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# Evaluation of Nutrient Content of Vermicompost Made from Different Substrates at Mechara Agricultural Research Center on Station, West Hararghe Zone, Oromia, Ethiopia

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**Abstract:** The study was conducted at Mechara Agricultural Research Centre during 2016–2018 to evaluate nutrient content of vermicompost made from different substrates. The treatments were sorghum straw, maize straw, teff straw, haricot bean straw, grass straw and mixture of all straws. A red worm (*Eisenia fetida*) was selected to digest the substrates. The substrates was chopped and added to the worm bin volume calculated using spherical frustum formula  $1/6\pi h(3a^2+3b^2+h^2)$  in a ration 2.5:1 ration of cattle manure to crop residue in weight basis. Water was sprayed to maintain optimum moisture for worms as it needed. The vermi composting process was started by releasing 100 worms in to the substrates. Matured composite vermicompost samples were prepared and collected for laboratory analysis. The laboratory result showed that, the pH and EC values of all type of vermicompost are found in suitable range for survival of earthworms and also for plant growth. Data with regards to %OC, C: N ratio and CEC of vermicompost made from all material is excellent and promise for improvement of soil properties. Relatively the highest (4.26%) and lowest (3.04%) TN content was recorded from vermicompost made from grasses and haricot bean substrates respectively. The highest value of available P and K was also registered from vermicompost prepared from all materials. Even if the values of recorded exchangeable Ca, Mg, K and extractable micro nutrients were different, the vermicompost obtained from all substrates were rich in exchangeable cations and micro nutrients. Therefore, the nutrient content of vermicompost prepared from all substrates showed the highest values for all macro and micro plant nutrients. Thus, the vermicompost made from all materials could correct the plant nutrient imbalance and could be used for vermicompost preparation based on the accessibility of materials. Also utilizing the vermicompost for crop production and enhancing soil fertility.

**Keywords:** Nutrient, Soil Fertility, Straw, Substrates, Vermicompost

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## 1. Introduction

Applications of heavy doses of chemical fertilizers and pesticides have increased the social and environmental risks across the globe. It has also affected soil microbes and fertility as well as minimized the resistance and power of plant against insect-pest and other prevailing diseases [33]. The uses of these synthetic fertilizers have also adversely

affected the human health and agricultural products [28]. Recently, the scientific community is trying to adopt the environmentally friendly, economically viable, safe and sustainable ways of soil fertilization to avoid the danger of chemical fertilizers by replacing the chemical fertilizers by organic fertilizers [33, 11, 19, 8].

Vermicomposting is an environmentally friendly process of bio-oxidation and stabilization of organic wastes which is

prepared from organic materials such as paper residues, crop residue, water hyacinth, animal dung, industrial wastes, municipal sewage sludges, Khat left over and eucalyptus twigs [11-14, 19, 8]. Those organic materials decomposed by waste eater earthworms (epigeic in nature) into a nutritive organic fertilizer i.e. vermicompost, rich in humus, macronutrients, micronutrients, beneficial soil microflora, actinomycetes, and plant growth regulators, and using them as an alternative to agrochemicals [2].

Earthworms are sometimes mentioned as farmer's friends, soil managers and nature's ploughmen. They consume organic matter; promote soil aeration, fragmentation and mixing of mineral particles [32]. Some species of earthworms have the capability of consuming different organic wastes including animal manure, green manure, industrial wastes, sewage sludge and crop residues [10]. Red worms *Eisenia fetida* is most widely used species in Ethiopia, because these species being epigeic display characteristics like high rates of processing of organic wastes, high reproductive rates and tolerant to wide range of environmental factors. During feeding of waste materials earthworms disintegrate and improve decomposition of the product through microbial activities and thus finally convert the unstable organic material into a stabilized form called vermicompost [32].

The decomposition rate of vermicompost is faster than conventional compost because in vermicompost the transformation of organic materials takes place through earthworm gut where the end materials contain high microbial activities, rich in nutrient contents, plant growth regulator, thus it proved that earthworms are able to convert garbage into 'gold' [7]. In addition, bulk density, water holding capacity, pH, electrical conductivity, nitrogen, phosphorus, and potassium content are improved by vermicomposting compare to composting material [9, 30]. Furthermore, vermicompost decreases the amount of heavy metal incorporated to soil compare to compost [22]. It has been also stated that vermicompost may have more compounds used as a plant hormone which enhances plant growth and development compare to compost [6, 26].

According to many study conducted in Ethiopia, vermicompost have high nutrient content and good quality. [8] reported that, the vermicompost prepared from the combination of soya bean straw and cattle manure showed high nutrient value and good quality and thus popularized the technology for farmers. [11, 19] indicated that, vermicompost originated from khat left over and eucalyptus twigs has high nutrient contents and able to produce good quality of vermicompost. Besides increasing plant nutrients, vermicompost also improve growth, total dry matter and grains yield of different crops. Therefore, its effect has been tested by many researcher and scholars. The results showed significant difference on plant growth and yield if it is integrated with chemical fertilizers. Integrated use of vermicompost and NPS fertilizer gave higher maize yield in vertisol of Ambo [36]. Application of vermicompost and

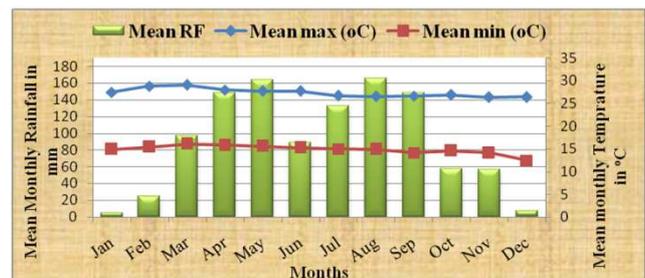
NPS fertilizers gave higher Teff yields and highest marginal rate of return in North Western Zone of Tigray Region, Ethiopia. The highest marketable yield of Potato was recorded by the application of vermicompost and Chemical fertilizers [19]. Application of nitrogen and vermicompost significantly reduced infestation of Striga in sorghum, improved soil moisture and nutrient contents, and enhanced growth and yield of the crop [3]. Combined application of vermicompost and NPK fertilizers has also significantly increased nutrient uptake, yield and yield components of wheat [24]. Combined use of vermicompost and chemical P fertilizer with lime is economically optimum and could be recommended for reclaiming soil acidity and improve nutrients for maize as it enhanced grain yield and yield components of maize plant in strongly acidic soils of Western Highlands of Ethiopia [1].

West Hararghe zone produces huge amount of crop residues and cow dung since the farmers practiced mixed farming systems. Therefore huge amount of organic materials are available for vermicomposting as a substitute for chemical fertilizers and also used for integrated application of vermicompost and chemical fertilizers for the crop. Therefore, keeping in view the importance of vermicompost, the present study was designed with the aim to evaluate the nutrient content of vermicompost made from different substrate in West Hararghe Zone, Oromia Region, Ethiopia.

## 2. Material and Methods

### 2.1. Description of the Study Area

The study was conducted in Daro lebu District, at Mechara Agricultural Research Centre in 2017/2018. The district is located in West Hararghe Zone, Eastern Ethiopia at a distance of 434 km to the East of Addis Ababa and about 115 km from Chiro, capital town of the zone. It lies at longitude of 40° 19.114' 00" E and latitude of 08° 35.589' 00" N and at an altitude of 1750 m above sea level. The area is characterized by a bimodal rainfall pattern of distribution. The short rainy season usually starts in March and extends to May, while the main/long rainy season stretches from end of June to September. The ambient temperature of the district varies from 14 to 26°C with an average of 20°C (McARC Metrological Station, 2010-2018).



**Figure 11.** Mean monthly rainfall, maximum and minimum temperatures of the study area from 2010-2018 (Mechara Agricultural Research Center Meteorological station).

## 2.2. Establishment of Vermiculture

Vermiculture was constructed for vermicompost production and multiplication of worms in Mechara Agricultural Research Center. The size of houses/vermiculture was 4 x 5m and the worm bin of shallow boxes were constructed in the house with the dimension of 0.4m of depth, 0.5m of width and 1m of length from concrete cement. Corrugated iron sheet was used to cover the top of the house and the sides of the house were covered by mesh wire in order to protect sunlight and rain and to avoid the entrance of flying predators from a worm. In addition, ash was used to control small ants.

## 2.3. Experimental Materials and Vermicompost Preparation

Vermicompost was prepared from different substrate materials that were locally available crop residues: Maize, sorghum, haricot bean, grasses and the whole mixture of straws and grass as a bedding material. Cattle manure was added to all substrates in equal amount. The collected substrates were chopped and added to the worm bin for the purpose of earth worm multiplication. A red worm (*Eisenia fetida*) was used as a decomposer, which was collected from Haramaya University. However, for the treatment purpose, plastic bag were used to apply the treatments/substrates in the vermiculture.

After all substrates chopped, they was added to plastic bags and mixed with decomposed cattle manure in a ration of crop residue to cattle manure 2.5:1 on weight basis. Water was sprayed to maintain optimum moisture for worms as it needed. A total of 3kg of substrates were filled the plastic bag which have a volume of 0.047m<sup>3</sup> based on the formula calculated as spherical frustum formula  $1/6\pi h(3a^2+3b^2+h^2)$  [18]. The vermicomposting process was started by releasing 100 worms in to the substrates where the three most important environmental factors (temperature, adequate moisture and ventilation) were maintained [17]. Bottom face of plastic bag was drilled to avoid water logging.

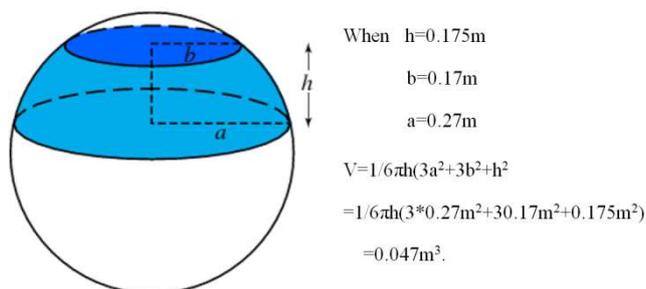


Figure 2. Spherical frustum formula.

The materials/substrates were transformed in to vermicompost after 3 months to give uniform humus in which no food scraps and residue materials are identifiable. The matured vermicompost was light and black or dark brown in color. The matured vermicompost was collected by manual harvesting which involved hand-sorting, or picking the worms directly from the vermicompost by hand. The

vermicomposts were dried and their representative samples were taken and prepared for laboratory test. The laboratory analytical values are the averages of triplicate for interpretation of the results.

## 2.4. Vermicompost Samples Analysis Methods

The collected vermicompost samples were analyzed for the parameters stated in the table below.

Table 1. Different parameters analysed for vermicompost samples and analysis methods.

Parameter	unit	methods
pH (H <sub>2</sub> O)	-	Potentiometric water extract
EC	mS/cm	Conductivity Cell Potentiometric
P <sub>avail.</sub>	mg P <sub>2</sub> O <sub>5</sub> /kg soil)	Olsen
K <sub>avail.</sub>	mgK <sub>2</sub> O/kg soil	Ammonium Acetate
OC	%	Walkley Black
TN	%	Kjeldehal
Exchangeable Ca	meq/100 gm of soil	Ammonium Acetate
Exchangeable Mg	meq/100 gm of soil	Ammonium Acetate
Exchangeable Na	meq/100 gm of soil	Ammonium Acetate
Exchangeable K	meq/100 gm of soil	Ammonium Acetate
CEC	meq/100 gm of soil	Ammonium Acetate
Extractable Fe	mg/kg soil	DTPA Extraction
Extractable Zn	mg/kg soil	DTPA Extraction
Extractable Cu	mg/kg soil	DTPA Extraction
Extractable Mn	mg/kg soil	DTPA Extraction

## 3. Data Analysis

The experiment was a laboratory analytical procedure on the different materials where values recorded are means of triplicate values recorded and interpreted following previous standards.

## 4. Result and Discussion

### 4.1. Chemical Properties of Vermicompost

#### 4.1.1. pH (H<sub>2</sub>O) and Electrical Conductivity (EC)

According to the laboratory analysis result, the pH value of vermicompost was ranged from 7.51 to 8.43 (Table 2). Relatively the lowest and the highest pH value were recorded from the vermicompost prepared from the grass and sorghum straw respectively. A pH greater than 8.5 is harmful to microorganism [31]. Thus, the pH values of all type of vermicompost are found in suitable range for survival of earthworms and also for plant growth. Similarly [20] obtained similar results in which the pH status of vermicompost was ranged from 6.8-8.41. [8] also reported that, the pH values of vermicompost are more suitable for plant growth as compared to conventional compost.

The laboratory analysis result of electrical conductivity of vermicompost was ranged from 3.29 to 5.27mS cm<sup>-1</sup> (Table 1). The highest and the lowest mean value of EC was recorded from grass and sorghum straw respectively. Salinity which has the value of EC greater than 8 mS cm<sup>-1</sup> is harmful to microorganism [31]. Therefore, the values of EC of vermicompost made from all materials are suitable for

survival of earthworm and applicable for crop production.

#### 4.1.2. Organic Carbon, C: N Ratio and Cation Exchange Capacity (CEC)

The analysed result showed that, relatively the highest mean value of organic carbon (34.66%) was recorded under digested grass and the lowest (21.26%) mean values of organic carbon was registered from the vermicompost prepared from haricot bean straw (Table 2). 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 [25, 11, 19, 8] whose found that the worm castings (vermicompost) contain higher percentage of organic carbon as compared to

conventional compost and garden soil. Low C: N ratio was registered from all types of vermicompost. Low C: N ratio indicates higher rate of mineralization [5] and thus the vermicompost prepared from all 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 [23, 21, 34, 13, 19, 8]. CEC of vermicompost made from all substrates was very high status which was ranged from 57.39 to 68.7 cmol+ kg<sup>-1</sup>. This result confirmed the study conducted by [20] who found that 57.8 cmol+ kg<sup>-1</sup> of CEC in vermicompost.

Table 2. Chemical properties of vermicompost prepared from different materials.

Parameters	digested substrates					
	Haricot bean	Grass	Mixed straw	Teff	Maize	Sorghum
pH-H <sub>2</sub> O (1:2.5)	8.41	7.51	8.09	8.15	8.39	8.43
EC (mS/cm) (1:2.5)	4.06	5.27	3.69	4.21	4.51	3.29
CEC (meq/100 gm)	57.39	58.26	63.04	68.70	66.09	63.04
Organic Carbon (OC) (%)	21.26	34.66	27.08	27.00	28.21	23.35
C: N Ratio	7.00	8.14	7.27	7.16	9.13	7.39

The recorded values are means of triplicates.

#### 4.2. Nutrient Contents of Vermicompost

##### 4.2.1. Total Nitrogen, Available Phosphorus and Potassium (NPK)

Data with regards to nutrient content of vermicompost, relatively the highest (4.26%) and lowest (3.04%) total nitrogen content was recorded from vermicompost made from grasses and haricot bean substrates respectively (Table 3). Similarly, [21] reported that 3.50% of total nitrogen was recorded from vermicompost. [8] also reported that, the vermicompost obtained from the combination of Maize Stover, Niger seed residue and sheep manure as well as the compost from the combination of soybean residue, Niger seed straw and sheep Manure had a higher value of total nitrogen content. The analyzed result also showed that, relatively the lowest (775.39mg/kg) and the highest (1277.62mg/kg) available phosphorous was recorded from the vermicompost obtained from haricot bean straw and grasses respectively (Table 3). 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 [27, 16]. The study is in conformity with the result of Nagavallema *et al.* (2004) who found that, the worm casting contains the highest available phosphorus contents with the values ranged from 1900 to 10,200mg/kg. The highest

(7327.7mg/kg) and the lowest (3740.40mg/kg) available potassium were recorded from the vermicompost prepared from teff and sorghum straw respectively (Table 3). The study is in line with the result of [25] who reported that, the highest (1500 to 7300mg/kg) available potassium was registered from vermicompost.

##### 4.2.2. Exchangeable Calcium, Magnesium and Potassium

The exchange complex of the vermicompost is dominantly occupied by exchangeable calcium than other basic cations in proportion. The analyzed result showed that highest (35.20 meq/100 gm) and lowest (26.80meq/100 gm) exchangeable Ca<sup>2+</sup> was recorded from vermicompost made from teff and haricot bean straw respectively while, the highest (13.20meq/100 gm) and lowest (10meq/100 gm) exchangeable magnesium was registered from vermicompost obtained from haricot bean and mixed straw substrates respectively. The highest (13.20meq/100gm) exchangeable potassium was recorded from vermicompost obtained from haricot bean straw and the lowest (10 meq/100 gm) was obtained from mixed straw substrates (Table 3). 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 (Ca<sup>2+</sup>, Ma<sup>2+</sup>, K<sup>+</sup>) were significantly increased in vermicompost as compared to pit compost.

Table 3. Macro and micro nutrient content of vermicompost prepared from different materials.

Parameters	digested substrates					
	Haricot bean	Grass	Mixed straw	Teff	Maize	Sorghum
Total Nitrogen (TN) (%)	3.04	4.26	3.73	3.77	3.09	3.16
Available P (AV. p) (mg P <sub>2</sub> O <sub>5</sub> /kg)	775.39	1277.62	829.91	1023.80	987.38	905.96
Available K (Av. K) (mgK <sub>2</sub> O/kg)	6963.6	4987.0	4571.5	7327.7	4545.47	3740.40
Exch. K (meq/100 gm)	11.59	10.00	20.72	20.92	19.90	18.97

Parameters	digested substrates					
	Haricot bean	Grass	Mixed straw	Teff	Maize	Sorghum
Exch. Ca (meq/100 gm)	26.80	31.20	32.00	35.20	34.00	34.00
Exch. Mg (meq/100 gm)	13.20	12.80	10.00	12.00	12.00	12.00
Fe (mg/kg)	29.56	29.05	38.23	54.24	46.01	46.02
Mn (mg/kg)	354.35	101.83	120.87	117.66	105.14	112.03
Cu (mg/kg)	4.24	1.30	2.67	0.90	4.20	6.67
Zn (mg/kg)	32.32	35.81	41.33	45.67	41.05	58.72

The recorded values are means of triplicates.

#### 4.2.3. Extractable Iron, Manganese, Copper and Zinc

The analyzed result revealed that the highest (54.24 mg kg<sup>-1</sup>) values of DTPA extractable iron was recorded from vermicompost made from teff straw and lowest (29.05 mg kg<sup>-1</sup>) value were registered from grass straw substrates. The highest (354.35 mg kg<sup>-1</sup>) and the lowest (101.83 mg kg<sup>-1</sup>) extractable manganese were recorded from vermicompost prepared from haricot bean and grass straw substrates respectively. The highest (58.72 mg kg<sup>-1</sup>) Zinc content among treatment was vermicompost made from sorghum straw while the least (32.32 mg kg<sup>-1</sup>) was recorded from haricot bean straw substrates. The highest (6.67 mg kg<sup>-1</sup>) and the lowest (0.9 mg kg<sup>-1</sup>) Copper content was recorded from vermicompost made from sorghum and teff straw substrates respectively (Table 3). Similarly, [15] was reported that, very high iron contents were recorded from vermicompost. [25, 29, 15, 21] indicated that Mn content of vermicompost was very high. Also, the result is in agreement with the findings of [15, 29], who found that very high Zn contents were recorded from vermicompost.

## 5. Conclusion and Recommendation

Vermicompost is nutritionally rich natural organic fertilizer, which releases nutrients in the soil and improves quality of the plants with renewed of physical and biological properties of soil. Though, vermicompost prepared from locally available materials such as haricot bean, grass, teff, maize and sorghum straw and mixture of all straws were analyzed for their nutrient evaluation. According to the result of this study, the nutrient content of vermicompost prepared from all substrates showed the highest values for all macro and micro plant nutrients. Thus, the vermicompost made from all materials could correct the plant nutrient imbalance if applied to the nutrient deficient soil and could be used for vermicompost preparation based on the accessibility of materials. In generally, there is a need for further studies on the rate of application of vermicompost and their effect on crop yields and soil physic chemical properties under field condition.

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