content of vermicompost may have contributed to the increase in soil exchangeable potassium levels seen after applying different levels. This is also confirmed by a significant and positive correlation (r=0.886 **) of exchangeable potassium with organic carbon (Table 12). In agreement with this Lim *et al.*(2015) reported an increase in exchangeable potassium with an increasing rate of vermicompost.

Table 11: Interaction effects of vermicompost and NPS on exchangeable potassium

	VC, % of the recommended rate (4.64 t ha-1)			
NPS (kg ha-1)	0	50	75	100
0	0.82fg	0.87fg	1.27bcd	1.53ab
50	0.89fg	0.94ef	1.17cde	1.57a
75	0.65g	1.01def	1.5ab	1.5ab
100	0.63g	0.93ef	1.39abc	1.51ab
LSD (5%)	0.93			
CV (%)	4.93			

Means with the same factor and column followed by the same letter are not significantly different at a 5% level of significance, CV: Coefficient of variation, LSD: A least significant difference.

Cation Exchange Capacity (CEC)

The analysis of variance showed that the interaction effects between vermicompost and NPS fertilizer were statistically significant on soil moisture ($P \leq 0.05$). Cation exchange capacity which can indicate the types of clay minerals present in the soil and the capacity of soil to retain nutrients and water; ranges between (15.43 to 23.25 cmol (+) Kg^{-1}) after applying vermicompost and NPS (Table 12). According to the rating by [19] these values fall in the range of moderate. The highest value of CEC (23.25 cmol (+) kg^{-1}) was recorded from 100% of the recommended rate (4.64 t ha^{-1}) and 75 kg NPS ha^{-1}, whereas, the lowest value (15.43 cmol (+) kg^{-1}) was recorded from the 100 kg NPS ha^{-1} and 0 t VC ha^{-1} treatment. As per a report by Athanase et al. vermicompost is an organic amendment that consists of the majority of nutrients, such as phosphates, exchangeable K, exchangeable Mg, and Ca in plant-available forms. Therefore, the increment in CEC over the might be controlled directly related to the increase of soil organic matter and synergetic effect of NPS and vermicompost. This can further be confirmed by a significant and positive correlation (r=0.83 **) between CEC and organic carbon (Table 13). Similarly, Manivannan et al.(2009) also reported an increase in CEC over the control due to the application of increasing rate fertilizer. From these findings, the application of vermicompost along with NPS fertilizer with high nutrient content was justified to improve soil organic matter and nutrient contents that might enhance soil fertility status. The application of organic along with inorganic fertilizers is a very common practice to replenish soil nitrogen, phosphorus, and potassium status [42].

Exchangeable Magnesium (Mg)

The interaction effect of both fertilizer and the main effect of vermicompost revealed significant differences at ($P \leq 0.01$). The exchangeable magnesium of the experimental site ranged from 2.97 to 5.31 cmol (+) kg^{-1}, which ranges from low to medium according to the rating by FAO (2006), after applying vermicompost and NPS fertilizers (Table 12). The highest value of exchangeable potassium (5.31 cmol (+) kg^{-1}) was recorded from 100 % of the recommended rate vermicompost (4.64 t ha^{-1}) and 100 kg NPS ha^{-1} fertilizer whereas the lowest value (2.97 cmol (+) kg^{-1}) was recorded in treatment that received 100 kg NPS ha^{-1} and 0 t VC ha^{-1} (Table 12). The increment in exchangeable magnesium is due to magnesium released from vermicompost to soils and synergitic effect of both fertilizers. Soil exchangeable potassium levels increased with Vermicompost level treatments might be due to the high potassium content of vermicompost. This is also confirmed by a significant and positive correlation (r=0.886 **) of exchangeable potassium with organic carbon (Table 13). In agreement with this [7] reported an increase in exchangeable potassium with an increasing rate of vermicompost.

Table 12: Interaction effects of vermicompost and NPS on exchangeable calcium, magnesium, and cation exchange capacity

	VC, % of the recommended rate (4.64 t ha-1)											
	Ca				Mg				CEC			
NPS (kg ha-1)	0	50	75	100	0	50	75	100	0	50	75	100
0	1.92c	3.4b	3.706b	4.39a	2.97gh	3.9de	4.43c	5.5ab	16.33gh	18.79ef	20.26d	22.47ab
50	1.91c	3.6b	3.71b	4.41a	2.87h	3.54ef	4.43c	5.25b	15.68h	17.58fg	21.05cd	21.85ab
75	2.27c	3.54b	3.83b	4.49a	3.3fgh	3.38fg	5.11b	5.83a	16.39gh	16.80gh	20.06de	23.25a
100	2.04c	3.51b	3.78b	4.39a	3.35fg	3.37f8	4cd	5.31ab	15.43h	16.6gh	20.23d	23.17ab
LSD (5%)	0.48	0.45										1.36
CV (%)	7.7	6.63										4.29

Means with the same factor and column followed by the same letter are not significantly different at a 5% level of significance, CV: Coefficient of variation, LSD: A least significant difference.

Pearson Correlation Coefficients

The Pearson correlation coefficient is the most often used method for calculating a linear correlation among response variables. Pearson correlation coefficients were computed amongst the selected soil physico-chemical properties such as pH, available phosphorous, exchangeable Magnesium Calcium, Potassium, and Total Nitrogen, (Table 13). A significant and positive correlation was observed among selected soil physico-chemical properties. Therefore, Soil pH was positively and extremely correlated with organic carbon (r=0.58**), yield (r=0.65**), available phosphorous (r=0.32*), and cation exchange capacity (r=0.83**). However, soil bulk density was highly significant and negatively correlated to other soil parameters (Table 13). Similarly, Krif *et al.*, (2020) reported the significant associations of Organic carbon with soil physico chemical properties and crop parameters. Based on the results obtained on acidic soil-treated vermicompost and NPS presented a significant rise in soil-selected properties.

Table 13: Simple correlation coefficients among the selected soil parameters

Parameters	BD	Av. P	pH	Ex. Ca	TN	OC	Ex. K	Ex. Mg
CEC	-0.70*	0.39*	0.39*	0.83**	0.83**	0.83**	0.83*	0.90**
Ex. Mg	-0.66**	0.39*	0.51**	0.80**	0.80**	0.83**	0.82**	1
K	-0.63**	0.43*	0.53**	0.84**	0.80**	0.83**	1	
OC	-0.67**	0.53**	0.58**	0.90**	0.97**	1		
TN	-0.71**	0.51**	0.59**	0.90**	1			
EX. Ca	-0.69**	0.40**	0.59**	1				
pH	-0.39*	0.32*	1					
Av. P	-0.39*	1						

Where, **= significant at 0.01, = *significant at 0.05, pH= power of hydrogen, Ex. Ca= exchangeable calcium, Ex. Mg= exchangeable calcium, TN= total nitrogen, GY=yield, OC= organic carbon, BD= bulk density.

Summary

Poor soil fertility is the key chemical constriction on soil that limits productivity in the western part of Oromia. The use of integrated vermicompost and NPS inorganic fertilizer is necessary to improve the soil's fertility status, which can raise production and income. Raising the soil's potential is essential for raising the yield and productivity of the crop. By using both organic and inorganic fertilizers, which were employed to achieve the major goals of soil fertility and crop production, the production per unit area will increase as the fertility of the soil is raised.

The studies were set up using a randomized complete block design (RCBD) with three replications, four levels of vermicompost rates (0, 2.32, 3.48, and 4.64-ton ha^{-1}), and four levels of NPS (0, 50, 75, and 100 kg ha^{-1}). The findings revealed a slight increment in pH, total nitrogen, and available phosphorus. The amount of exchangeable calcium, exchangeable magnesium, cation exchange capacity, and organic carbon results in some reduction of soil acidity and some improvement of soil fertility. If organic and inorganic fertilizers are applied together in a sustainable manner, such as with vermicompost and NPS, the soil's fertility is increased.

Conflict of Interest Statement

The authors state that there is no conflict of interest

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