

Research Article

Characterization of Vermicompost for Major Plant Nutrient Contents Made from the Combination of Different Organic Materials in North Shewa Zone, Oromia, Ethiopia

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Abstract

Chemical fertilizers contribute significantly to environmental degradation, soil fertility loss, reduced agricultural productivity, soil degradation, and climate change. To address these issues, an experiment was conducted at Fitche Agricultural Research Centre to characterize nutrient content in vermicompost prepared from various feedstock materials. A vermiculture house (4 x 5 m) was constructed with worm bins made of shallow concrete boxes (0.4 m depth, 0.5 m width, 1 m length). It was covered with corrugated iron sheets and mesh wire to protect the worms from sunlight, rain, and predators. The treatments included barely straw, faba bean straw, teff straw, wheat straw, and a mixture of all straws. Red worms (*Eisenia fetida*) were used to compost the substrates, which were chopped and mixed in a 2:1 ratio (cattle manure to crop residue by weight). Water was sprayed to maintain optimum moisture. Vermicomposting started by releasing worms into the substrate. Mature vermicompost samples were collected and analyzed. Results showed pH values in the slightly acidic range and electrical conductivity suitable for earthworm survival and plant growth. Organic carbon, C: N ratio, and cation exchange capacity data indicated promising soil-improving properties. The highest C: N ratio (20.57) was observed in teff and wheat straw compost; the lowest in faba bean compost. Available phosphorus and potassium were highest in faba bean straw compost. All vermicompost types were rich in exchangeable cations (Ca, Mg, K, Na). Vermicompost from faba bean, barley, and teff straw exhibited the highest macro nutrient content, suggesting their potential to correct nutrient imbalances and improve soil fertility, production, and productivity.

Keywords

Vermicompost, Soil Fertility, Straw, Nutrient Content

1. Introduction

The application of heavy doses of chemical fertilizers and pesticides has raised significant social and environmental concerns globally. These chemicals have adversely affected soil microorganisms and fertility, reducing plants' natural resistance to insect pests and diseases [24]. In addition, the use

of synthetic fertilizers has posed risks to human health and agricultural product safety [20]. In response, the scientific community is increasingly exploring environmentally friendly, economically viable, safe, and sustainable alternatives such as organic fertilizers to replace chemical fertilizers [24, 10, 12, 7].

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Received: 3 November 2025; Accepted: 17 November 2025; Published: 2 February 2026



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Vermicomposting is one such sustainable technique involving the bio-oxidation and stabilization of organic waste materials like crop residues, animal dung, industrial waste, and municipal sludge through the activity of earthworms [7]. This process produces vermicompost, a nutrient-rich organic fertilizer containing humus, essential macronutrients and micronutrients, beneficial soil microflora, and plant growth regulators [2].

Often regarded as "farmers' friends," earthworms play a crucial role in promoting soil aeration, fragmentation, and mixing of soil minerals [23]. The earthworm species *Eisenia fetida*, widely used in Ethiopia, is highly effective due to its adaptability, rapid processing of organic wastes, and high reproduction rate [9]. Through their digestion process, earthworms enhance microbial activity and convert organic waste into stable vermicompost [23].

Compared to conventional composting, vermicomposting results in faster decomposition, higher microbial activity, and greater nutrient availability, including nitrogen, phosphorus, and potassium [8, 21]. It also improves soil physical properties like bulk density and water-holding capacity and reduces heavy metal content relative to traditional compost [15]. Research shows vermicompost contains plant hormones that further stimulate plant growth and development [6, 18].

Numerous studies from Ethiopia confirm that vermicompost made from various organic combinations such as soybean straw, cattle manure, khat leftovers, and eucalyptus twigs is rich in nutrients and of high quality [7]. The integration of vermicompost with chemical fertilizers has demonstrated significant improvements in crop growth, yield, nutrient uptake, and disease resistance across several crops including maize, teff, potato, sorghum, and wheat [25, 3, 16, 1].

In the North Shewa zone, where mixed farming yields abundant crop residues and cow dung, these organic resources represent a valuable input for vermicomposting. This study aims to (1) characterize vermicompost prepared from major crop residues in the area concerning major plant nutrients and (2) identify the best material combinations for producing high-quality vermicompost. Therefore, the trial was carried out with objectives of:

- 1) To characterize vermicompost prepared from the combination of residue of major crops in the study area in terms of major plant nutrient and
- 2) To identify the materials combination for the best quality of vermin compost.

2. Material and Methods

2.1. Description of the Study Area

The study was conducted at Fitch Agricultural Research Center, located 112 km north of Addis Ababa in the Girar Jarso District of North Shewa Zone, Ethiopia. The geographical coordinates of the district are between 09°38'52.8"N to

10°00'10.8"N latitude and 38°34'22.8"E to 38°50'20.4"E longitude, with an elevation ranging from 1300 to 3419 meters above sea level. The average annual rainfall is 1200 mm according to meteorological data from Fitch Station. The area's mean maximum and minimum temperatures are 35 °C and 11.5 °C, respectively.

2.2. Establishment of Vermiculture Station

A vermiculture facility was established at the Fitch Agricultural Research Center to produce vermicompost and multiply composting worms. The vermiculture house measured 4 x 5 meters. Shallow worm bins made of concrete with dimensions of 0.4 m depth, 0.5 m width, and 1 m length were constructed inside the house. The house's top was covered with corrugated iron sheets, while mesh wire protected the sides to prevent sunlight, rain, and flying predators from entering. Protective barriers were installed at the basement and around the walls to safeguard the worms from ants and other crawling predators.

2.2.1. Experimental Materials and Treatments

1. Vermicompost Preparation

The bedding materials used in this experiment included crop residues such as teff straw, wheat straw, barley straw, and faba bean straw, sourced from the center's experimental fields. Cattle manure was used as feedstock for the worms and was added to all substrates. The earthworm species used was the red, non-burrowing species *Eisenia fetida*, measuring 10 to 15 cm in length with a lifespan of about 28 months, collected from Salale University.

Twelve treatment combinations of bedding and feed materials were tested. Each combination followed a crop residue (dry organic waste) to animal manure ratio of 1:2 by weight after partial fermentation for 2-3 weeks using conventional composting methods. The treatments were as follows:

- a) 50% Teff straw + 100% Cattle manure
- b) 50% Wheat straw + 100% Cattle manure
- c) 50% Barley straw + 100% Cattle manure
- d) 50% Faba bean straw + 100% Cattle manure
- e) 25% Teff straw + 25% Wheat straw + 100% Cattle manure
- f) 25% Teff straw + 25% Barley straw + 100% Cattle manure
- g) 25% Teff straw + 25% Faba bean straw + 100% Cattle manure
- h) 25% Wheat straw + 25% Barley straw + 100% Cattle manure
- i) 25% Wheat straw + 25% Faba bean straw + 100% Cattle manure
- j) 25% Barley straw + 25% Faba bean straw + 100% Cattle manure
- k) 12.5% each of Teff straw, Wheat straw, Barley straw, and Faba bean straw + 100% Cattle manure
- l) 100% Cattle manure only

Vermicomposting started by introducing earthworms into the partially decomposed medium while maintaining optimal environmental factors—temperature, moisture, and ventilation [11]. Harvesting was done manually by hand-sorting worms from the compost. Harvested vermicompost was dried, heaped, and stored, with representative samples collected for laboratory analysis.

2.2.2. Vermicompost Harvesting and Laboratory Analysis

Vermicompost samples were sieved to remove earthworms and undecomposed materials. The homogeneous vermicompost was stored separately, and its quality analyzed at the Oromia Soil Laboratory, Engineering Corporation.

- 1) pH and electrical conductivity (EC) were measured in a 1:2.5 soil-to-water suspension using a pH meter and EC meter, respectively [26]
- 2) Organic carbon was determined by the [27].
- 3) Total nitrogen was analyzed using the Kjeldahl method [28]. Available phosphorus was measured by the Olsen method utilizing ascorbic acid as a reducing agent [29]. Total exchangeable bases (Ca^{2+} , Mg^{2+} , K^+ , Na^+) were determined— Ca^{2+} and Mg^{2+} by atomic absorption spectrometry (AAS), and K^+ and Na^+ by flame photometry [30]
- 4) Cation exchange capacity (CEC) was analyzed as described by [31]

2.3. Data Analysis

Laboratory analyses were conducted in triplicate, and mean values were used for interpretation following established standards.

3. Result and Discussion

3.1. pH (H_2O) and Electrical Conductivity (EC)

Laboratory analysis result indicate that, the pH value of vermin compost was ranged from 5.6 to 6.5 (Table 1). Relatively

the highest and the lowest pH value were recorded from the vermin compost prepared from the Faba bean straw and barely straw respectively. A pH greater than 8.5 is harmful to micro-organism [22]. Thus, except the pH values of Faba bean straw and Cattle manure, all type of vermin compost are found in moderately acidic, it might be due to raw material vermin compost prepared.

The laboratory analysis result revealed that electrical conductivity of vermin compost was ranged from 0.073 to 0.181 dS cm^{-1} (Table 1). The highest and the lowest mean value of EC was recorded from Wheat straw + Barley straw and Barley straw + Faba bean + Cattle manure respectively. Salinity which has the value of EC greater than 8 dS cm^{-1} is harmful to microorganism [22]. Therefore, the values of EC of vermin compost made from all materials are suitable for survival of earthworm and applicable for crop production.

3.2. Organic Carbon, C: N Ratio and Cation Exchange Capacity

The result indicate that, relatively the highest mean value of organic carbon (30.34%) was recorded under decomposition of Faba bean straw with cattle manure and the lowest (26.22%) mean values of organic carbon was recorded from the vermicompost prepared from Cattle manure (Table 1). In general, the status of organic carbon in all types vermicompost is high when compared with its availability in garden soil. This finding is in conformity with the study of [10] whose found that the worm castings (vermicompost) contain higher percentage of organic carbon as compared to conventional compost and garden soil. The highest C: N ratio (20.57) was recorded under Tef straw + wheat straw with cattle. Low C: N ratio was registered from faba bean straw with cattle manure of vermin compost. Low C: N ratio showed that higher rate of mineralization [5] and thus the vermicompost prepared from all materials/substrates contains high percentage of total nitrogen. Therefore lower C: N ratio was recorded due to higher mineralization of nitrogen. In line with this result, several studies confirmed that the lowest C: N ratio was recorded from vermicompost [12].

Table 1. Chemical Properties of Vermicompost Prepared from Different Materials.

Parameters	Decomposed materials											
	TC	WC	BC	FC	TWC	TBC	TFC	WBC	WFC	BFC	TWBFC	C
pH- H_2O	5.8	5.8	5.6	6.5	5.9	5.7	5.9	5.9	5.9	5.8	5.7	6.5
EC (dS/cm)	0.14	0.141	0.170	0.123	0.146	0.13	0.14	0.181	0.136	0.073	0.126	0.114
CEC ($\text{cmol}^+\text{kg}^{-1}$)	95.2	93.2	94.8	85.9	97.1	93.7	92.8	94.6	105.7	113.5	91.6	98.6
OC (%)	29.42	28.36	28.44	30.34	26.54	28.95	29.82	28.22	27.5	29.25	27.93	26.22

Parameters	Decomposed materials											
	TC	WC	BC	FC	TWC	TBC	TFC	WBC	WFC	BFC	TWBFC	C
C: N Ratio	16	17.51	15.2	14.9	20.57	19	17.04	18.1	19.01	19.12	17.24	17.3

TC = Tef straw + Cattle manure, WC= Wheat straw + Cattle manure, BC= Barley straw + Cattle manure, FC= Faba bean straw + Cattle manure, TWC= Tef straw + Wheat straw + Cattle manure, TBC= Tef straw + Barley straw + Cattle manure, TFC= Tef straw + Faba bean straw + Cattle manure. WBC= Wheat straw + Barley straw + Cattle manure, WFC= Wheat straw + Faba bean straw + Cattle manure, BFC= Barley straw + Faba bean + Cattle manure, TWBFC= Tef straw + Wheat straw + Barley straw + Faba bean straw + Cattle manure, C= Cattle manure only

Cation exchangeable capacity result of vermicompost prepared using different substrate were varied from 85.9 to 113.5cmol+/kg (Table 1). As the results indicate that the highest (113.5cmol+/kg) and the lowest (85.9 cmol+/kg) were obtained from vermin compost prepared using Barley straw + Faba bean straw and Faba bean straw respectively. This result was in agreement with finding of [32] CEC rating indicated

the CEC of vermicompost made from all substrates was rated to very high status. This result was also in agreements with the study conducted by [13] which was 57.8 cmol+ kg-1. Cation exchange capacity is the capacity of the soil to hold and exchange cat ions. Therefore application of vermicompost made from all substrates could increase CEC content of the soil in areas where soil with low CEC.

3.3. Total Nitrogen, Available Phosphorus and Potassium (NPK)

Table 2. Macro Nutrient Content of Vermin Compost Prepared from Different Materials.

Parameters	Decomposed materials											
	TC	WC	BC	FC	TWC	TBC	TFC	WBC	WFC	BFC	TWBFC	C
TN (%)	1.83	1.62	1.66	2.03	1.29	1.52	1.75	1.56	1.44	1.53	1.62	1.52
Available P (PPm)	205.92	163.14	419.01	532.9	114.69	126.45	119.76	114.23	152.29	124.61	94.38	143.99
Available K (PPm)	790.0	687.5	683.75	794.74	732.54	782.5	713.5	727.5	777.16	788.42	746.9	756.82
Exch. Ca cmol+/kg	28.6	27.6	19.8	29.5	29.27	28.3	33.66	28.1	24.6	27.5	35.33	29.5
Exch. Mg cmol+/kg	22.3	21.4	6.7	22.6	22.04	22.0	22.53	20.9	21.1	21.8	22.78	23.2
Exch. K cmol+/kg)	20.0	17.7	17.3	20.1	18.88	19.8	18.39	18.8	20.0	20.0	19.25	19.2
Exch. Na cmol+/kg	12.3	15.7	18	18.9	25.04	17.6	11.23	20.8	21.0	13.0	20.36	14.1

TC = Tef straw + Cattle manure, WC= Wheat straw + Cattle manure, BC= Barley straw + Cattle manure, FC= Faba bean straw + Cattle manure, TWC= Tef straw + Wheat straw + Cattle manure, TBC= Tef straw + Barley straw + Cattle manure, TFC= Tef straw + Faba bean straw + Cattle manure. WBC= Wheat straw + Barley straw + Cattle manure, WFC= Wheat straw + Faba bean straw + Cattle manure, BFC= Barley straw + Faba bean + Cattle manure, TWBFC= Tef straw + Wheat straw + Barley straw + Faba bean straw + Cattle manure, C = Cattle manure only

Total nitrogen content of vermicompost, relatively the highest (2.03%) and lowest (1.29%) content was recorded from vermicompost made from Faba bean straw + Cattle manure and Tef + Wheat straw materials with cattle manure respec-

tively (Table 2). Similarly, [14] reported that 3.5% of total nitrogen was recorded from vermicompost.

Analyzed sample also revealed that, relatively the highest (532.9ppm) and the lowest (114. 23 ppm) available phosphorous was recorded from the vermin compost obtained from

faba bean straw and Wheat straw + Barley straw + Cattle manure respectively (Table 2). The enhanced P level in vermicompost suggests phosphorous mineralization during the process. The worms during vermicomposting converted the insoluble P into soluble forms with the help of P-solubilizing microorganisms through phosphatases present in the gut, making it more available to plants [19]. The study is in conformity with the result of [17] who found that, the worm casting contains the highest available phosphorus contents with the values ranged from 1900 to 10,200mg/kg.

The data showed that the highest (794.74ppm) and the lowest (683.75ppm) available potassium were recorded from the vermicompost prepared from Faba bean straw and Barley straw respectively (Table 2). The study is in line with the result of [17] who reported that, the highest (1500 to 7300mg/kg) available potassium was registered from vermicompost.

3.4. Exchangeable Calcium, Magnesium, Potassium and Sodium

The analyzed result indicate that highest (35.33 cmol+/kg) and lowest (19.8cmol+/kg) exchangeable Ca^{2+} was recorded from vermin compost made from Tef straw + Wheat straw + Barley straw + Faba bean straw and Barley straw respectively while, the highest (23.2cmol+/kg) and lowest (6.7 cmol+/kg) exchangeable magnesium was recorded from vermicompost obtained from Cattle manure only and Barley straw + Cattle manure materials respectively. The highest (20.1cmol+/kg) exchangeable potassium was recorded from vermin compost obtained from Faba bean straw + Cattle manure and the lowest (17.3 cmol+/kg) was obtained from Barley straw + Cattle manure substrates While, the highest (25.04cmol+/kg) and lowest (13cmol+/kg) exchangeable Sodium was registered from vermin compost obtained from Tef + Wheat straw+ Cattle manure and barley + faba bean straw + Cattle manure materials respectively (Table 2). In general, the vermicompost obtained from all substrates were rich in exchangeable cations. The result is in agreement with the findings of [4] reported that the exchangeable bases were significantly increased in vermin compost as compared to pit compost.

4. Conclusion and Recommendation

Conclusion

This study demonstrated that vermicompost prepared from different locally available substrates combined with cattle manure exhibits varied nutrient contents influenced by the feed-stock material. Vermicompost made from faba bean straw and cattle manure showed the highest pH, macronutrient levels, and best decomposition rate (C: N ratio), followed by barely straw and teff straw combinations. These nutrient-rich vermicomposts improve the physical and biological properties of soil and consequently enhance plant quality and growth. The findings confirm the potential of vermicomposting as an ef-

fective, natural organic fertilizer that can optimize nutrient release in soils and sustain crop production.

Recommendation

Farmers are encouraged to prioritize the use of vermicompost made from faba bean straw and cattle manure when these materials are available, followed by vermicompost from barely and teff straw mixtures due to their superior nutrient profiles and composting quality. It is advisable to integrate vermicompost with inorganic fertilizers in future crop production systems to enhance fertilizer use efficiency and sustainability. Further research should focus on quantifying the equivalence of vermicompost to inorganic fertilizers and optimizing integrated nutrient management practices for different crops and soils.

Abbreviations

NPK	Nitrogen, Phosphorus and Potassium
C: N	Carbon to Nitrogen Ratio
pH	Power of Hydrogen
P	Phosphorus
N	Nitrogen
EC	Electrical Conductivity

Acknowledgments

The author gratefully acknowledges the Oromia Agricultural Research Institute for their financial support and the Fitch Agricultural Research Center for facilitating logistics. Special thanks go to the Soil Fertility Improvement and Problematic Soil Research Team members for their active participation in conducting this research. The author also extends sincere appreciation to Salale University for their cooperation in providing earthworms (*Eisenia fetida*) used in the vermicompost trial.

Author Contributions

Dereje Girma Kebede: Project administration, Writing – original draft

Tadela Geramu Etefa: Writing – review & editing

Meron Tolosa Gemachise: Supervision

Dejene Getahun Abebe: Supervision

Conflicts of Interest

The authors declare no conflicts of interest.

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