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IAssessment of Fertiliser Quality and Plant Growth Dynamics of Vermicomposts obtained from Oligochaete Action on different Organic Wastes

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Abstract

The present investigation attempts to analyse the physico-chemical and bacteriological characteristics of the vermicomposts obtained as a result of the action of epigeic earthworm species Eudrilus eugeniae on organic substrates viz., leaf litter and kitchen waste. Further, assessment of quality of the two vermicompost samples with regard to plant growth promoting efficiency was carried out. In the present study, pH of leaf litter (7.91) and kitchen waste (7.64) reached to near neutrality. Electrical conductivity was high in kitchen waste (2.23 dSm^{-1}) than leaf litter (2.01 dSm^{-1}) vermicompost. The ash content was high in kitchen waste (74.6%) than leaf litter (52.4%) vermicompost. Organic carbon content was high in leaf litter (23.62%) than kitchen waste (10.56%) vermicompost. Total nitrogen was high in kitchen waste (0.88%) than leaf litter (0.81 %) sample. The C/N value was high in leaf litter (26.84) than kitchen waste (13.03) sample. Total phosphorus was high in leaf litter (0.16%) than the kitchen waste (0.10%) vermicompost. Total potassium was found to be high in leaf litter (0.11%) than kitchen waste (0.07%) vermicompost. The total number of bacteria present in the vermicompost samples was 3.6 x 10^{8} CFU/gm and 4.2 x 10^{8} for leaf litter and kitchen waste, respectively. Ca content was maximum and Na content was minimum in both samples. Although the values of some micronutrients were high in the kitchen waste sample, the values of organic carbon, NPK and the C/N ratio suggest that the leaf litter sample was qualitatively better than kitchen waste sample. Plant growth promoting ability of the vermicomposts was conducted using Zea maize and Trigonella foenum-graecum. Although the samples show inconsistency in terms of nutrient availability and microbial activity, outcome of plant growth analysis suggests that the vermicompost obtained from leaf litter substrate was superior to kitchen waste substrate in its efficiency as a biofertiliser. The findings can have potential application in the fields of agriculture, horticulture and floriculture.

Keywords: Eudrilus eugeniae; leaf litter; kitchen waste; vermicomposting; physico-chemical analysis; bacteriological assay; plant growth assessment; biofertiliser.

I. INTRODUCTION

Every year, India produces 3,000 million tons of valuable organic waste, which could be used as feedstock for making useful items, such as energy, fertiliser or recycled raw material [1]. Composting is one of the ways of managing organic wastes involving biological aerobic transformation of organic wastes into stabilised organic product [2]. Vermicomposting is a simple biotechnological method, in which earthworms are used to enhance the process of waste conversion and produce a better end product [3]. It is an efficient nutrient recycling process that involves harnessing earthworms as versatile natural bioreactors for organic matter decomposition [4].

Earthworms are voracious feeders of organic wastes and play an essential role in carbon turnover, soil formation, participate in cellulose degradation and humus accumulation; affecting the physical, chemical and biological properties of soil [5-7]. Earthworms stimulate and accelerate microbial activities by increasing the population of soil microorganisms [8]. Earthworm activity increases the population of plant growth-promoting rhizobacteria [9]. They harbour 'nitrogen-fixing' and 'decomposer microbes' in their gut and excrete them along with nutrients in their excreta [10]. Excreted mucus stimulates antagonism and competition between diverse microbial populations resulting in the production of some antibiotics and hormone-like biochemicals, boosting plant growth [11]. Vermicomposts containing macronutrients and micronutrients, vitamins, enzymes, hormones [12-13], are rich in nutrient availability and microbial activity therefore can significantly enhance soil fertility influencing plant growth and productivity and suppress the population of plant pathogens and pests [4;14-17]. Vermicompost improves soil structure, texture, aeration and water holding capacity [18].

Environmental degradation is a major threat confronting the world, and the unrestrained use of chemical fertilisers contributes largely to the deterioration of the environment. There is a growing realisation that the adoption of ecological and sustainable farming practices can only reverse the declining trend in the global productivity and environment protection [19]. As earthworms play a critical role in recycling organic matter essential for fertility of soil [20], they can be effectively employed for management of organic wastes by converting them in a rich biofertiliser, which is an ideal substitute to chemical fertilisers; thereby promoting environmental sustainability. As the human population is growing at an unprecedented rate, wastes generated as a result of anthropogenic activities have become a growing menace, thereby creating a necessity for waste management techniques. Of all other wastes, organic wastes can be treated efficiently in an ecofriendly manner by employing earthworms. Oligochaete action supported by gut microfloral activity not only speeds up the rate of decomposition but also results in a vermicast of high nutritional value.

Enormous work has been done in the field of biofertiliser production and its application in the growth of agricultural and horticultural crops [18]. According to [21-22], earthworm intestine contains a wide range of microorganisms, enzymes and hormones which aid in rapid decomposition of half-digested material transforming them into vermicompost in a short time (nearly 4–8 weeks). Bibliography [23] have found that vermicompost works as a 'soil conditioner' and its continued application over the years lead to significant improvement in the quality of soil and farmland, even the degraded and sodic soils. Further, [24] asserts that vermicompost is at least 4 times more nutritive than cattle dung compost. In Argentina, farmers who use vermicompost consider it to be seven times richer than conventional composts in nutrients and growth promoting values [25-26]. Bibliography [27] investigated the physico-chemical parameters from vermicompost of *Eudrilus eugeniae* and *Eisenia foetida* and concluded that the production of vermicompost was found to be better in *E. eugeniae* than in *E. foetida*. Bibliography [28] investigated the potency of vermicompost using *Musa paradisiaca* (banana peel) waste and *Eudrilus eugeniae* earthworm as it effectively decomposes the waste. They also studied the physico-chemical parameters and nutrient content in the vermicompost. The enzymes and nutrients showed elevated levels in vermicompost. The efficacy of vermicompost was also checked and studied on the vegetable plant *Solanum lycopersicum* (tomato). Based on their studies they concluded that vermicompost obtained from the degradation of banana peel waste by *Eudrilus eugeniae* is an effective biofertiliser.

Bibliography [29] made innovative use of *Eudrilus eugeniae* to recycle organic food waste into vermicompost. Bibliography [30] tested the potential of different vermicast formulations (viz., EM (effective microorganism activated solution, IMO (decomposing vegetable or food waste) and control towards their chemical composition and microbial functional diversity as a biofertiliser. They concluded that EM vermicompost is a better biofertilizer than IMO and Control vermicomposts as demonstrated through its properties and performance. Bibliography [31] reviewed the impacts of earthworms on soil components and dynamics stating that the earthworm populations are important decomposers contributing to aggregate formation and nutrient cycling processes involving nitrogen cycles, phosphorus and carbon. Bibliography [4] reviewed the microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential concluding that the vermicompost may be used to promote sustainable agriculture and also for the safe management of agricultural, industrial, domestic and hospital wastes which may otherwise pose serious threat to life and environment. Bibliography [32] conducted an experimental study to obtain the vermicompost using partially decomposed fruit waste with paper and tannery industry sludges using *Eudrilus eugeniae*. They observed that the castings rich in microorganism enhance the plant growth hormones and the vermicompost produced from fruit waste and industrial sludge can help to build up the soil fertility for sustainable agriculture. Bibliography [33] reviewed vermicomposting acts as a powerful crop nutrient over the conventional compost and protective soil conditioner against the destructive chemical fertilizers for food safety and security.

The present study was undertaken to assess the compost characteristics, nutrient composition, and bacterial population as influenced by the activity of earthworms during the process of vermicomposting using different organic wastes; and efficiency of vermicompost as a biofertilser. Physico-chemical analysis and enumeration of bacterial population from vermicomposts generated from different substrates using *Eudrilus eugeniae* was conducted.

II. MATERIALS AND METHODS

The study was carried out in successive stages of:- collection of organic wastes; vermiculture operation; generation of vermicompost; enumeration of bacterial population of the vermicompost at predetermined intervals; and physico-chemical analysis of the vermicomposts thus obtained from leaf litter and kitchen waste from Ahmednagar College campus, using the earthworm species *Eudrilus eugeniae*. *E. eugeniae* popularly known as the 'African Night Crawler' is a large, rapidly growing, prolific and ideal epigeic vermicomposting candidate under tropical conditions. *E. eugeniae* is reddish brown in colour, its adult size is 5–7 mm × 80–190 mm, maturity time is 40-49 days and incubation time is 12-16 days. The limits and optimal temperature and moisture of *E. eugeniae* are 25°C (16°C-30°C) 80% (70%-85%), respectively [34].

Period of investigation extended from July 2015 to April 2016. Vermicomposts were produced using leaf litter and kitchen waste. Pre-composting comprises a short period of high temperature treatment followed by a period of lower temperature, facilitating mass reduction, waste stabilisation and pathogen reduction [35]. Accordingly, the organic wastes were precomposted for the stabilisation of the wastes and reduction in the mass. Parameters like pH, temperature and moisture content of the composting wastes were monitored at regular time intervals of 15 days. The bacteriological analysis in the form of CFU/gm of vermicompost samples was done at 0^{th}, 15^{th}, 30^{th} and 45^{th} day of vermicomposting. Serial dilution agar plating of vermicompost samples were carried out as per [36]. The physico-chemical parameters like pH, electrical conductivity, moisture content, ash content, organic carbon, macronutrients like nitrogen, phosphorous, potassium and micronutrients like iron, zinc, manganese, copper, calcium, magnesium, sulphate, sodium, chromium and lead were analysed using standard methods as per [37] at Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.). Comparative analysis of the efficiency of vermicompost samples was carried on two varieties of plants namely *Zea maize* (monocotyledonous candidate) and *Trigonella foenum-graecum* (dicotyledonous candidate). Parameters like plant height, root and shoot length and leaf number were analysed after a growth period of 15 days, so as to ascertain the growth enhancing ability of the vermicompost samples.

III. RESULTS AND DISCUSSION

The present study involved vermicomposting of two substrates namely leaf litter and kitchen wastes using the earthworm species *Eudrilus eugeniae.* To determine the quality of the vermicomposts, related physical chemical and microbiological parameters were considered. The values of the pH, temperature and moisture content of the vermicomposting samples are given in Table 1.

Table 1. pH, Temperature and Moisture Content of Vermicompost Samples

Sl. No.	Parameter	0th Day		15th Day		30th Day		45th Day	
		Leaf Litter	Kitchen Waste	Leaf Litter	Kitchen Waste	Leaf Litter	Kitchen Waste	Leaf Litter	Kitchen Waste
1	**pH**	6.5	8.2	8.5	8.6	7.3	7.4	7.1	7.8
2	**Temperature (˚C)**								
	Ambient	33		32		30		34	
	Compost	34	35	36	35	30	29	27	28
3	**Moisture content (%)**	55.35	40.5	54.6	45.2	55.8	55.0	52.5	49.5

The stability and solubility of various compounds in compost is influenced by the pH of the compost [38-39]. The pH of the vermicompost samples was neutral to alkaline in nature. Except the pH of leaf litter sample was slightly towards acidic range. pH range of leaf litter sample was 6.5 to 8.5, whereas of kitchen waste sample was 7.4 to 8.6. The results are in the line of observations made by [40] who observed that the pH of food waste increased during the vermicomposting process and changed from 5.6 in the first week to 7.53 at the end of 7th week. They suggested that the general increase in pH value recorded during the vermicomposting process, indicated alkalinisation of the food waste because of the release of ammonia from the degradation and mineralization of organic compound. Decrease of pH in vermicompost might be due to participation of microbes in the decomposition during vermicomposting. Production of CO_2, and organic acids by microbial decomposition during vermicomposting was the underlying factor for the pH decrement [41].

The temperature of the composting pile and the ambient temperature were monitored during the entire period of composting. The range of ambient temperature was from 32 to 34˚C. Temperature of compost increased till the 15th day in both the samples and decreased further till 45th day in leaf litter sample. The temperature regime in the compost indicated that the organic materials passed through different phases like mesophilic, thermophilic, cooling and maturation as already reported by Bib. [42-43]. The temperature started dropping in the compost pile once the material was stabilized, which also indicated that the pile was becoming anaerobic and should be aerated by turning [44]. As observed the thorough mixing and turning of the composting material enhanced the composting process. During vermicomposting, temperature and moisture can act synergistically [45]. In the present study the percentage of moisture content of leaf litter sample ranged from 52.5 to 55.8 and that of kitchen waste samples ranged from 40.5 to 55.0. Microbial decomposition is known to occur simultaneously with deliberate vermicomposting, where the consortium of earthworms, the microflora living in their intestines, and those in the growth medium, enhance the decomposition process of the substrate [2]. Bib. [46] observed that the total microbial biomass of the organic wastes significantly ($P < 0.05$) increased due to vermicomposting.

Variation in the bacterial population during the successive stages of vermicomposting was quantitatively assessed by microbial enumeration technique to find out colony forming units per gram (CFU/gm) of the compost sample. The CFU/gm of the vermicompost samples are given in Table 2. The CFU/gm of vermicompost from kitchen waste was high than the leaf litter waste (see Fig. 1). The CFU in both the sets increased till the 30th day and then there was a subsequent decline in CFU. As observed by others, this may be probably due to decrease in nutrient content of the substrate and also due to utilisation of bacteria by the earthworms. Similar results have been reported by Bib. [47] that there was maximum increase in microbial population in the early stages of composting which was dependent on initial substrate used and environmental conditions of the composting.

As has been reported by Bib. [11] and mentioned by Bib. [48] that the earthworms promote microbial growth and activity. Bib. [24] found that the total bacterial count was more than 10^{10} per gram of vermicompost. Bib. [49-50) reported bacterial count of 32 million per gram in fresh vermicast compared to 6-9 million per gram in the surrounding soil. Similarly, Bib. [51] while studying the microbial population in vermicompost prepared from cow dung and municipal solid wastes (MSW) as substrates, observed that the total bacterial count was 73 x 10^8. It was least in vermicompost obtained from MSW, whereas the total bacterial count was 16 x 10^8. In the present study, the total number of bacteria present in the vermicompost samples after 30 days of composting was found to be 3.6 x 10^8 CFU/gm and 4.2 x 10^8 for leaf litter and kitchen waste, respectively (see Table 2).

Table 2. Bacterial Population at Specified Intervals During Composting Process

	Colony Forming Units/gram of the vermicompost samples from 10^{-6} dilution			
Time Interval	**0^{th} Day**	**15^{th} Day**	**30^{th} Day**	**45^{th} Day**
Leaf Litter	3.0 x 10^8	3.3 x 10^8	3.6 x 10^8	2.9 x 10^8
Kitchen Waste	3.5 x 10^8	3.8 x 10^8	4.2 x 10^8	3.2 x 10^8

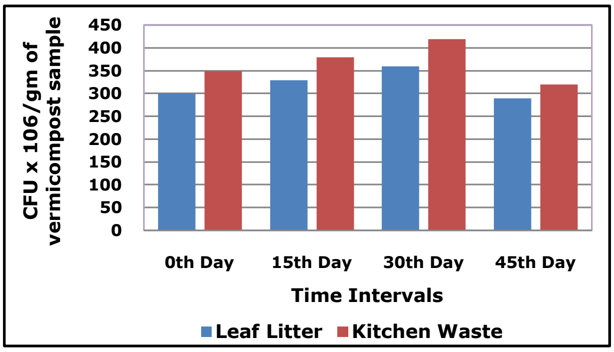

Figure 1. Bacterial Population during Composting Process

Vermicompost is a nutritive organic fertilizer rich in NKP, micronutrients, beneficial soil microbes like ‘nitrogen-fixing bacteria’ and ‘mycorrhizal fungi’ and are scientifically proving as ‘miracle growth promoters and protectors’ [52]. In the present study, the physico-chemical analysis of the compost after completion of the vermicomposting process was conducted. The vermicomposts obtained show difference in their physico-chemical properties, which may be probably due to the different organic substrates used during the vermicomposting. The details of the physico-chemical properties of the vermicompost samples are given in Table 3.

Table 3. Physico-chemical Parameters of Vermicompost Samples

Sl. No.	Parameter	Vermicompost Sample	
		Leaf Litter	Kitchen Waste
1	pH	7.91	7.64
2	Electrical Conductivity (dSm^{-1})	2.01	2.23
3	Moisture Content (%)	5.15	7.2
4	Ash Content (%)	52.4	74.6
	Macronutrient (%)		
5	Organic Carbon (%)	23.62	10.56
6	Total Nitrogen	0.88	0.81
7	Total Phosphorous	0.16	0.10
8	Total Potassium	0.11	0.07
9	C/N Ratio	26.84	13.03
	Micronutrient (mg/Kg)		
10	Iron (Fe)	882.65	886.31
11	Manganese (Mn)	571.8	621.32
12	Zinc (Zn)	100.97	79.77
13	Copper (Cu)	39.82	40.15
14	Sodium (Na)	6.4	7.0
15	Calcium (Ca)	2253	2301
16	Magnesium (Mg)	647.65	633.42
17	Sulphate (SO4)	984.8	925.2
18	Chromium (Cr)	79.9	93.65
19	Lead (Pb)	63.65	25.25

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19	Lead (Pb)	63.65	25.25

Bib. [53] reported that pH and EC changes were caused by decomposition of organic acids, suggesting that simple parameters such as pH and EC might be good indicators of compost stability. In the present study, the pH at the end of composting had reached to near neutrality. Though the difference was very less, the pH was found to be high in vermicompost obtained from leaf litter (7.91) than the kitchen waste (7.64). Electrical conductivity was found to be high in kitchen waste

(2.23 dSm^{-1}) than the leaf litter (2.01 dSm^{-1}) vermicompost. Science has established the fact that the EC affects the compost quality because it reflects its salinity and suitability for crop growth.

The moisture content was found to be high in kitchen waste (7.2%) than the leaf litter (5.15%). After recording the moisture content the sample was further dried in muffle furnace to estimate the ash content of the vermicompost samples. The ash content was found to be high in kitchen waste sample (74.6%) than the leaf litter vermicompost (52.4%). Estimation of the macronutrients of the vermicompost samples showed that the organic carbon content was found to be high in leaf litter sample (23.62%) than the kitchen waste sample (10.56%) as shown in Fig. 2. Total nitrogen was found to be high in kitchen waste sample (0.88%) than the leaf litter sample (0.81%). The C/N value was found to be high in leaf litter sample (26.84) than the kitchen waste sample (13.03). Bib. [54] proposed that narrower C/N ratio facilitates partial mineralization of the organic substrate, leading to carbon losses throughout the earthworm feeding, which in turn enhanced the rate of organic matter decomposition. Almost similar results were observed by Bib. [55]. Total phosphorous was found high in leaf litter sample (0.16%) than the kitchen waste sample (0.10 %). Bib. [54] have stated that the process of mineralization and mobilization of phosphorus by bacterial and faecal phosphatase activity of earthworms could be the main reason for presence of phosphorus in the vermicompost. Total potassium was found to be high in leaf litter sample (0.11%) than the kitchen waste sample (0.07%) as represented in Fig. 3.

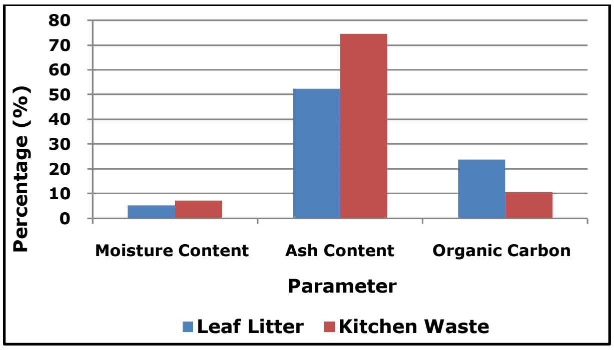

Figure 2. Variation in Moisture, Ash and Organic Carbon Content of Vermicompost Samples

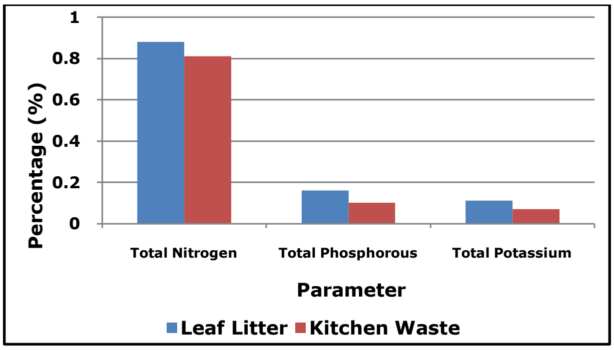

Figure 3. Variation in NPK of Vermicompost Samples

As suggested by earlier research, the NPK content in vermicompost samples may be attributed to the mineralisation process caused by earthworm action along with microorganisms on the organic substrates. Increased level of phosphorus during vermicomposting is due to earthworm gut-derived phosphatase activity and also increased microbial activity in the cast [56]. In the present investigation, the micro-nutrient content in the two vermicompost samples was found to differ. Of all the nutrients, Ca was the maximum and Na was the minimum in both the vermicompost samples. It was observed that the micro-nutrients like Zn, Mg, Pb and SO_4 were found to be high in leaf litter sample, whereas, Fe, Mn, Cu, Na, Ca and Cr were found to be high in the kitchen waste sample (see Fig. 4a and 4b).

The increased level of macro and micronutrients in the vermicompost samples were in conformity with the results of earlier works [57-58]. The results of the present study showed that the vermicomposts thus obtained are rich in nutrients and suitable to be used as an organically rich source of biofertiliser.

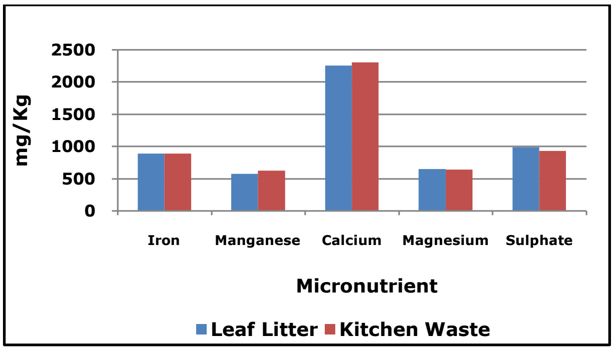

Figure 4a. Micronutrient Content of Vermicompost Samples

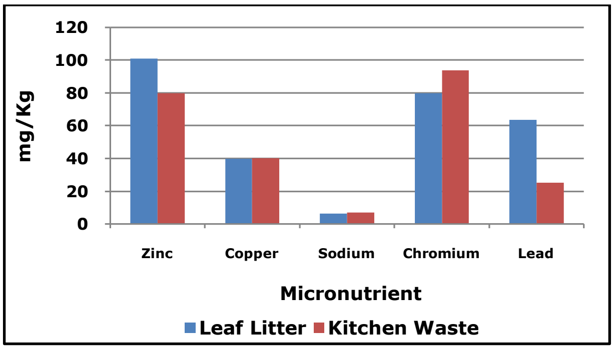

Figure 4b. Microntrient Content of Vermicompost Samples

Vermicomposts are produced from organic wastes through interactions between earthworms and microorganisms, and can be utilized as plant growth media or soil amendments [59]. Vermicompost efficiency as biofertiliser was tested by analysing the growth parameters such as root length, shoot length and number of leaves; wherein soil was taken as control against the vermicompost samples. Vermicompost quality analysis was conducted using two plants namely *Zea maize* and *Trigonella foenum-graecum* (see Table 4; Fig. 5).

Table 4. Plant Growth Analysis after application of different Vermicompost Samples

Sample	Mean Shoot Length		Mean Root Length		Mean No. of Leaves	
	Zea maize	*Trigonella foenum-graecum*	*Zea maize*	*Trigonella foenum-graecum*	*Zea maize*	*Trigonella foenum-graecum*
Control (CS)	23.50	6.04	5.20	3.10	04	05
Leaf Litter (VLL)	33.50	8.52	12.50	5.20	07	08
Kitchen Waste (VKW)	25.50	7.96	6.50	4.30	05	06

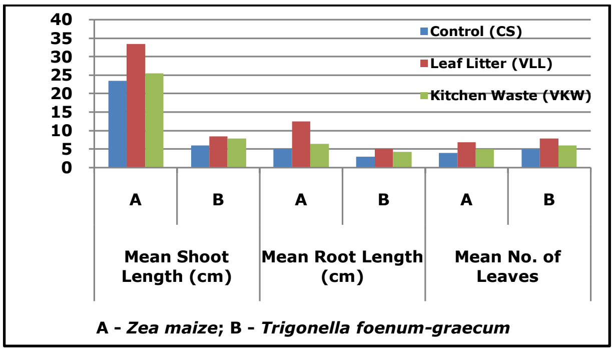

Figure 5. Plant Growth Analysis after application of different Vermicompost Samples

Vermicompost is usually more stable than their parent materials with increased availability of nutrients and improved physico-chemical and microbiological properties [54 and 60]. Adding vermicasts to soil improves soil structure, fertility, plant growth and suppresses diseases caused by soil-borne plant pathogens, increasing crop yield [61-63]. Soil amended with vermicompost produced better quality of fruits and vegetables with less content of heavy metals or nitrate, than soil fertilized with mineral fertilisers [64]. The analysis of various growth parameters like plant height, root and shoot length and leaf number after 15 days of cultivation revealed that both the plants grew better on leaf litter sample than on kitchen waste sample; whereas minimum growth was seen in case of control sample (soil) (see Image 1-4).

Image 1 and 2 *Zea maize* and *Trigonella foenum-graecum* Growth Analysis Experiment Setup, respectively

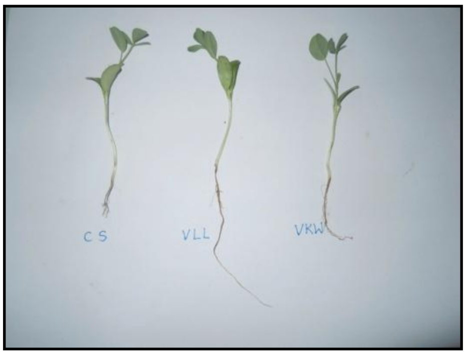

Image 3 and 4 Shoot and Root Length Analysis of *Zea maize* and *Trigonella foenum-graecum*, respectively

IV. CONCLUSIONS

Earthworms can be effectively employed for the biodegradation of different types of organic wastes into substances which can be readily utilised by the plants. The nature of organic substrate is a deciding factor of vermicompost quality in cases where the earthworm species used and environmental conditions are kept constant. It can be reaffirmed that the biophysical and biochemical action of earthworm gut microflora on organic substrate renders it into a stabilised product. Apparently, the abundant presence of bacteria in the vermicompost is indicative of their active role in the composting process. The gradual decline in bacterial number in the final phases of composting process points towards the decreasing availability of the nutrients as a result of substrate exhaustion.

Although the values of some micronutrients were high in the kitchen waste sample, the values of organic carbon, NPK and the C/N ratio suggest that the leaf litter sample was nutritionally richer than that of kitchen waste sample. Plant growth analysis following the application of vermicompost samples revealed the superiority of leaf litter sample as a fertiliser. Finally, it can be concluded that urban organic wastes can be converted into a valuable biofertiliser by the ecofriendly method of vermicomposting, which has been found to be a safe, hygienic, cost-effective and sustainable way of organic waste management, by many.

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