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Evaluation of Earthworm Multiplication Bedding Materials for Effective Vermicompost Production at Jimma, Southwestern Ethiopia

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Abstract: Rapid expansion of urbanization and industrialization has led to generation of huge quantities of waste materials where majority of organic waste is dumped in landfill sites, creates the organic load on the ground water, and more emissions of landfill gases. The best possible alternative to minimize these potential pollutants is through the process of vermicomposting because earthworms have the ability to convert organic waste into wealth (compost). This experiment was done to evaluate the effect of bedding materials for vermicompost production and performance of earthworm at Jimma Agricultural Research Center, Southwestern Ethiopia. The experiment consisted of three types of bedding materials including (cattle manure, donkey manure and poultry droppings) and four incubation periods (40, 60, 80 and 90 days) arranged factorially in completely randomized block design (RCBD) in three replications. The performance of worms was measured based on more suitable for vermicomposting including biological parameter, which measured the growth rate, the chemical nature of compost (pH), final number of worm, organic matter content (OM) of worm casts, total nitrogen (Tot. N) Content and carbon to nitrogen ratio. All of the above mentioned parameters showed that there is a significant difference observed on type of bedding materials used using ANOVA test. The LSD at ($p < 0.05$) test demonstrated that donkey manure followed by poultry droppings was more influential in worm biomass production, growth rate, total nitrogen and organic carbon content. In case of pH content of worm cast, it reveals that the optimum pH for worm growth rate is near to neutral condition. As conclusion, different types of bedding material will influence the worm growth.

Keywords: Vermicomposting, Bedding Materials, Biological Parameters

1. Introduction

Now a day's more attention has been given to convert different organic waste materials in to wealth products at low-input as well as eco-friendly basis. Vermicomposting is one of the mechanisms to reduce this organic waste and it has been practically used all over the world. It is the process of producing compost by utilizing earthworms to turn the organic waste materials into high-quality compost that consists mainly of worm cast in addition to decayed organic matter [5, 11] Earthworms help to convert organic wastes materials (agro-wastes, animal manure and domestic refuse) into highly nutrient rich nutrient sources for plants and it is an eco- biotechnological process that transforms energy rich and complex organic substances into a stabilized humus-like product. It (worm cast) is a finely divided peat-like product with excellent physical characteristics including structure, porosity, aeration, drainage and moisture-holding capacity. It is an organic nutrient source rich in major macronutrients including (N, P and K), micronutrients and beneficial soil microbes (nitrogen fixing and phosphate solubilizing bacteria and actinomycetes), is a sustainable alternative to substitute chemical fertilizers, which is an excellent growth promoter and protector for crop plants. Vermicompost not only add nutritional value of soil also improves the physical, chemical and biological properties and contributes to organic enrichment [1, 4, 7].

Research on Vermicomposting will provide farmers and users with an environmental friendly nutrient source and assist in promoting the agriculture sector towards a greener for the coming years. Developing such technology will help in cost management in agriculture, which is increase in the recent years and has added to the burden of farmers in terms of chemical fertilizers and chemical pesticides. Therefore, expanding this technology could be an effective solution to the problem where it could substitute the chemical inputs in crop productivity and reduce the economic cost and on the other hand may also lead to organic produce which fetches higher market price. The increase in living standards around the world has created a growing demand for such organic produce, or cultivation using only natural pesticides and fertilizers, which are perceived to be healthier for consumers and environment friendly [13].

Earthworms are surface dwellers and feed on organic matter on soil surface, they do not inhabit the soil rather they live in and consume surface litter. These worms are domesticated and, when fed plant and animal wastes, they produce vermicompost, a process that has many advantages over conventional composting. This technology serves both social and environmental goals of sustainable agriculture and is widely employed mainly in developed countries, Canada, United States, France, India, Australia, New Zealand, Cuba and Italy [15, 16].

The nutrient content and bioavailability of vermicompost is higher compared with conventional (traditional) thermophilic process based compost. Thus, application of vermicompost as fertilizer showed greater positive influenced on crop yield, soil physicochemical properties and microbial biomass and activities [8, 12]. Different studies showed the potential of vermicompost as growth media for vegetable and fruit crop seedlings [2, 3] where the seedling growth including seedling height; stem girth and seedling survival after fled plantation showed significant improvement.

In Ethiopia, vermicomposting was done using crop residue (sorghum and tef straw), industrial waste, fruit waste and khat waste as bedding materials [15] using different earth worm species (essp. Esinia fetida) revealed variation between earthworms for their reproduction. Currently, the demands to this technology in Jimma Zone have shown progressive increase. However, scientific references regarding vermicompost production media and awareness on farmers are still lacking. Worms need appropriate bedding material in addition to food. Therefore, this experiment was conducted to evaluate best earthworm bedding material and to determine best harvesting time combination for quality compost production.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Jimma Agricultural Research Center Southwestern Ethiopia at greenhouse during 2017/2018 season. The experimental site was located at about 358 km far from Addis Ababa city and 12km from Jimma town towards Southwest direction. Geographically it is located at 7° 40′.212″ N latitude, 36° 47′.055″ E longitude and an altitude of 1763 masl. The average annual maximum and minimum air temperature was 27.2°C and 11.8°C, respectively and the area receives adequate amount of rainfall (1198mm) per annum.

2.2. Treatment Set up and Experimental Procedure

The experiment consists three types of bedding materials (poultry dropping, cattle manure and donkey manure) with four harvesting time (45, 60, 80 and 90 days). It was laid out in a completely randomized block design (RCBD) in factorial arrangement replicated three times. The experiment was done under shade in special constructed house for the process. Thus, the methods used for mass rearing and maintaining of earthworms were used for vermicompost preparation (cast harvest). The materials were produced from three different inputs (cattle manure, poultry dropping and donkey manure) as bedding material for vermicomposting and bulking in the composting process. The composting materials with the top layer (wetted shreds of card board) were mixed thoroughly by hand then an earthworm (Esinia fetida) was introduced uniformly to all beds. Moistened bedding was prepared prior to adding worms, as it may heat initially and harm the worms. This activity was started in special constructed bins with (1m long × 0.6m width × 0.45m depth) and the worms were predetermined by number. A well-adapted earthworm species (Eisenia Fetida) was introduced in all bins containing different bedding materials. Predetermined numbers of earthworms (350) were introduced into the bin. The required data, such as amount of cast produced, final number of earthworms in each unit, and compost nutrient analysis for N, OC, and pH was done. The collected data were subjected to analysis of variance using 9.3 version computer software.

2.3. Collection of Bedding Materials

The organic waste used to feed the earthworm was donkey manure, poultry droppings and caw manure and was collected from nearby local farmers. Primarily the collected waste materials were partially dried in the shaded light and washed with water before used. The main reason is to avoid salt content of feeding media worms are very sensitive to salts and to leached out the urine because if the manure is from animals raised or fed off in concrete lots, it may contain excessive urine because the urine cannot drain off into the ground. This manure was leached before use to remove the urine. Excessive urine will build up dangerous gases in the bedding. Then accordingly, the worm product was harvested, partially dried and finally, screened the fully ingested compost from undigested materials.

2.4. Earthworm Observation

Total biomass of the worms was determined by measuring the wet weight in each box at the beginning and at the end of the experiment according to the time allocated to each bedding material. To accomplish this, worms were removed from the bedding by hand, gently removed all of extraneous material. All of the worms within each box were weighed as a unit. The formula below was used to determine worm growth response to the different bedding material as described [20]. Growth rate was determined with the formula: $R = \frac{N2-N1}{T}$ Where, R=Growth rate, N_1=Initial earthworm biomass (mg), N_2=Final earthworm biomass achieved (mg) and T=Time of incubation period.

2.5. Parameters Measured

Vermicompost pH: One representative sample was taken and mixed with distilled water at a weight ratio of 1:2.5 (10g compost and 25ml distilled water). The beaker was covered and left for 2 hours and shake occasionally. The pH was measured with a pH meter [22] and the sample solution was stir regularly. Temperature was measured daily to ensure the heat generated from decomposition process was not highly increasing

2.6. Statistical Analysis

The collected data were summarized and statistically analyzed using the analysis of variance (ANOVA) procedure for RCBD using SAS 9.3 version software [18]. Treatment means that differed significantly was separated using LSD procedure at 5% level of significance.

3. Results and Discussion

3.1. pH

From the results obtained as such significant variation was not observed regarding on vermi cast pH value due to different feeding material. In all bedding materials used, pH was ranged from slightly acidic to neutrality value (pH=7), the highest pH value (pH=8) was recorded from plots where cattle manure was used as bedding material incubated for 80 days as indicated (Table 1). The chemical nature of vermicompost (pH) value of vermicompost near to neutral might have been probably be due to the secretion of NH_4^+ ions during the vermicomposting process that reduce the pool of H^+ ions and the catalytic fixation of CO_2 as $CaCO_3$ by carbonic anhydrase in the earthworms' gut [17]. When the bedding media is highly acidic it is harmful for growth and development of most of the plants. Thus, near-neutral and slightly alkaline pH values of these vermicompost show great potential to use as soil amendment for crop production [9, 10, 21].

3.2. Nitrogen Content

Similar to pH of vermicast, a significant difference was not obtained in all these vermicompost bedding materials for nitrogen content. Activities of endosymbiotic microbes and gut enzymes of earthworm aid in transformation of ingested organic matters into vermicompost constituting major macronutrients such as (N, P and K) in plant available forms [14, 23]. The value of total N content ranged from 0.9-1.4% where the highest value (1.4 and 1.39%) was recorded from feeding of poultry droppings incubated for 80 days and donkey manure incubated for 90 days compared to other bedding materials. This might be due to high nitrification rate in which ammonium ions are converted into nitrates [6]. The current result of total nitrogen content is in the range of normal vermicompost N value, which can range quite widely from 0.1% to 4% as reported by. Earthworm processed waste material contains higher concentration of exchangeable K due to enhanced microbial activity during composting process, which consequently enhances rate of mineralization [9, 23].

3.3. Carbon: Nitrogen (C: N) Ratio

Carbon to Nitrogen (C:N) ratio is a factor related to the decomposition rate of the waste material and, even it is recognized as a factor related inversely with the growth rate of earthworms and reproduction capacity in decomposition process. The current result showed, earthworm product show expected relations with beddings initial C: N ratio. Accordingly the highest C: N value (26.40) was obtained from donkey manure as bedding material with gestation period of 45 days. Although the worms do consume their bedding as it breaks down, it is very important that this be a slow process. High protein/nitrogen levels can result in rapid degradation and its associated heating, creating inhospitable, often fatal, conditions. Heating can occur safely in the food layers of the vermi culture or vermicomposting system, but not in the bedding. Different values of growth and reproduction rate were observed in bedding with high and low earthworm performance. Typically, bedding materials should stable compost (not high in soluble salts), retain moisture, remain loose, and not contain much protein or organic nitrogen compounds that readily degrade. These compounds would be quickly degraded with the release of ammonia, and this might temporarily increase the pH of bedding material, which is not good for the worms.

In general, the chemical nature of organic waste influences the palatability by earthworms directly or indirectly, which consequently affect their efficiency during decomposition process. Absorbency (bedding material should have high in absorbency and retain water fairly), bulking potential (if the material is too dense to begin with, or packs too tightly, then the flow of air is reduced or eliminated) and porosity of the bedding materials are amongst all. Another characteristic for good bedding material is low protein and/or nitrogen content (high Carbon: Nitrogen ratio). Although the worms do consume their bedding as it breaks down, it is very important that this be a slow process. High protein/nitrogen levels can result in rapid degradation and its associated heating, creating inhospitable, often fatal, conditions.

Therefore, it is hypothesized that earthworm growth patterns in this study were related to the chemical profile of the bedding. Moreover, beddings, in which earthworm showed better growth patterns, were probably with supplying of easily metabolizable organic matter, non-assimilated carbohydrates, and even low concentration of growthretarding substances, which favors earthworm growth in waste system [19].

Table 1. *Effect of bedding materials and harvesting time on compost quality.*

Treatments	pH (1:2.5)	TN (%)	OC (%)	OM (%)	C:N
Poultry droppings inoculated 45 days	7.26	1.18	27.06	46.65	22.93
Poultry droppings inoculated 60 days	7.09	1.65	27.14	46.79	16.45
Poultry droppings inoculated 80 days	7.43	1.39	24.79	42.74	17.83
Poultry droppings inoculated 90 days	7.18	1.30	22.97	39.60	17.67
Cattle manure inoculated 45 days	7.14	1.55	21.57	37.19	13.92
Cattle manure inoculated 60 days	7.92	1.17	20.26	34.93	17.32
Cattle manure inoculated 80 days	8.00	1.26	21.49	37.05	17.05
Cattle manure inoculated 90 days	7.75	0.60	14.20	24.48	23.66
Donkey manure inoculated 45 days	6.65	0.70	18.48	31.86	26.40
Donkey manure inoculated 60 days	6.67	1.15	20.92	36.05	18.19
Donkey manure inoculated 80 days	6.35	0.90	18.35	31.65	20.39
Donkey manure inoculated 90 days	6.72	1.40	13.79	23.77	9.85

Where, TN=Total nitrogen, OC=Organic carbon, OM=Organic matter and C: N Carbon to nitrogen ratio.

4. Conclusion

From the results obtained, we concluded that type of bedding materials used produced various result on selected biological parameters and compost production. Each of bedding material has its own characteristics that differ from one another and can influence the parameter. The result showed that donkey manure was better in term of growth rate and biomass production of worm compared to cattle manure and poultry droppings. Better results of biomass as well as growth rate potential of composting with earthworm can be observed using donkey manure as bedding material. From this we can specify use of this bedding material to achieve the desire objective. pH value of bedding material also affect the growth rate of worm during composting process. It was stated that pH near the neutral state are the best pH for vermicomposting. So, using appropriate bedding and/or feeding material for earthworm culture could optimize vermicomposting practices. There is an opportunity to study the influence of bedding material interrelating with environmental in field of earthworm technology. Although a great work is required to establish the optimal conditions for culturing earthworms for sustainable vermiculture operations, further studies are required to explore the potential of utilization of cattle manure and poultry droppings in mixture with horse manure.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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