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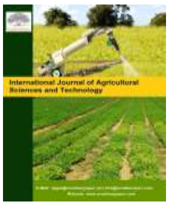

Research Paper

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Evaluation of Vermicompost Nutrient Composition Prepared From Different Organic Materials, in Adola Rede District, Southern Ethiopia

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Abstract

Vermicomposting is a non-thermophilic process that transforms organic waste materials into valuable fertilizer through the combined action of worms and mesophilic microbes. The objective of the study was to evaluate vermicompost nutrient composition prepared from different organic materials. The treatments were consisted of four experimental materials such as Teff straw, Haricot bean straw, mixture of Teff and Haricot bean straw and combination of green *Ricinus communis* and *Myrica salicifolia* leaves.The collected materials were chopped and added to the worm bin of shallow boxes and mixed with decomposed cattle manure in a ratio of 2:1 on weight basis. To digest the selected materials a red worm (*Eisenia fetida*) was used and the vermi composting process was started by releasing 150 earthworms in to the materials. The harvested vermicomposts from different materials were stored separately and finally the vermicompost nutrient composition quality was analyzed. The laboratory results showed that, the pH value of vermicompost was ranged from 8.21- 8.45 and the values of all type of vermicompost are found in suitable range for survival of earthworms and plant growth. In terms of CEC, the highest 41.43 meq/100gm was recorded in vermicompost prepared from Haricot bean straw followed by mixture of Teff and Haricot bean straw (40.72 meq/100gm). The highest 19.03% OC and 32.81% OM were registered in vermicompost made from mixture of Teff and Haricot bean straw. The maximum (1.58%) total nitrogen, 695.97 mg/kg available phosphorus and 12,594.4 mg/kg available potassium was found in Haricot bean straw. Therefore, nutrient composition of vermicompost prepared from different organic materials showed the maximum values of all necessary nutrients for plant growth. Hence, to maintain soil fertility and sustain crop production, farmers of the study area and similar agroecologies could be used for vermicompost preparation based on the availability of vermicompost materials.

Keywords: *Evaluation, Organic materials, Nutrient composition, Soil Fertility, Straw, Vermicompost*

1. Introduction

Heavy use of agrochemicals killed the beneficial soil organisms and destroyed their natural fertility, impaired the power of 'biological resistance' in crops making them more susceptible to pests and diseases. Moreover, chemically grown foods have adversely affected human health. The scientific community all over the world is desperately looking for an

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economically viable, socially safe and environmentally sustainable alternative to the agrochemicals (USBA,1980). The harmful effects of chemical fertilizers have moved scientists' focus toward "green substitutes" with low environmental impact. Among these, vermicompost is an appealing alternative to conventional chemical fertilizers (Benedeti *et al.,* 2015).

Vermicomposting is a non-thermophilic process that transforms organic waste materials into valuable fertilizer through the combined action of worms and mesophilic microbes (Ravindran *et al.,* 2016). Vermicompost is a potential input for sustainable agriculture. The beneficial effects of vermicompost application in soil have been well documented in several studies. Studies have revealed that plant respond to vermicompost application like 'hormonal induced activity' as it contain high level of nutrients, humic acids and humates (Atiyeh *et al.,* 2000).

Vermicomposting is defined as a bio-oxidative process in which detritions earthworms interact with microorganisms and other fauna within the decomposer community, thus accelerating the stabilization of organic matter and greatly modifying its physical and biochemical properties of soil (Domínguez and Edwards, 2010). Moreover, vermicomposting is considered a sustainable approach to waste management and agricultural production. As a result, it minimizes chemical fertilizers' application to soil, reducing their harmful effects and the amount of waste directed to landfills (Tripathi *et al.,* 2005).

Vermicompost is a peat-like organic fertilizer with high nutritional contents, aeration, porosity, and water-holding capacity, prepared by the joint action of earthworms and microbes. In addition to organic waste management, vermicompost is recognized as an effective plant growth promoter (Coria-Cayupaan *et al.,* 2009). Furthermore, vermicompost is an excellent soil additive made up of digested compost and worm castings are much higher in nutrients and microbial life; therefore, considered as a higher value product and worm castings product contain up to 5 times the plant available nutrients found in average potting soil mixes (Ruz-Jerez *et al.,* 1992). Therefore, Nitrogen, Phosphorus, Potassium, and other micronutrients become more available due to microbial activities in vermicompost (Goutam *et al.,* 2011).

Vermicompost also has a positive influence on vegetative growth, stimulating shoot growth and root development (Edwards *et al.,* 2004). The other positive influence of vermicompost application include alterations in morphology of crop plants such as increased leaf area and root branching and stimulated flowering, increase in the number and biomass of flowers and overall increase in fruit yield (Arancon *et al.,* 2003; Singh *et al.,* 2008; Lazcano *et al.,* 2009).

In Midland Agroecology of Guji Zone, majority of the farmers use inorganic fertilizers for crop production that contribute to soil degradation, because chemical fertilizers supply only nutrients and exert no beneficial effects on soil physical condition. However, organic fertilizers increase both crop productivity and soil fertility. In Guji Zone, large amount of crop residues and animal dungs are produced, due to farmers of the study area practiced both crop and livestock production. Therefore, large quantity of organic materials are available for vermicompost production. Thus, the objective of the study was to evaluate vermicompost nutrient composition prepared from different organic materials in Adola Rede District of Guji Zone, Southern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Site

The study was conducted in Adola Rede District of Guji Zone, in Southern part of Ethiopia (Figure 1). The district is found at a distance of 475 km from Addis Ababa, capital city of Ethiopia. The district is bordered by Ana Sora district in the North, Wadera district in the South and Odo Shakiso district in the West and Girja district in the East directions. Geographically, the area lies between 5°44'10"- 6°12'38" North latitude and 38°45'10"-39°12'37" East longitude within an altitudinal range of 1500–2000m above sea level.

The study district is characterized by three agro-climatic zones, namely lowland (60%), midland (29%) and highland (11%) (ARANRO, 2020). The mean annual maximum and minimum temperature of the study district is 28 °C and 16 °C respectively. The rainfall pattern of the study area is bimodal for lowland and midland areas and uni-modal for highland parts and the mean annual rainfall of the study district is 1000 mm. The major soil types found in the study district are Nitisols and orthcacrosols and it is dominantly brown soil

2.2. Farming System of the Study Site

The study district is characterized by a crop-livestock mixed farming system and a semi-nomadic economic activity is also practiced as a means of livelihood by some of its residents. The farmers of the study district produce both in autumn and spring seasons. The area is well known for the cultivation of cereal crops such as bread wheat, teff and maize, pulse crops like haricot bean, chickpea, and others such as fruits and vegetables. They also engaged in the production of coffee as means of livelihood. Moreover, the study district has a huge potential for livestock production as witnessed by farmer's livestock ownership (ARBoFED, 2017).

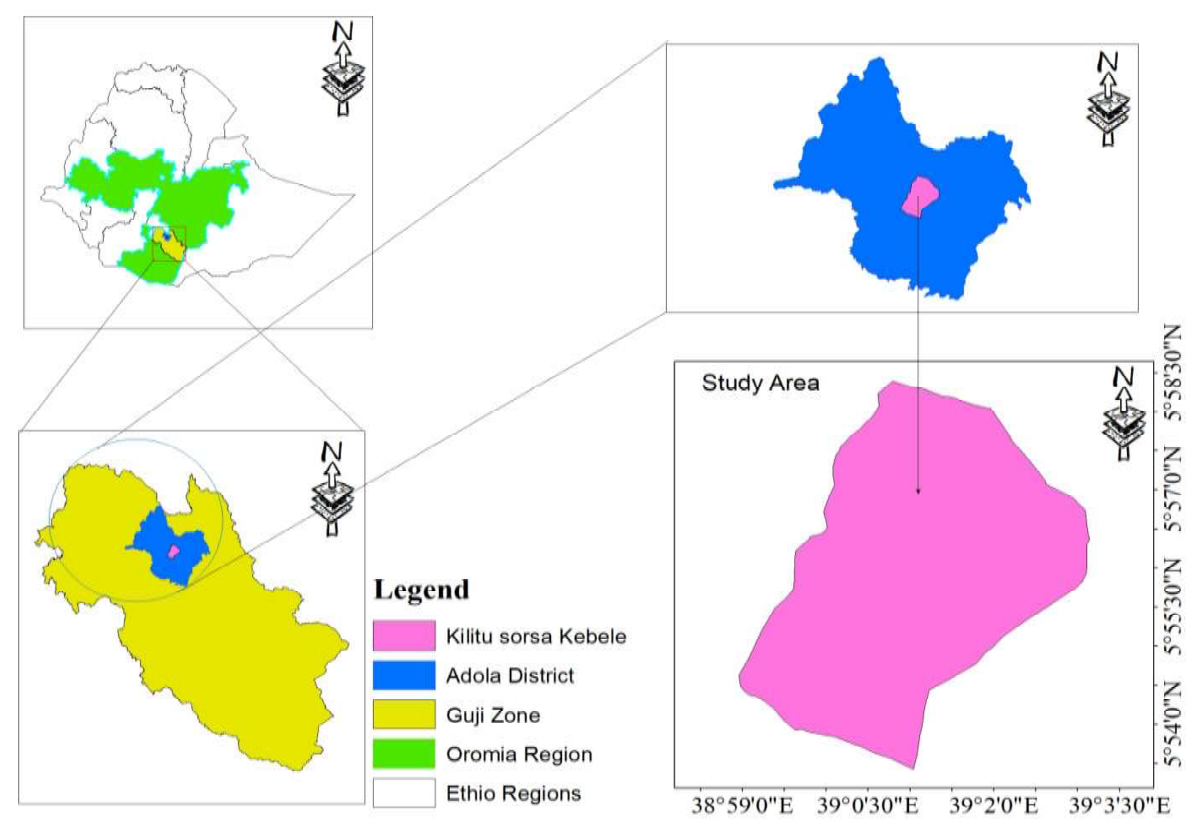

Figure 1: A Map Showing the Study Area

2.3. Establishment of Vermiculture

For multiplication of worms and vermicompost production vermiculture was constructed in Kiltu Sorsa Kebele of Adola Rede District, in Southern Ethiopia. The size of the constructed vermyhouse/vermiculture was 5 x 4 m. Inside the vermyhouse, the worm bin of shallow boxes were constructed with the dimension of 0.5m of depth, 0.5 m of width, 1m of height and 1.5m of length from concrete cement. From 1.5m length of the shallow boxes, 1.2m of length was used for multiplication of worms and vermicompost production and the remaining 0.3m of length was used for storage of the vermicompost produced . The top of the vermyhouse/ vermiculture was covered with corrugated iron sheet and the sides of the vermyhouse were covered by wood to avoid from the direct contact of sun rays and rains and to prevent the entrance of flying predators from a worm.

2.4. Experimental Materials

Vermicompost was prepared from different organic materials which was locally available from farmers field of the study area. The treatments were consisted of four experimental materials such as cereal crop straws of teff and wheat, pulse crop straw of haricot bean, mixture of both cereal and pulse crop straws and mixture of green *Ricinus communis* and *Myrica salicifolia* leaves.

2.5. Vermicompost Preparation

The collected crop straws and green leaves materials were chopped and added to the worm bin of shallow boxes and mixed with decomposed cattle manure in a ratio of 2:1 on weight basis. A red worm (*Eisenia fetida*) was used as a decomposer and water was sprayed to maintain optimum moisture for worms as it needed. After the three most important environmental factors such as adequate moisture, temperature and ventilation were maintained , 150 earthworms was counted and added in to the materials.

2.6. Parameters and Analytical Methods

The harvested vermicompost prepared from different organic materials were stored separately and finally the vermicompost nutrient composition quality was analyzed in Horticoop Ethiopia, Soil, Water and Plant Analysis Laboratory. The selected parameters such as pH, Organic carbon, Total nitrogen, Phosphorus, Cation Exchange Capacity and Total exchangeable bases (Ca, K, Mg, Na, S and B) were determined by the following procedures (Table 1).

Table 1: Analytical Methods of Selected Parameters of Vermicompost Nutrient Composition

Analytical Methods		
Parameters	**Examination Standards**	
Acidity	pH-H_2O	ES ISO 10390: 2014 (1:2.5)
Organic Carbon	OC	Walkely And Black
Total Nitrogen	TN	ES ISO 11261:2015 (Kjeldahl Method)
Phosphorus	P	ES ISO 11263: 2015 (Olsens Method)
Cation Exchange Capacity	CEC	Ammonium Acetate Method
Calcium (Ca),Potassium (K),Magnesium (Mg),	Mehlich-3	
Note: Sodium(Na), Sulfur (S) and Boron (B)		

3. Data Analysis

The raw data was subjected to Genstat software (20th edition). The laboratory result of vermicompost nutrient composition prepared from different organic materials were summarized and presented using graphs.

4. Results and Discussion

4.1. Chemical Properties of Vermicompost Materials

4.1.1. pH (H_2O)

pH is determine both quality and quantity determinants of nutrients contents in vermicompost. The laboratory analysis results of vermicompost nutrient composition prepared from different organic materials showed that ,the pH value of vermicompost was ranged from 8.21- 8.45 (Figure 2). The highest and lowest pH value of 8.45 and 8.21 were recorded in vermicompost prepared from green *Ricinus communis+Myrica salicifolia* leaves and that of only haricot bean straw respectively (Figure 2). Earthworms are sensitive to soil pH and most of the previous studies have revealed that earthworm density, diversity, and survival are typically low in acidic soils (Moore *et al.,*2013; Chan and Mead, 2003). In their study findings, Santamaria *et al.,*2001, also indicated that a pH greater than 8.5 is very harmful. Because, if the value of pH(1:2.5 H_2O) is in the range of alkalinity and salinity it is not suitable to both earthworms and microorganism.

However, the pH value of all vermicompost materials of the current study was found in suitable range for survival of earth worms and plant growth. According to Kale *et al.* (1986) ; Haimi and Huhta (1987) the near-neutral pH of vermicompost may be attributed by the secretion of NH^+_4 ions that reduce the pool of H^+ ions and the activity of calciferous glands in earthworms containing carbonic anhydrase that catalyzes the fixation of CO_2 as $CaCO_3$, thereby preventing the fall in pH. Moreover, previously Edwards and Bohlen (1996) indicated that the castings of earthworms which comprise about 90% of good quality compost are also neutral in nature.

This result is consistent with the findings of Jouquet *et al*. (2013) and Tolera and Tesfaye (2021) who reported that the average pH (1:2.5 H_2O) value of the vermicompost was ranged from 6.8-8.41 and 6.85 respectively. The study result is also supported with the findings of Mulugeta *et al*. (2022) and Tadele *et al*. (2020) who found that the pH value of vermicompost was ranged from 6.93-7.83 and 7.51-8.43 respectively. Whereas, in contrary to this study, Yvonne *et al*. (2019) indicated that the pH was slightly acidic in the vermicompost prepared from different materials. In addition, on their former studies Ndegwa and Thompson (2000); Suthar and Singh (2008) were reported lower pH in vermicomposts.

4.1.2. Cation Exchange Capacity

The cation exchange capacity (CEC) which can indicate the capacity of soil to retain nutrients and water; ranges between 29.90 (meq/100 gm) to 41.43 (meq/100 gm) in vermicompost prepared from different organic materials (Figure 2).

The highest value of cation exchange capacity 41.43 (meq/100 gm) and 40.72 (meq/100 gm) were recorded from Haricot bean straw and mixture of Haricot bean and Teff straw respectively (Figure 2).Whereas, the lowest value of 29.90 (meq/100 gm) and 30.62 (meq/100 gm) were recorded from Teff straw and green *Ricinus communis+Myrica salicifolia* leaves (Figure 2).

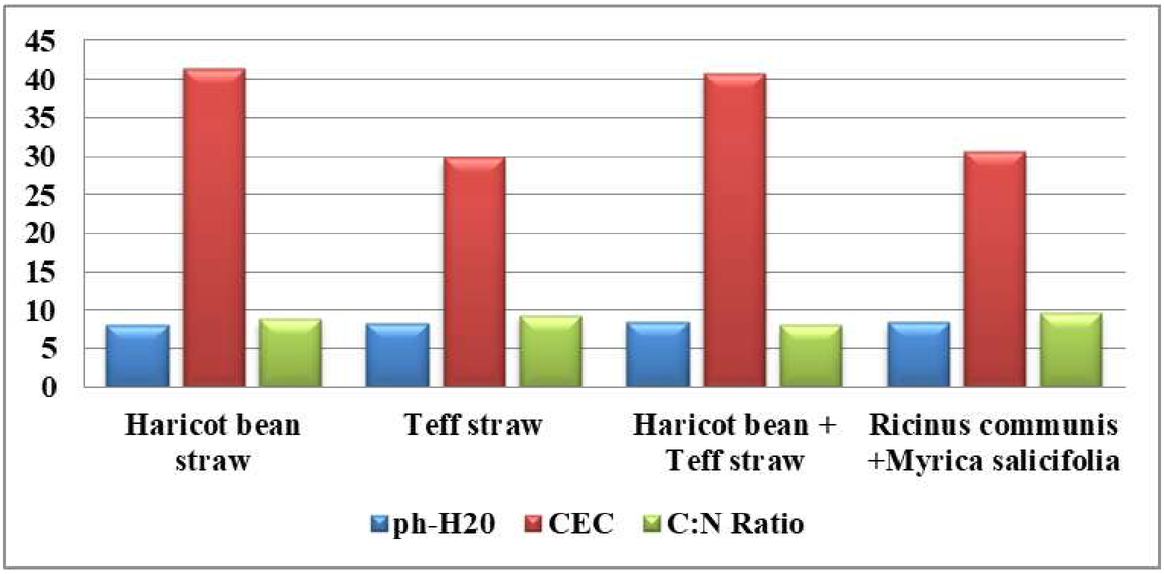

Figure 2: Laboratory Results of pH-H_2O, CEC and C:N Ratio of Vermicompst Materials

The present study revealed that, the CEC of vermicompost made from green *Ricinus communis+Myrica salicifolia* leaves and Teff straw were rated to high status. However, the CEC of vermicompost prepared from Haricot bean straw and mixture of Teff and Haricot bean straw were rated to very high status (Figure 2). This might be due to high organic matter content, better mineralization and full decompositions of substrates used for production of vermicompost. The result is in consistence with the findings of earlier investigators of Venegas *et al.* (2004) and Holcombe and Longfellow (1995). On their study findings indicated that, vermicompost had the highest CEC, due to the organic matter and the worm castings in the vermicompost have nutrients that are 97% utilizable by plants and the castings have a mucous coating which allows the nutrients to time release.

The highest CEC recorded in vermicompost of the current study is in agreement with the findings of Tadele *et al.* (2020); Wako (2021) and Muulgeta *et al.* (2022); who reported that CEC of vermicompost ranges from 57-68.70 mg/kg, 54.24-57.15 cmol+/kg and 33.23 to 65.43 cmol+/kg for vermicompost made from different substrates respectively and the recorded amount of CEC of their findings were rated to very high status. Moreover, in support of this study Jouquet *et al.*(2013) reported that 57.8 cmol+ kg-1of CEC in vermicompost which was rated to very high status.

4.1.3. C:N Ratio

The highest C:N of 9.62 and 9.30 were recorded in vermicompost prepared from the combination of *Ricinus communis* and *Myrica salicifolia* green leaf material and that of Teff straw respectively (Figure 2). On the other hand, least C:N value of 8.89 and 8.05 were obtained from Haricot bean straw and mixture of Teff and Haricot bean substrates respectively (Figure 2). The major effect of C:N ratio in vermicompost is on bacterial activity, high C:N ratio decrease bacterial activity because of nitrogen shortage that is essential for bacterial. However, the C:N ratio recorded in all types of vermicompost materials of this study was lower. On their study findings, Brady and Weil (2002) reported that low C:N ratio indicates higher rate of mineralization. Therefore, 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. Moreover, the narrow carbon to nitrogen ratio in the vermicompost indicates that the compost is well decomposed and N can be released to soil for plant use. This is in conformity with the studies of Garg *et al*. (2006); Mirian *et al*. (2006); Hiranmai and Anteneh (2016) reported that the lowest C:N ratio was recorded from vermicompost prepared from different materials.

4.1.4. Organic Carbon (%)

Soil organic carbon is the most important component in soils as it affects almost all soil properties. It is an essential part of the soil that influences its physical, chemical and biological characteristics. Moreover, it is a major indicator of soil fertility, soil quality and agricultural productivity. The laboratory analyzed result of this study showed that, comparatively the highest mean value of organic carbon (19.03%) and (17.22%) were recorded under digested mixture substrates of Teff and Haricot bean and from digested material of Haricot bean residue respectively (Figure 3). However, the lowest mean values of (13.19%) and (12.13%) organic carbon were registered in vermicompost prepared from green *Ricinus communis+Myrica salicifolia* leaves and Teff straw respectively (Figure 3).

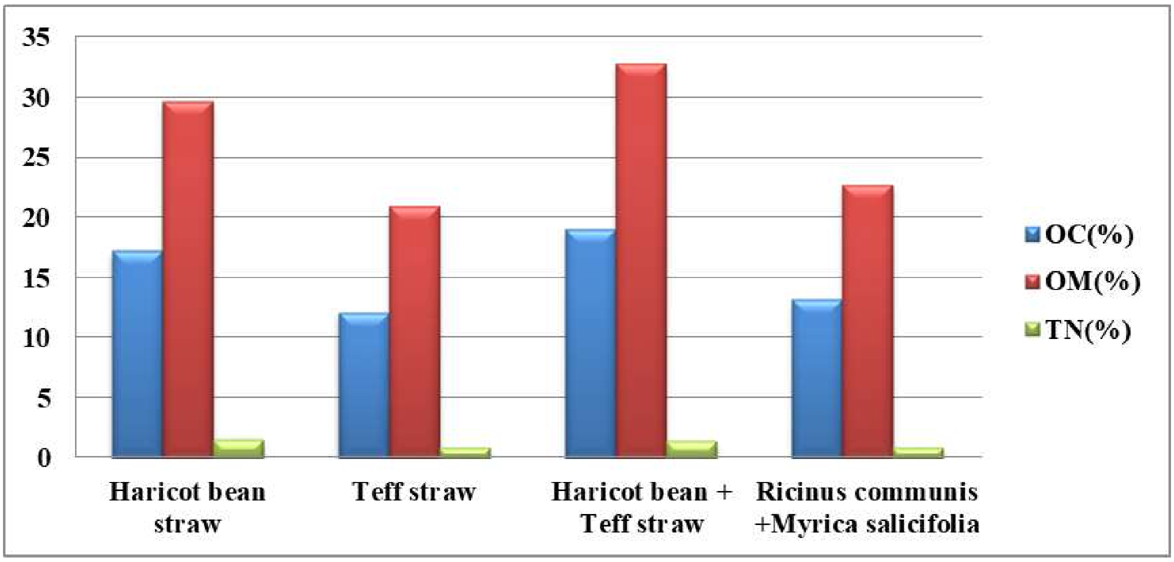

Figure 3: Oc(%), Om(%) and Tn(%) Nutrient Composition of Vermicompst Materials

This study showed that, the range of organic carbon in all types of vermicompost prepared from different materials were rated to very high status. This could be due to the nutrients content in vermicompost generally depends on the digested material that is being used for vermicompost preparation. This finding is similar with the study results of Nagavallemma *et al*. (2004); Eyasu and Anteneh (2015); Hiranmai *et al*. (2016); Derib *et al*. (2017); Varsha *et al*. (2020) were found the higher percentage of organic carbon for vermicompost prepared from different substrates.

4.1.5. Organic Matter (%)

According to the result of laboratory analysis, the vermicompost prepared from the combination of Haricot bean and Teff straw, and that of Haricot bean only had a higher value of 32.81% and 29.69% organic matter contents respectively (Figure 3). The vermicompost prepared from the combination of green *Ricinus communis* and *Myrica salicifolia* leaves and that of Teff straw only, hold third and fourth position with the value of 22.74% and 20.91% organic matter contents respectively (Figure 3).

The findings of this study showed that, from all vermicompost materials higher value of organic matter were recorded. This could be due to the nutritional quality of vermicompost is determined primarily by the type of the substrate (raw materials) and species of earthworms used for composting, along with microbial inoculants, aeration, humidity, pH and temperature. In support of this study, Richards (1954) indicated that vermicompost is rich in organic carbon and beneficial organisms that increase the amount of organic matter in the soil.

4.2. Nutrient Content of Vermicompost Materials

4.2.1. Total Nitrogen

The analysis of total nitrogen content result shows that, the maximum (1.58%) total nitrogen was found in vermicompost prepared from Haricot bean straw followed by combination of Teff and Haricot bean straw (1.46%). While, the lowest (0.89%) and (0.92%) total nitrogen were recorded in vermicompost prepared from mixed of green *Ricinus communis* and *Myrica salicifolia* leaves and that of Teff straw respectively (Figure 3). The vermicompost total nitrogen varies significantly as a function of the substrates used for production. Because, as the findings of this study indicated that different digested substrates were contains different nitrogen contents.

These results generally agree with previous studies on vermicompost which have reported the total nitrogen enrichment by vermicomposting. In this respect, Lange (2005); Hepperly *et al.* (2009); Derib *et al*. (2017) recorded increased level of total nitrogen in vermicompost prepared from different materials. Moreover, in support of this study Tolera and Tesfaye (2021), Ali and Kashem (2018), Kalantari *et al*.(2010), Dickerson (1994) and Tekalign (1991) were recorded (1.64%), (1.33%), (3.5%), (1.94%) and (>0.25%) of total nitrogen respectively in vermicompost made from different substrates.

4.2.2. Available Phosphorus

The results of laboratory analysis indicated that, the highest (695.97 mg/kg), (661.26 mg/kg) and (651.63 mg/kg) of available phosphorus were recorded in vermicompost prepared from Haricot bean straw, combination of green *Ricinus communis* and *Myrica salicifolia* leaves and that of Teff straw respectively (Figure 5). However, as compared to the others the lowest (587.40 mg/kg) of available phosphorus was registered in vermicompost prepared from mixture of Teff and Haricot bean straw (Figure 5). Therefore, the nutrients status of the vermicompost obtained from different substrates had various content of available phosphorus. This could be due to the nutritive value of vermicompost is highly dependent on base substrate used for its production.

In support of current study, Muzafer and Pinky (2017) on their findings reported that available phosphorus content in vermicompost depends on the types of feed materials used. As well, Borah *et al.* (2007) indicated that when earthworm poops their cast on/in soil they build up important soil nutrient especially nitrogen (N), phosphors(P), potassium (K) and other important nutrients. The highest available P recorded in current study was in consonance with the study results of Ceritoglu *et al.* (2019), Nath *et al.* (2009), Alam *et al.* (2007) and Nagavallemma *et al.* (2004) who reported that highest available phosphorus were recorded in vermicomposts.

4.2.3. Available Potassium

The highest (12,594.4 mg/kg) available potassium was registered from the vermicompost obtained from Haricot bean straw followed by mixture of Teff and Haricot bean substrates (10,013 mg/kg). On the other hand, (6,109.66 mg/kg) and (5,508.75 mg/kg) least available potassium were recorded from the vermicompost prepared from combination of green *Ricinus communis* and *Myrica salicifolia* leaves and that of Teff straw respectively (Figure 4).

The vermicompost obtained from all substrates were rich in available potassium and among the vermicompost materials different values of available potassium were recorded. The result is supported with the findings of Suthar et al. (2005) reported that quality of vermicompost depends on feed quality, microbial biomass and decomposition activities during the process. In agreement with this study, Tognettia *et al.* (2010); Wako (2021) reported that (8,200 mg/kg), (13,350 mg/kg) of highest available potassium contents in vermicomposts respectively . However, in contrary to this study Kalantari *et al.* (2010) reported the lowest 950 mg/kg of available potassium in vermicomposts.

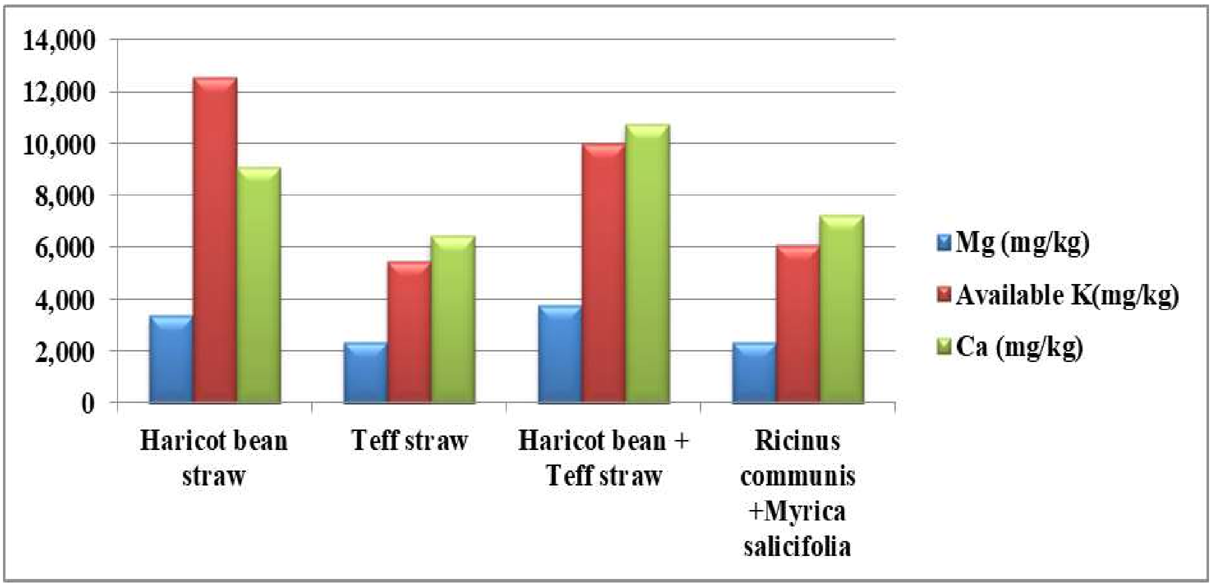

Figure 4: Mg(mg/kg), Available K(mg/kg) and Ca(mg/kg) Nutrient Content Composition of Vermicompst Materials

4.2.4. Calcium and Magnesium

The laboratory analysis results of Calcium and Magnesium nutrient composition of the vermicompost prepared from different substrates are presented in figure 4. It was found that the highest Calcium values of (10,781.30 mg/kg) and (9,113.73 mg/kg) were registered in vermicompost produced from combination of Haricot bean and Teff straw and that of only Haricot bean straw respectively. In terms of Magnesium nutrient values, (3761.47 mg/kg) was recorded in mixed of Haricot bean and Teff straw followed by Haricot bean straw (3367 mg/kg). However, the least Calcium and Magnesium nutrient contents were obtained from vermicompost prepared from Teff straw and green *Ricinus communis* + *Myrica salicifolia* leaves. The result is in line with the findings of Tadele *et al.* (2020), Mohammed *et al.* (2016), Amir and Fouzia (2011) who reported that the available bases of Calcium and Magnesium were significantly highest in vermicompost.

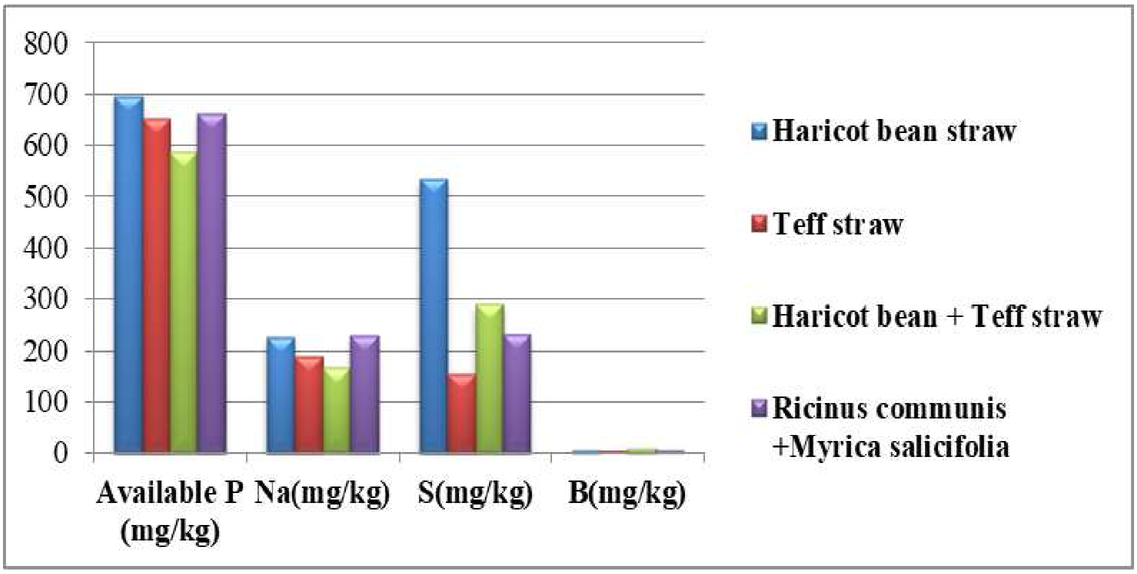

Figure 5: Available P (Mg/Kg), Na (Mg/Kg) and S (Mg/Kg) and B(Mg/Kg) Nutrient Content Composition of Vermicompst Materials

4.2.5. Sodium, Sulfur and Boron

The result of this study showed that the vermicompost obtained from different organic materials had also different nutrient status. In this regard, the maximum (229. 2 mg/kg of Sodium), (533.71 mg/kg of Sulfur) and (9.43mg/kg of Boron) were found in vermicompost produced from combination of green *Ricinus communis* and *Myrica salicifolia* leaves , Haricot bean straw and mixed of Teff and Haricot bean straw respectively (Figure 5). Whereas, the lowest 155.33mg/kg of Sulfur and 5.2mg/kg of Boron were recorded in vermicompost prepared from Teff straw (Figure 5). Moreover, from combination of Teff and Haricot bean straw the lowest 165.66 mg/kg of Sodium content was recorded (Figure 5). This result is in accordance with Suthar *et al.* (2005) who reported that quality of vermicompost depends on feed quality, microbial biomass and decomposition activities during the process.

5. Conclusion and Recommendations

Vermicompost is a peat-like organic fertilizer with high nutritional contents, aeration, porosity, and water-holding capacity, prepared by the joint action of earthworms and microbes. In addition to organic waste management, vermicompost is recognized as an effective plant growth promoter. Therefore, based on the objective of the study vermicompost nutrient composition prepared from different available materials such as haricot bean straw, teff straw, combination of *Ricinus communis* and *Myrica salicifolia* green leaf materials and mixture of teff and haricot bean straw were evaluated. Based on the findings of this study, even if the values of recorded vermicompost nutrient composition prepared from different materials were varied, the nutrient content composition of vermicompost prepared from all selected materials were showed the highest values. Therefore, in order to maintain soil fertility and sustain crop production, farmers of the study area and similar agroecologies could be used for vermicompost preparation based on the availability of materials. Moreover, there is a need for further studies on the rate of application of vermicompost and their effect on crop yields and soil physical and chemical properties.

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