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Characterization of Vermicompost for Major Plant Nutrient Contents and Manuring Value

Derib Kifle[1], Gemechu Shumi[2]and Abera Degefa[3]
[1]*Bako Agricultural Research Center, P O box 03, Bako, Ethiopia E- mail:deraltes2009@gmail.com*
[2]*College of Natural and Computational Science, Wollega University, P O box 395*
[3]*Ethiopian Sugar Corporation Research and Development, P O box 15*

Abstract

The study was conducted at Bako Agricultural Research Centre (BARC) during 2015–2016.The experiment was designed to characterize vermicomposts prepared from residue of main crops in the area and animal wastes in terms of major plant nutrient composition in order to identify the best quality compost. Fourteen types of bedding and feed materials combination were used as a treatment which was transformed in to vermicompost after 3 months to give a uniform humus like loamy material. Laboratory analysis of the vermicompost for its chemical property and nutrient composition revealed that unlike the pH value of conventional compost which falls in alkaline array detrimental to growth of plants, the pH values of all type of vermicompost were found in suitable range for plant growth. In terms of % organic carbon, CN ratio and total nitrogen content, all types of vermicompost has out smarted the conventional compost significantly. The vermicompost obtained from the combination of maize stover, niger seed_residue and sheep manure as well as that produced from combination of soybean residue, Niger seed_straw and sheep Manure have shown higher value of 2.42%. . However, these types of vermicomposts were found to be very poor in other primary and secondary plant nutrient elements. With regard to other plant growth limiting nutrients the vermicompost produced from soybean residue and cattle manure scored a higher value in total phosphorus, total potassium and total magnesium. The result of this study indicated that in spite of supplying other macro and micro nutrients needed for plant growth, 4.64 tons of this vermicompost can replace the recommended amount of urea(92 kg N), supplying simultaneously 139 kg of DAP (64.49 kg P_20_5), an amount which exceeds the blanket recommended dose of phosphorus for maize. Thus, by virtue of the accessibility of raw materials, simplicity of its production and better availability of the nutrient contained in it to the plant, utilizing the vermicompost of soybean straw and cattle manure has a paramount importance in enhancing crop productivity and improving soil fertility.

Keywords: Soil fertility, Vermicompost, Feedstock, *Eisenia fatida*, Agro chemicals

Introduction

Tropical soils are deficient in all necessary plant nutrients on the one hand and large quantities of such nutrients contained in domestic wastes and agricultural byproducts are wasted on the other hand. It is estimated that in cities and rural areas of developing countries million organic wastes are generated annually which is either burned or land filled (Gandhi *et al*, 1997)

The extensive use of chemical fertilizers leads to loss of soil fertility due to imbalanced use of fertilizers that has adversely impacted agricultural productivity and causes soil degradation. Now there is a growing realization that the adoption of ecological and sustainable farming practices can only reverse the declining trend in the global productivity and environment protection (Aveyard 1988, Wani and Lee 1992, Wani *et al.*, 1995)

In maintaining soil fertility through natural nutrient cycle, composting of organic materials and returning it back to the soil is a common activity in developed nations (Peter *et al.*, 2000).

Composting is a technology for recycling organic materials in order to achieve enhanced agricultural production. Vermicomposting appears to be the most promising as high value biofertilizer which not only increases the plant growth and productivity by nutrient supply but also is cost effective and pollution free. Vermicompost can be described as a complex mixture of earthworm faeces, humified organic matter and microorganisms, which promotes soil aggregation and stabilizes soil structure and improving the air- water relationship of soil when added to the soil or plant growing media, increases germination, growth, flowering, fruit production and accelerates the development of a wide range of plant species (Ndegwa *et al.,* 2001).

Vermicomposting is faster and less labor intensive than traditional composting methods, requires less space, and creates little odor. It is a promising biotechnology for many waste management applications and is an easy way to make a positive environmental impact by reducing the amount of green-waste that finds its way into landfills, incinerators, and sometimes the ocean. The resulting nutrient-rich compost end product is an environmentally sound amendment to enrich soil for plant growth that contributes in counteracting the deterioration of the environment due to rampant use of chemical fertilizers (Inbar *et al.,* 1993)
Composting worms are small mesophillic, red purple worms that prefer an environment of decaying organic matter rather than soil (Piper, 2005). They reproduce quickly, consume large amounts of organic material, and tolerate the environment of a worm bin. Earthworms consume various organic wastes and reduce the volume by 40–60 (Dominguez, 2004). Earthworms and its vermicast promises to usher in the 'Second Green Revolution' by completely replacing the destructive agrochemicals which did more harm than good to both the farmers and their farmland. Earthworms excreta (vermicast) is a nutritive 'organic fertilizer' rich in humus, NPK, micronutrients, beneficial soil microbes—'nitrogen fixing and phosphate solubilizing bacteria' and 'actinomycetes' and growth hormones 'auxins', 'gibberlins' and 'cytokinins'. Both earthworms and its vermicast and body liquid (vermiwash) had been scientifically proving as both 'growth promoters and protectors' for crop plants (Rajiv *et al.,* 2010). Extensive research on inorganic fertilization and plant breeding,

carried out within the framework of conventional agriculture, has allowed agricultural producers to fine-tune nutrient inputs and plant needs in order to maximize yields. However, such detailed knowledge has not yet been attained as regards the nutrient composition of organic fertilizers as vermicompost in sustainable agriculture.

Given the complex and variable composition of vermicompost in comparison with inorganic fertilizers and the myriad of effects that it can have on soil functioning, a clear and objective concept of vermicompost is required, and the complex interactions between vermicompost-soil-plant must be unraveled in order to maintain consumer confidence in organic fertilizer (Cristina and Domínguez, 2010).

In Ethiopian context, vermin-composting is a recently adopted biotechnology in which the effort of on farm verification and demonstrating its utilization was made by Haramaya University, Ambo Plant Protection Research Center and Holetta Agricultural Research Center. However, there were very limited attempt of characterizing vermin-compost and identifying it by the nutrient content and other quality parameters considered in enhancement of crop productivity and soil fertility due to lack of experience in analyzing this fertilizer by domestic laboratories. Among few individual efforts domestically made, Gezahegn et al. (2012) have vermicomposted coffee husk, enset waste, khat waste and vegetable waste using the epigeic earthworm *Eisenia foetida* and found to be as a good option for improving solid waste management in Ethiopia and production of excellent bio-fertilizers for agronomic purposes.

Among the wettest parts of Ethiopia Western Oromia receives rainfall from April to December, that allow the growth of considerable amounts of decomposable materials needed to prepare compost. However, due to lack of awareness and technical know-how, these materials are usually wasted without proper use despite the fact that soil fertility in the region is declining rapidly from time to time. The sub optimal level of NP fertilizers currently being used for crop production under farmers' conditions has aggravated the situation of soil fertility degradation and reduction of crop productivity (Heluf *et al.,* 2004). These and other facts have sparked the idea of looking for alternative sources of fertilizers other than the commercial one. To this effect, the vermiculture station was established and vermicompost preparation was launched at Bako Agricultural Research Center in the last cropping season. Therefore, this study was conducted to characterize vermicomposts prepared from residue of main crops in the study area and animal wastes in terms of major plant nutrient composition and to identify the best quality vermicompost.

Materials and Methods

Description of the study area

The study was conducted at Bako Agricultural Research Centre in 2015/2016. The centre is located in the Western part of Ethiopia at a distance of 250 km away from Addis Ababa. It lies at latitude of 9^0 6′ 00′′N and longitude 37^0 9′ 00′′E and at an altitude of 1650 m above sea level. It has a warm humid climate with annual mean minimum and maximum temperature of 13.5^{0}C and 23.7 ^{0}C respectively. The area receives an annual rainfall of 1237 mm from May to October with maximum precipitation in the month of June to August (BARC Metrological station, 2016).

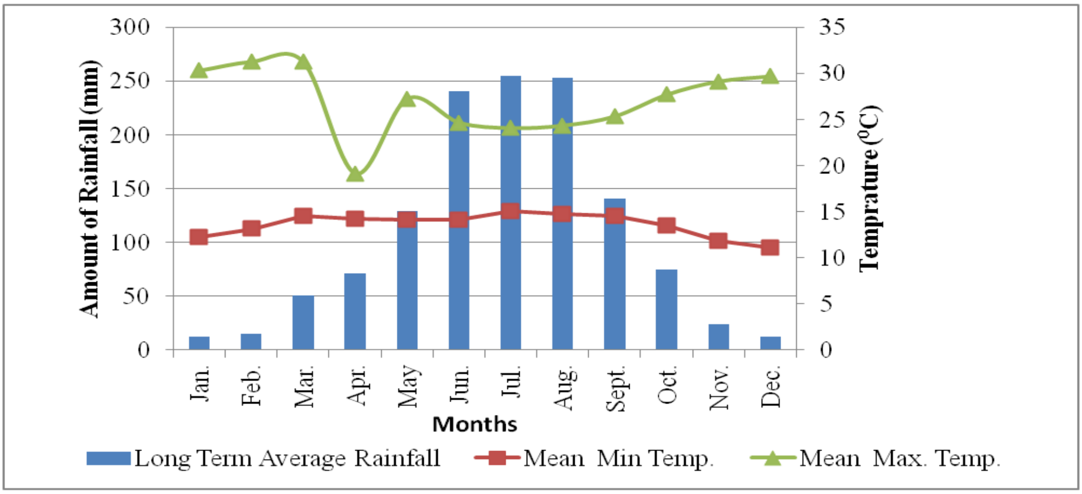

Fig 1. The long term average monthly rainfall and temperature (minimum and maximum) of Bako Agricultural Research Center (1990-2012)

Establishment of vermiculture station

Vermiculture station which comprises of three rooms including raw material preparation, vermicomposting and drying and storage rooms was constructed in a shady and ventilated area of the center. The station is a simple prototype of an elevated barn like housing with corrugated iron roof and netted strips of bamboo walls with meshed wire extension on its upper part designed to ventilate the rooms and to avoid the entrance of flying predators. A protective structure was also laid out at the basement and around the walls of the room to prevent the composting worms from the attacks of ants and other crawling enemies of the worms.

Experimental materials and treatment

Vermicompost preparation

The materials used in this experiment were crop residue; maize stover, soybean straw and niger seed refuse that are obtained from experimental fields of the center as a bedding material and animal wastes; cattle manure sheep dropping and poultry manure collected from animal farms of the center as a feedstock for composting worms. The earthworms employed in the study were the red non burrowing type of species known as *Esinea Fatida*, which are 10 to 15 cm long with life span of only 28 months, collected from Ambo Crop Protection Research Center.

The treatments consist of fourteen types of bedding and feed materials combination were used as a treatment which undergone partial fermentation for 20 days with the combination ratio of crop residue (Dry Organic Waste) to animal manure 1: 2 on weight basis.

Treatments (Feedstock Compositions)

1. Maize Stover + cattle manure
2. Soybean straw + cattle manure
3. Niger seed straw + cattle manure
4. Maize Stover + Soybean straw + Cattle manure
5. Maize Stover + Niger seed straw + Cattle manure
6. Maize Stover + Soybean straw + Sheep waste
7. Maize Stover + Niger seed straw + Sheep waste
8. Maize Stover + Soybean straw + Poultry manure
9. Maize Stover + Niger seed straw + poultry manure
10. Soybean straw + Niger seed straw + Cattle manure
11. Soybean straw + Niger seed straw + Sheep waste
12. Soybean straw + Niger seed straw + poultry manure
13. Maize st.+ Soybean st. + Niger seed st. + cattle man. + Sheep waste. + Poultry waste.
14. Cattle manure only

The vermicomposting process was started by releasing worms in to the partially decomposed medium in condition where the three most important environmental factors (temperature, adequate moisture and ventilation) were maintained (Glenn, 2009). However, during the composting process it was observed that worms in the treatment which poultry manure was used as major feed material couldn't survive much longer than a day to sustain the composting activity. This was probably due to toxic effect of the poultry waste which was possibly contaminated with chemicals used in the farm that paralyzed and finally killed the compost worms. The materials in the other combination was safely transformed in to vermicompost after 3 months to give a uniform humus like loamy material in which no food scraps and residue materials are identifiable. It is light and black or dark brown in color. The compost was collected by manual harvesting which involved hand-sorting, or picking the worms directly from the compost by hand. The vermicomposts were dried, heaped, and stored while their representative samples were taken and prepared for laboratory test and the analysis was done to determine their nutrient level (ICRISAT and APRLP, 2003)

Laboratory analysis

The prepared vermicompost samples were analyzed in Jije Analytical Testing Service Laboratory for their major plant nutrient composition and some chemical properties worth considering in characterizing the materials to an extent (Kalpita *et al*, 2015)

Major Parameters and Test Methods

pH of the vermicomposts was measured by FAO-Potentiometric-Water extract method (Sahilemedehin and Taye, 2000).Organic carbon (OC) was determined by FAO -Loss on ignition method at 450^{o}C (Cohen,1993),Total Nitrogen (TN) was measured using FAO - Kjeldahl method (ISO 11261, 1995). Total Potassium (TK) and Total Phosphorous (TP) was determined by FAO - Aqua regia digestion extract – Flame photometer (FAO, 2002). Total Calcium (Ca) and Total Magnesium (Mg) was estimated by FAO - Aqua regia Digestion extract – EDTA Titration method (Sahilemedehin and Taye, 2000)

Data analysis

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

not an open field type which is commonly subjected to effects of different treatment variation as slope, fertility and other gradients as any agronomic experiments do,which calls for statistical analysis. This is rather a greenhouse type experiment conducted with uniform and controlled internal and ambient environmental conditions simply to measure the nutrient contained in the vermicompost like any other organic fertilizer such as pit compost and FYM. The laboratory analytical values obtained are means of triplicates, which were used for interpretation of the result of the study.

Result and Discussion

Chemical property and nutrient level of the vermicomposts

Total nitrogen, pH and Organic matter

According to the result of laboratory analysis, 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 2.42 % total nitrogen content. The compost from the combination of Corn pulp, Soybean strawand sheep manure and that of cattle manure only, hold second and third position with the value of 2.17% and 2.1% respectively (Table 1). The conventional compost is superior in its pH value which falls in the alkaline range of pH scale. Unlike the pH value of conventional compost which is detrimental to growth of plants, the pH values of all type of vermicompost are found in suitable range for plant growth. Considering the organic carbon, CN ratio and total nitrogen content, all types of vermicompost has out smarted the conventional compost significantly. The modification of acidity was possibly due to nitrogenous waste excreted by the earth worms and the vermiwash released in the process which increased the moisture content thus neutralizing the pH of the vermicompost.

Table 1. Laboratory analytical Results of the vermicomposts

Feed material Combinations	pH (H2O)	% OC	% OM	%TN	CN ratio	% T.P	% T.K	%T.Ca	%T.Mg
Maize St. + Cattle Manure	8.29	32.11	55.3	1.53	20.99	1.22	2.42	5.32	2.1
Soybean Str. + Cattle Manure	8.20	32.22	55.5	1.98	16.27	1.39	3.94	7.91	8.7
Niger Str. + Cattle Manure	8.51	35.21	60.7	1.98	17.78	0.69	2.29	3.08	1.85
Maize St.+Soybean st.+ Cattle Manure	8.4	35.38	61.0	1.37	25.82	0.68	1.8	5.27	3.8
Maize St.+ Niger Str. + Cattle Manure	8.12	34.43	59.3	1.75	19.67	0.69	1.75	8.39	3.78
Maize St.+ Soybean Str.+ Sheep Manure	8.74	33.00	56.8	2.17	15.21	0.80	2.7	6.26	6.89
Maize St.+ Niger Str. + Sheep manure	8.88	35.09	60.5	2.42	14.50	0.90	2.32	3.08	3.33
Soybean Str.+ Niger str.+Cattle Manure	8.12	37.24	64.2	1.98	18.81	0.72	1.92	5.29	3.18
Soybean Str.+ Niger Str.+ Sheep Manure	8.56	36.02	62.1	2.42	14.88	0.83	2.53	5.29	5.71
Crop Residue (Ms. Sbs. NSS)+ Fym (cattle+sheep Manure)	8.05	35.50	61.2	1.98	17.93	0.83	2.22	3.17	8.24
Cattle Manure only	8.16	42.87	73.9	2.1	20.41	0.69	1.7	5.31	1.91
Conven. Compost	9.25	19.32	33.3	0.87	22.21	0.47	1.53	8.39	4.40

The values recorded are means of triplicates

This is in conformity with the study of Nagavallemma et al. 2004. Who found that the worm castings (vermicompost) contain higher percentage of organic carbon (13.8%) and total nitrogen (1.61%) compared to the conventional compost that contained 12% organic carbon and 0.8% total nitrogen. The same trend was obtained by Musaida et al., (2012) who stated that earthworms play an important role in the recycling of N in different agro ecosystems evident in vermicomposting which converts household and agricultural waste into compost within 8 weeks, reduces the C:N ratio and retains more N than the traditional methods of preparing composts.

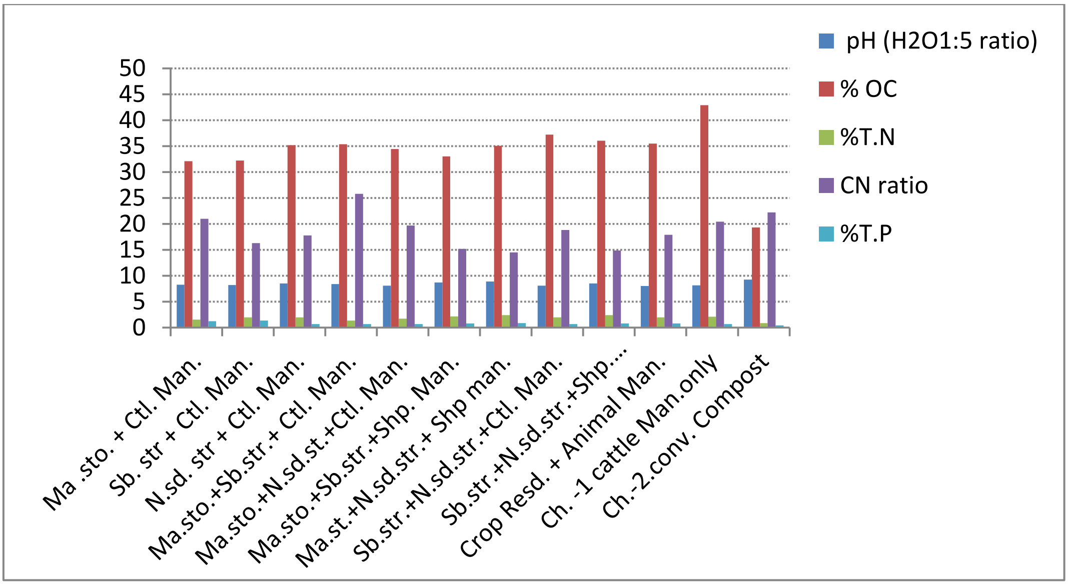

Fig 1. pH, organic matter and primary nutrient(N&P) content of the vermicomposts

Total phosphorus, total potassium, total calcium, and total magnesium

With regard to other plant growth limiting nutrients the vermicompost produced from soybean residue and cattle manure scored a higher value in total phosphorus, total potassium and total magnesium while the vermicompost produced from maize stover,niger seed straw and cattle manure has scored higher value in total Calcium (Table 1).

The higher total phosphorus content in the vermicompost is attributed to the mineralization and mobilization of phosphorous contained in feedstock due to earthworm activity as earthworms play an important role in the release of phosphates on organic matter. The increase in potassium and magnesium is boosted in similar way by the earthworm activity on the feed material. The result of this study is in line with the finding of Amir and Fouzia (2011) who reported that vermicomposts have rich source of nutrient content, a higher base Exchange capacity and more exchangeable sodium, magnesium and potassium than pit compost and garden soil. The analytical result of this experiment collaborates the result of Pius and Thompson (2000) who also reported that and showed vermicomposting resulted in a significant increase in total and available P, exchangeable K, exchangeable Ca and total Mg, emphasizing that the higher concentrations of plant nutrients in end product of vermicomposting indicate a potential for using agriculture wastes in sustainable crop production.

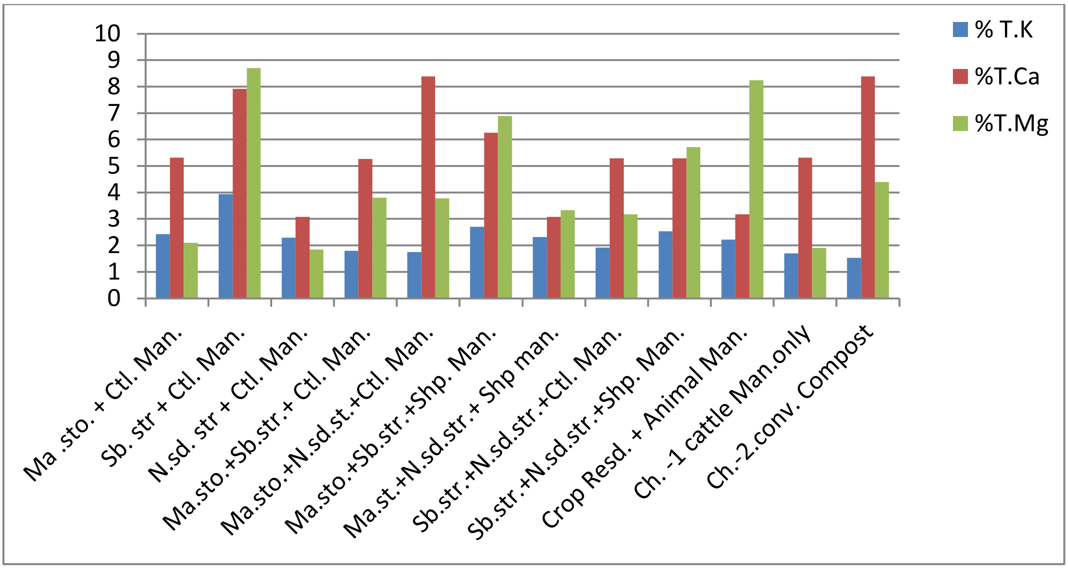

Fig 2. Total phosphorus, total potassium, total calcium, and total magnesium

In terms of the nitrogen economy of the vermicompost, the material that is obtained from maize stover, Niger seed residue and sheep manure as well as the compost from the combination of Soybean residue, Niger seed residue and Sheep Manure were much better than the other combinations. However, these types of vermicomposts are found to be very poor in other primary and secondary plant nutrient elements as it is shown in the table. With respect to other major plant nutrients such as phosphorus, potassium and magnesium, the vermicompost prepared from soybean straw and cattle manure has out ranked the other types of compost.

The manuring value of this type of vermicompost can be illustrated by taking maize, which is one of the major crops in the experimental area and other parts of western Oromia as an example. The blanket fertilizer recommended for this crop which is being used nowadays is 200kg urea and 100kg DAP. According to the result of this study, 4.64 tons of vermicompost prepared from soybean straw and cattle manure can replace the recommended amount of urea in terms of nitrogen which at the same time supply 139 kg of DAP (64.49 kg P_20_5), an amount which exceeds the recommended dose of phosphorus for the crop.

Conclusion and Recommendation

According to the results of this study, integrated effect of all the nutrients present in vermicompost could help to avoid plant nutrient imbalance when applied to the soil in general. Among the different combinations, vermicompost obtained from soybean straw and cattle manure can be of paramount importance when it comes to nutrients composition in enhancing crop productivity, improving soil health and fertility. The accessibility of raw materials, simplicity of its production and better availability of the nutrient contained in it to the plant could be suggested and recommended to farmers in the study area.

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