RESEARCH ARTICLE

A Synergetic Approach of Agricultural Waste Management through vermicomposting

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Abstract

The present study was conducted to investigate the vermicomposting potential of epigeic earthworm, *Eisenia foetida* for rice straw and cow dung. The experiment comprised of ten treatments T_1 - [Chopped Rice straw + cow dung (1:1)] + 1kg worm), T_2 - [Unchopped Rice straw + cow dung (1:1)] + 1kg worm), T_3 - [Chopped Rice straw + cow dung (1:1)] + 2kg worm), T_4 - [Unchopped Rice straw + cow dung (1:1)]+ 2kg worm), T_5 - [Chopped Rice straw (70%) + soil (10%) + cow dung (20%) + 1kg worm], T_6 - [unchopped Rice straw (70%) + soil (10%) + cow dung (20%) + 1kg worm], T_7 - [Chopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2kg worm], T_8 - [Unchopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2kg worm], T_9 - [cow dung + 1kg worm] and T_{10} - [cow dung only], single replicate arranged in a randomized block design. The experimental results revealed that out of all the treatments, higher values of N, P and K were observed in T_7 - Chopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2 kg worm. The micronutrient content was also found higher in this treatment with higher biomass production. The multiplication of earthworms was significantly higher than only cow dung and other treatments. The vermicompost produced can be of significant value to the end users like farmers for replacement of chemical fertilizers and procuring better prices for the organic produce using such composting material locally available at much lower cost. Vermicomposting might prove to be a positive approach towards sustainable waste management system.

Keywords: Eisenia foetida; farmyard manure; vermicompost; soil; nutrient content

Introduction

Waste is produced as a result of every human activity. Significant amounts of solid waste are produced by industrial, residential and agricultural activities, which eventually cause an ecological imbalance (Lim and Wu, 2016). The primary agricultural waste products include cobs, husks, rice straw etc. Rice straw, which makes up nearly 45% of all rice produced globally, is the greatest agricultural crop leftover. India produces 112 MMT of rice straw annually and roughly 80% of this material is thrown away or left in fields as garbage (Singh et al., 2016). In India, it's typical to burn these leftovers in the fields. Burning rice straw results in a number of issues, including smog and air pollution, as well as the destruction of the rice straw's nutrients (Yan et al., 2013). A sustainable recycling waste management system is required to solve these issues.

The greatest approach towards agricultural waste management is through vermicomposting (Adhikary, 2012). It is a process of turning organic waste into high-quality organic manure made of worm cast by the action of earthworms (Chaudhuri et al., 2000). Vermicompost is currently a crucial component of an organic agricultural system since it is simple to manufacture, safe and has outstanding qualities. Vermicompost produced has great moisture-holding capacity, a low C/N ratio, high nutrients, aeration, structure and drainage (Ismail, 2005; Edwards et al., 2011). It is a nutrient-rich organic fertiliser rich in NPK, nitrogen-fixing and phosphate-solubilizing microorganisms (Christy, 2019). The total amount of nutrients in vermicompost is determined by the properties of the raw material utilized in the process. Cattle dung has a good C/N ratio and is palatable for earthworms, making it an ideal substrate for vermicomposting (Lim et al., 2016). Vermicompost improves the physical, chemical and biological characteristics of the soil and provides organic enrichment (Ansari and Jaikishun, 2011; Chauhan and Singh, 2013).

For environment friendly soil restoration techniques, agricultural wastes like rice straw and farmyard manure may be transformed into nutrient-rich vermicompost (Suthar, 2007). The best earthworm for vermicomposting is the epigeic species, *Eisenia foetida*. These earthworms are frequently used for vermicomposting because they are simple to handle, widely accessible and sensitive to environmental changes.

The goal of the current study was to assess *Eisenia foetida's* vermicomposting capacity for producing high-quality vermicompost from locally accessible organic waste sources (rice straw and farmyard manure). Vermicomposting research will help farmers produce eco-friendly biofertilizer, encourage sustainable agriculture and promote sound agricultural practices to preserve soil productivity. With these considerations in mind, the current study was created to explore the potential for vermicomposting using rice straw and cattle dung. Hence, studies were also designed to investigate the effectiveness of cattle dung and rice straw when combined in various ratios.

Material and Method

The research experiment was carried out in the vermicompost unit of school of organic farming, PAU, Ludhiana by arranging the vermi beds in randomized block design .The earthworm species used for the experiment was *Eisenia foetida*. The beds were arranged by keeping ten treatments replicated singly. The treatments were as follows T_1- [Chopped Rice straw + cow dung (1:1)]+ 1kg worm, T_2 -[Unchopped Rice straw + cow dung (1:1)]+ 1kg worm and T_3 -[Chopped Rice straw + cow dung (1:1)]+ 2kg worm, T_4 -[Unchopped Rice straw + cow dung (1:1)]+ 2kg worm, T_5 (Chopped Rice straw (70%) + soil (10%)+ cow dung (20%)] + 1 kg worm, T_6- [unchopped Rice straw (70%) + soil (10%) + cow dung (20%)] + 1 kg worm, T_7- [Chopped Rice straw (70%) + soil (10%) +cow dung (20%)] + 2 kg worm, T_8 – [Unchopped Rice straw (70%) + soil (10%) +cow dung (20%)] + 2 kg worm, T_9 - [cow dung + 1 kg worm] and T_{10} - [cow dung only].Before the start of experiment, raw material to be used for study is tested for TOC, TN, TP, TK, C:N ratio, Micronutrients (Zn, Cu, Mn and Fe) content. The above said material was composted in readymade vermibeds available in the market (6ft X 3ft X 1.5 ft). Optimum conditions like humidity, temperature were maintained throughout the experiment. To facilitate the process of composting, the organics in the beds were regularly stirred and mixed manually. During the study period every possible care was taken to avoid any contamination and to protect the earthworms from ants and natural enemies. Generally, the vermicompost was ready for use in 2 months, however different treatments has taken different days of preparation. After preparation of vermicompost, the samples were collected from nine spots from each bed. These nine spots were mixed together to make three representative samples. These representative samples were considered as replications. The total nutrient analysis was done using standard procedures. The data were analyzed statistically using SPSS software (standard version 23.0).

The parameters analyzed are as follows (A) Total Nitrogen Content (%) - The total nitrogen content was estimated by Micro-kjeldahl (Jackson, 1973) method. 0.25 g portions of the vermicompost was placed in the digestion tube and 1 g digestion mixture (400 parts of K_2SO_4, 20 parts of $CuSO_4$, 3 parts of HgO and 2 parts of SiO_2 powder) was added along with 4.5 ml of concentrated H_2SO_4 in each digestion tube. The sample was then digested on heater till a clear solution was obtained. After the digestion the sample was cooled and the volume was made upto 50 ml by adding distilled water. 5 ml aliquot was taken in the Kjeldahl flask containing 10 ml 40% NaOH. The solution was subjected to steam distillation. NH4-N evolved was absorbed in 4% boric acid mixed indicator solution until the appearance of green colour. The amount of nitrogen was determined by titration against N/70 H2SO4 until the appearance of green colour. (B) Total Phosphorus Content (%) - The total phosphorus content was estimated by using Vanado-molybdo-phosphoric yellow colour method in nitric acid (Jackson, 1967). 0.25 g test sample was digested in 10 ml diacid and volume was made upto 50 ml with distilled water. 2 ml of the filtrate prepared was mixed with 5 ml of vanadomolybate reagent in a volumetric flask . Intensity of yellow colour developed was measured on spectrophotometer at wavelength of 470 nm. (C) Total Potassium Content (%) - The total potassium content was estimated by Flame Photometer (Jackson, 1967) method. 2 ml of filtrate (diacid digested samples) was taken in 25 ml volumetric flask.The solution was fed to the atomizer assembly of the flame photometer, the galvanometer which had already been adjusted with standard K solutions. The reading was noted and the concentration of potassium was determined. (D) Total Organic Carbon (%) - total organic carbon was estimated using rapid titration (Walkley and Black, 1934) method. 0.1 g of test sample was weighed and 10 ml 1N potassium dichromate solution was added to it. After 30 minutes, 20 ml of sulphuric acid was added and then incubated further for 60 minutes. The solution was then diluted with 100 ml distilled water. Floculating agent sodium fluoride and 10 drops of diphenylamine indicator was added and titrated against N/2 FAS (Ferrous Ammonium Sulphate), until the colour shifted from turbid blue to brilliant green. Volume of N/2 FAS used was recorded for total organic carbon content determination. (E) Total manganese (Mn in ppm), total copper (Cu in ppm), total zinc (Zn in ppm) and total iron (Fe in %) was estimated by using the Atomic Absorption Spectrophotometer (AAS). The AAS works on the principle that an element whose quantity is to be estimated is irradiated with radiations from a cathode lamp, it absorbs the radiations in direct proportion to the concentration of the element. (F) To estimate the biomass production the earthworms were weighed (balance 2kg × 0.001 g) before starting the experiments and at the end of the experiment to determine the changes in body weight.

Statistical Analysis

The data obtained from the results were statistically analysed using SPSS software (standard version 23.0). The data of various parameters are expressed as the mean ± standard error of mean (SEM). The values were compared at 95% level of significance. A ‘p’ value of 0.05 was chosen as a standard for statically significant difference.

Results And Discussion

Initial Nutrient analysis of vermicompost from different test substrates

The nutrient content of test substrate used before the vermicomposting during the experimental period is shown in table 1. The nutrients i.e. nitrogen, phosphorus, potassium and total organic carbon varied among the organic agro wastes. Percent nitrogen content in FYM was 0.36 ± 0.03 % and in Rice straw was 0.39 ± 0.05 %. The phosphorus content recorded in FYM and rice straw was 0.36 ± 0.03% and 0.30 ± 0.04%, respectively. The percent potassium content was 0.54 ±0.05% in FYM and 0.77 ±0.07 % in rice straw. The total organic content was 47.32 ± 0.42% and 50.22 ± 0.52% in FYM and rice straw, respectively. The micronutrient concentration of Zn recorded was 88.12 ± 13.63 ppm in FYM and 62.23 ± 15.60 ppm in rice straw. The Cu concentration recorded was 12.43 ± 1.56 ppm in

FYM and 2.42 ± 0.96 ppm in rice straw. The Mn concentration recorded was 108.16 ± 15.24 ppm and 586.38 ± 23.45 ppm in FYM and rice straw respectively. The Fe concentration recorded was 0.20 ± 0.01% and 0.08 ± 0.03% in FYM and rice straw, respectively.

Table 1: Basic analysis of substrate used for vermicomposting

Manure property	Cow dung	Rice Straw
TOC (%)	47.32 ± 0.42	50.22 ± 0.52
TN (%)	0.36 ± 0.03	0.39 ± 0.05
TP (%)	0.36 ± 0.03	0.30 ± 0.04
TK (%)	0.54 ±0.05	0.77 ±0.07
C:N	51	45
Zn (ppm)	88.12 ± 13.63	62.23 ± 15.60
Cu(ppm)	12.43 ± 1.56	2.42 ± 0.96
Mn(ppm)	108.16 ± 15.24	586.38 ± 23.45
Fe (%)	0.20 ± 0.01	0.08 ± 0.03

Values are Mean ± S.E of triplicates

Final nutrient analysis of vermicompost from different test substrates

The total nitrogen content of the final vermicomposts is shown in table 2. Total nitrogen content increased in all the treatments. Among different test samples, increase in total nitrogen content was maximum in T7 and minimum in T10. The total nitrogen content followed the following decreasing order trend T7 (1.88 ± 0.05) > T5 (1.84 ± 0.04) > T8 (1.75 ± 0.03) > T3 (1.72 ± 0.03) > T6 (1.56 ± 0.02) > T4 (1.43 ± 0.02) > T1 (0.86 ± 0.05) > T2 (0.74 ± 0.03) > T9 (0.66 ± 0.02) > T10 (0.38 ± 0.02). There was significant difference noted between the all the treatments as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$). Earthworms helps in enhancing the nitrogen levels in the final vermicompost by adding body fluid, vermicast, mucus, enzymes and growth hormones Suthar (2007); Suthar (2009); (Bhat et al., 2018); Garg and Kaushik (2004) suggested that nitrogen content in the final vermicompost is related to the quality of the initial substrate used and due to mineralization of organic matter. Previous studies have reported that the nitrogen values ranges between (0.9 – 1. 5%). Earlier studies have reported the value of N between 0.9 and 1.5% (Waseem et al., 2013) but in (2009) Suthar reported that the value of nitrogen ranges between (2.49 – 3.17%) in the vermicompost. In 2012 Sujit Adhikary analysed the nitrogen content and reported it to be in the range of (0.51- 1.61%). According to (Sebayang et al., 2022) the percentage of nitrogen increased from 0.89% to 1.92 % following the process of vermicomposting.

Total organic carbon content of the final vermicomposts is shown in table 2. The total organic content decreased in all the test samples. Among different test samples, lowering of total organic content was maximum in T7 and minimum in T10. The total organic content followed the increasing trend as follows: T7 (17.23 ± 0.37) < T8 (18.46 ± 0.69) < T5 (20.42 ± 0.38) < T6 (22.63 ± 0.52) < T3 (23.45 ± 0.21) < T4 (24.12 ± 0.13) < T2 (26.86 ± 0.42) < T1 (28.02 ± 0.22) < T9 (29.02 ± 0.24) < T10 (30.94 ± 0.36). There was significant difference noted between the different treatments as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$). The carbon content in the final vermicompost is decreased due to microbial degradation and also, earthworms feed on the organic matter. The earthworms accelerate the decomposition process by feeding on the organic matter. Carbon is the major building block for all organisms present abundantly in the organic matter and hence, required for the composting process (Ansari and Jaikishun, 2011; Ansari and Rajpersaud, 2012). The present study results differ from the results of the previous study in which the organic carbon content ranges between (18.5–23%) Mane and Raskar (2012).

According to (Sebayang et al., 2022) the total carbon content decreases form 40.31% to 36.02% which coincide with the present study which shows similar decreasing trends.

C/N Ratio

The C:N ratio decreased during the vermicomposting process due to decomposition, microbial respiration, nitrogenous excretion (Solis-Mejia et al., 2012), mineralization and stabilization of organic matter (Kaushik and Garg, 2003). According to Senesi (1989) decrease in carbon:nitrogen to less than 20 reported show advanced degree of maturity in the organic matter waste. The C/N ratio in initial analysis of substrate was 45.29 which decreased to 19.07 after the process of vermicomposting (Sebayang et al., 2022).

The total phosphorus content of the final vermicomposts is shown in table 2. Among different test samples, increase in total phosphorus content was maximum in T7 and minimum in T10. The total phosphorus content followed the following decreasing order trend T7 (0.96 ± 0.05) > T8 (0.88 ± 0.03) > T5 (0.82 ± 0.03) > T6 (0.79 ± 0.05) > T3 (0.74 ± 0.02) > T4 (0.66 ± 0.02) >T1 (0.54 ± 0.02) > T9 (0.52 ± 0.02) > T2 (0.49 ± 0.03) > T10 (0.37 ± 0.03). There was significant difference noted between the all the treatments as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$). The present study results (0.3- 0.9%) are somewhat similar with the results obtained by Mane and Raskar (2012). The total phosphorus content recorded by Marlin and Rajeshkumar (2012) in the vermicompost obtained from city waste, saw dust, sugarcane trash, pressed mud and slaughter house waste was (2.68–3.61%) which is also different from the present study. The available phosphorus from the organic waste is released during the process of vermicomposting by the earthworm gut phosphatases and by P-solubilizing microorganisms present in the worm casts (Suthar, 2009; Goswami et al., 2013). The concentration of P recorded in initial substrate was 0.83% which increased to 1.15% after vermicosting (Sebayang et al., 2022). The present study results also concide with the findings of Kaplan, 2016).

Total Potassium content of the final vermicomposts is shown in the same table. Among different test samples increase in total potassium content was observed in all the treatments. The total potassium content followed the decreasing order trend T7 (1.78 ± 0.04) > T8 (1.69 ± 0.02) > T5 (1.53 ± 0.03) > T3 (1.41 ± 0.02) > T6 (1.26 ± 0.04) > T4 (1.21 ± 0.02) >T1 (0.78 ± 0.04) > T2 (0.69 ± 0.02) > T9 (0.67 ± 0.03) > T10 (0.55 ± 0.02). There was significant difference noted between the all the treatments as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$). The results obtained in the present study are somewhat similar with the previous studies by Nath et al. (2009). According to Nath et al. (2009) the total potassium content ranged between (0.64–0.76%) in the vermicompost obtained from rice straw and other waste material. The present study results are similar with the results reported by (Meenatchi, 2008 and Waseem et al., 2013) i.e the P content ranged between (0.54- 1.72%). Potassium, exchangeable calcium, phosphates etc. are present in the vermicompost in plant available form (Orozco et al., 1996). Due to microbial activity, vermicompost contains high level exchangeable K, which further increases the rate of mineralization (Suthar, 2007). The concentration of potassium ions in vermicompost The content of potassium increased from 1.25% to 2.17% following vermicomposting using *Eisenia foetida* (Sebayang et al., 2022) similar increasing trends are observed in the present study.

The total concentrations of the micronutrients, viz. zinc (T-Zn), copper (T-Cu), manganese (T-Mn) and iron (T-Fe) in different treatments vermicomposts are shown in table 4. Among different test substrates, the concentration of Zinc (ppm) followed the following decreasing trend T7 (973.68 ± 63.02) > T8 (907.23 ± 52.53) > T5 (842.50 ± 45.36) > T6 (779.75 ± 43.32) > T3 (564.24 ± 33.32) > T4 (512.35 ± 32.64) > T1 (424.62 ± 24.52) >T2 (314.82 ± 19.34) > T9 (153.57 ± 15.45) > T10 (102.38 ± 12.42). The concentration of Zinc showed significant difference in all the treatments as compared to T10 (Cow dung) according to Tukey's test ($p < 0.05$). The concentration of copper (ppm) followed the following decreasing trend T7 (49.60 ± 7.09) > T5 (45.26 ± 7.53) > T8 (39.81 ± 5.62) > T6

(37.28 ± 5.33) > T3 (36.19 ± 5.82) > T4 (32.78 ± 4.83) > T1 (27.82 ± 2.08) > T2 (27.23 ± 3.30) > T9 (19.82 ± 2.70) > T10 (11.45 ± 2.78). No significant difference was observed among the treatments but there was significant difference reported as compared to T10 (cow dung) according to Tukey's test ($p < 0.05$).The high level of copper can be due to the presence of copper containing oxidizing enzymes. The concentration of manganese (ppm) followed the decreasing trend T7 (794.73 ± 63.35) > T8 (752.96 ± 57.99) > T5 (688.72 ± 52.56) > T6 (618.92 ± 45.41) > T3 (574.60 ± 35.92) > T4 (538.63 ± 39.43) > T1 (487.31 ± 23.59) > T2 (462.52 ± 42.19) > T9 (457.27 ± 37.24) > T10 (110.51 ± 17.38). There was significant difference recorded in the treatments as compared to T10 (Cow dung) according to Tukey's test ($p < 0.05$). The concentration of Iron (ppm) followed the following decreasing trend T7 (1.82 ± 0.04) > T5 (1.73 ± 0.05) > T8 (1.65 ± 0.05) > T6 (1.61 ± 0.05) > T3 (1.18 ± 0.06) > T4 (1.01 ± 0.03) > T1 (0.98 ± 0.04) > T2 (0.86 ± 0.05) > T9 (0.69 ± 0.02) > T10 (0.18 ± 0.02). Significant difference was recorded among the treatments according to Tukey's test ($p < 0.05$). The present study result varies from the earlier reported values 5.70–120.00 ppm for Zn, 2.00–37.70 ppm for Cu and 10.00–105.00 ppm for Mn (Meenatchi, 2008; Waseem et al., 2013). Vermicompost typically contains high concentrations of total NPK and micronutrients (Karmegam and Daniel, 2009; Prakash and Karmegam, 2010).The total content of Zinc, copper, manganese and iron is high in the vermicompost as compared to the substrate used. This indicates that these micro- elements accumulate in the vermicompost. The findings of the present study coincide with the results reported by early researchers (Ismail, 1997; Ansari and Sukhraj, 2010; Ansari et al., 2016). The plant nutrients such as N,P,K, Fe, Mn, Zn, Cu and other micronutrients present in the organic manures enhances their potential as alternative sources of nutrients to enhance the soil health and productivity (Subbaiah 2019).

Among all the treatments T7, T8, T5 and T6 are the best suited treatments to produce vermicompost with high NPK, high micronutrients and low C: N ratio.

Table 2: Final analysis of vermicompost produced

Treatment	TOC (%)	TN (%)	TP (%)	TK (%)	C:N
T_1	28.02 ± 0.22^f	0.86 ± 0.05^c	0.54 ± 0.02^c	0.78 ± 0.04^c	35.02
T_2	26.86 ± 0.42^e	0.74 ± 0.03^b	0.49 ± 0.03^b	0.69 ± 0.02^b	36.29
T_3	23.45 ± 0.21^d	1.72 ± 0.03^f	0.74 ± 0.02^e	1.41 ± 0.02^e	13.63
T_4	24.12 ± 0.13^d	1.43 ± 0.02^d	0.66 ± 0.02^d	1.21 ± 0.02^d	16.86
T_5	20.42 ± 0.38^b	1.84 ± 0.04^g	0.82 ± 0.03^f	1.53 ± 0.03^f	11.09
T_6	22.63 ± 0.52^c	1.56 ± 0.02^e	0.79 ± 0.05^{ef}	1.26 ± 0.04^d	14.50
T_7	17.23 ± 0.37^a	1.88 ± 0.05^g	0.96 ± 0.05^h	1.78 ± 0.04^h	9.16
T_8	18.46 ± 0.69^a	1.75 ± 0.03^f	0.88 ± 0.03^g	1.69 ± 0.02^g	10.54
T_9	29.02 ± 0.24^f	0.66 ± 0.02^b	0.52 ± 0.02^{bc}	0.67 ± 0.03^b	43.96
T_{10}	8.14 ± 0.36^g	0.38 ± 0.02^a	0.37 ± 0.03^a	0.55 ± 0.02^d	21.42

Values are Mean ± S.E of triplicates

Values with at least one same alphabetic superscript in column do not differ significantly ($p > 0.05$) w.r.t to treatments

Table 3: % Increase or decrease in TOC, TN, TP and TK among various treatments

Treatment	(%)Decrease in TOC		(%) increase in TN		(%) increase in TP		(%) increase in TK	
	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw
T_1	40.78	44.20	138.88	120.51	50.00	80.00	44.44	1.29
T_2	43.23	46.51	105.5	89.74	36.11	63.33	27.77	-10.38
T_3	50.44	53.30	377.77	341.02	105.55	146.66	161.11	83.11
T_4	49.02	51.97	297.22	266.66	83.33	120.00	124.07	57.14
T_5	56.84	59.33	411.11	371.79	127.77	173.33	183.33	98.70
T_6	52.17	54.93	333.33	300.00	119.44	163.33	133.33	63.63
T_7	63.58	65.69	422.22	382.05	166.66	220.00	229.62	131.16
T_8	60.98	63.24	386.11	348.71	144.44	193.33	212.96	119.48
T_9	38.67	42.21	83.33	69.23	108.64	73.33	24.07	-12.98
T_{10}	97.88	83.79	5.55	-2.56	2.77	23.33	9.25	-28.57

Table 4: Final analysis of micronutrients in the vermicompost

Treatment	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (%)
T_1	424.62 ± 24.52^{c}	27.82 ± 2.08^{bc}	487.31 ± 23.59^{b}	0.98 ± 0.04^{d}
T_2	314.82 ± 19.34^{b}	27.23 ± 3.30^{bc}	462.52 ± 42.19^{b}	0.86 ± 0.05^{c}
T_3	564.24 ± 33.32^{d}	36.19 ± 5.82^{cde}	574.60 ± 35.92^{bcd}	1.18 ± 0.06^{e}
T_4	512.35 ± 32.64^{cd}	32.78 ± 4.83^{bcd}	538.63 ± 39.43^{bc}	1.01 ± 0.03^{d}
T_5	842.50 ± 45.36^{ef}	45.26 ± 7.53^{de}	688.72 ± 52.56^{de}	1.73 ± 0.05^{fg}
T_6	779.75 ± 43.32^{e}	37.28 ± 5.33^{cde}	618.92 ± 45.41^{cd}	1.61 ± 0.05^{f}
T_7	973.68 ± 63.02^{g}	49.60 ± 7.09^{e}	794.73 ± 63.35^{e}	1.82 ± 0.04^{h}
T_8	907.23 ± 52.53^{fg}	39.81 ± 5.62^{cde}	752.96 ± 57.99^{e}	1.65 ± 0.05^{f}
T_9	153.57 ± 15.45^{a}	19.82 ± 2.70^{ab}	457.27 ± 37.24^{b}	0.69 ± 0.02^{b}
T_{10}	102.38 ± 12.42^{a}	11.45 ± 2.78^{a}	110.51 ± 17.38^{a}	0.18 ± 0.02^{a}

Values are Mean ± S.E of triplicates

Values with at least one same alphabetic superscript in column do not differ significantly ($p > 0.05$) w.r.t to treatments

Table 5: % Increase or decrease in micronutrients in the vermicompost

Treatment	(%) Increase in Zn		(%) increase in Cu		(%) increase in Mn		(%) increase in Fe	
	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw	w.r.t Cowdung	w.r.t Rice straw
T_1	381.86	582.33	123.81	1049.58	350.54	-16.89	390	1125
T_2	257.26	405.89	119.06	1025.20	327.62	-21.12	330	975
T_3	540.30	806.70	191.15	1395.45	431.25	-2.00	490	1375
T_4	481.42	723.31	163.71	1254.54	397.99	-8.14	405	1162.5
T_5	856.08	1253.84	264.11	1770.24	536.76	17.45	765	2062.5
T_6	784.87	1153.01	199.91	1440.49	472.35	5.54	705	1912.5
T_7	1004.94	1464.64	299.03	1949.58	634.77	35.53	810	2175
T_8	929.53	1357.86	220.27	1545.04	596.15	28.40	725	1962.5
T_9	74.27	146.77	59.45	719.00	322.77	-22.01	245	762.5
T_{10}	16.18	64.51	-7.88	373.14	2.17	-81.15	-10	125

Table 6: Earthworm population and biomass production during the study period

Treatment	Earthworm population (No.)	Biomass production(kg)	Days of preparation
Chopped Rice straw + cow dung (1:1)+ 1kg worm),	2221	324.67	60
Unchopped Rice straw + cow dung (1:1)+ 1kg worm)	2212	321.60	70
Chopped Rice straw + cow dung (1:1)+ 2kg worm)	2190	215.33	70
Unchopped Rice straw + cow dung (1:1) + 2kg worm	1145	195.75	75
Chopped Rice straw (70%) + soil (10%)+ cow dung (20%) + 1 kg worm	2961	428.40	90
Unchopped Rice straw (70%) + soil (10%) + cow dung (20%) + 1 kg worm	2349	310.21	138
Chopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2 kg worm	2384	350.78	118
Unchopped Rice straw (70%) + soil (10%) + cow dung (20%) + 2 kg worm	2390	341.75	140
Cow dung (100%) + 1 kg worm	2372	264.00	65
Cow dung only	-	500.0	160
CD	14	NS	-

Correlation analysis among nutrients, Biomass production and Earthworm population

A correlation analysis among nutrients, biomass production and earthworm population is shown in table 5. The N content positively correlates with P and K (r= 0.961 and 0.974, respectively), Zn, Cu, Mn and Fe (r= 0.936, 0.949, 0.890 and 0.919, respectively) and negatively correlates with TOC and biomass (r= -0.042 and -0.234, respectively). Similarly P content positively correlates with K, Zn, Cu, Mn and Fe (r= 0.977, 0.970, 0.953, 0.937 and 0.959, respectively) and negatively correlates with TOC and biomass production (r= -0.070 and -0.155, respectively). The K content positively correlates with Zn, Cu, Mn and Fe (r= 0.950, 0.932, 0.885, and 0.905, respectively) and negatively correlates with TOC and biomass production (r= -0.176 and -0.127, respectively) indicating an increase in NPK content with decreasing TOC content. The content of Zn positively correlates with Cu, Mn and Fe (r= 0.957, 0.909 and 0.973, respectively) and content of Cu positively correlates with Mn and Fe (r=0.945 and 0.969, respectively) and negatively correlates with biomass production (r= -0.024 and -0.160, respectively). Similary, the content of Mn positively correlate with Fe (r=0.956) and negatively correlates with biomass production (r= -0.308). The results coincide with the findings of (Kováˇcik et al., 2022). No significant correlation was analyzed between the nutrients (N, P, K, Zn, Cu, Mn and Fe) and earthworm population.

Table 7: Correlation analysis among nutrients, Biomass production and Earthworm population

	N	P	K	TOC	Zn	Cu	Mn	Fe	Earthworm population	Biomass production
N	1	.961**	.974**	-0.042	.936**	.949**	.890**	.919**	0.182	-0.234
P		1	.977**	-0.070	.970**	.953**	.937**	.959**	0.293	-0.155
K			1	-0.176	.950**	.932**	.885**	.905**	0.205	-0.127
TOC				1	-0.122	0.048	0.239	0.067	0.261	-.719*
Zn					1	.957**	.909**	.973**	0.320	-0.024
Cu						1	.945**	.969**	0.317	-0.160
Mn							1	.956**	0.364	-0.308
Fe								1	0.457	-0.108
Earthworm population									1	.809**
Biomass production										1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

The efficacy of *Eisenia foetida* for bioconversion of agricultural waste like rice straw and farmyard manure (cowdung) into highly nutritive vermicompost is highly triumphant. The vermicompost produced was a homogenous mixture with dark color having high NPK value and low C:N ratio. Concentration of micronutrients like Cu, Zn and Mn were high in the vermicompost. The present study findings can be employed in improving the process of bio-management of agricultural waste by vermiconverting it into valuable, cost effective, pollution free and nutrient rich organic manure as well as it will assist the farmers to use eco-friendly biofertilizer and promoting good agricultural practices to maintain soil productivity and encouraging sustainable agriculture.

Declaration

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