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Effect of tertiary combinations of animal dung with agrowastes on the growth and development of earthworm *Eisenia fetida* during organic waste management

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Abstract

Background: Abundant uses of chemical fertilizers have adversely affected the soil. The large production of livestock dung is recorded in India annually. The presence of abundant agrowastes and animal dung causes serious problems to animals as well as to human beings, due to the improper management of these wastes. Due to the presence of different physicochemical parameters, these agrowastes and animal dung as food source influence not only the earthworm population but also affect their growth and reproduction during vermicomposting. The effect of agrowastes (wheat straw, banana pills) and bran (barley, rice, and gram bran) with cow and goat dung as tertiary combinations (1:1:1) on the growth and reproduction of *E. fetida* was investigated.

Results: The significant ($P < 0.05$) highest cocoon production was 5.92 ± 0.01/worm/2 weeks observed in CWRr. The reproduction rate as the number of hatchling emerged per cocoon was also significantly the highest ($P < 0.05$) in CWBr as 1.9 ± 0.03. The maximum biomass gained was up to 898.67 ± 2.04 mg/worm, and significant growth rate was 7.32 ± 0.02 mg/worm/day in CWGr combination. There was a significant decrease in pH, C/N ratio, TOC, and EC while there was a significant increase in TKN, TK, TAP, and TCa in different tertiary combinations of final vermicompost when compared to the initial feed mixture.

Conclusion: The tertiary combinations of dung and bran with agrowastes used were effective and efficient culture media for the large-scale production of *E. fetida*, which will be important for the production of vermicompost.

Keywords: *Eisenia fetida*; Growth rate; Tertiary combinations; Vermicomposting; Organic wastes

Introduction

Abundant uses of chemical fertilizers have not only caused the loss of soil fertility but also increase the large amount of agrowastes. The production of cow livestock and goat dung are 11.6 and 0.70 kg/animal/day, respectively, in India (Garg et al. 2006). The presence of abundant agrowastes and animal dung causes serious problems to animals as well as to human beings if there is improper management of these wastes. So, it is in emergent need to retain the soil fertility as well the handling of abundant production of agro- and animal wastes. The use of earthworm population for the increase of soil organic matter (Steven et al. 2009) and management of biological wastes have proved to be successful in processing animal wastes, *Eichhornia* (water weeds) and *Parthinium* weeds (Yadav and Garg 2010), by the method of vermicomposting. Vermicomposting is a suitable way for waste management and production of organic manure with the help of the earthworms. Many earthworm populations have converted more wastes into rich nutrient biofertilizers. In vermicomposting, different microorganisms (bacteria, actinomycetes, algae, fungi, and other micro fauna) were colonized, and as a result,the concentration of various enzymes, plant hormones, growth stimulator, and vitamins increased directly or indirectly (Suthar 2010). Gunadi et al. (2002) also reported that pre-composting solid organic wastes were essential to growth, reproduction, and survivability of the earthworm. One

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solution of this problem is to enhance the large population and better growth of the earthworm *Eisenia fetida* by different combinations of agrowastes, brans, and animal excreta. Livestock dung has been used as a main substrate for growth and development of *E. fetida*; some agricultural wastes with it are also used for the improvement of the growth and reproduction of the earthworm. The growth and reproduction of the earthworm was significantly affected by various factors such as waste type, temperature, density, moisture, chemical complexity, bulky material, and earthworm species during vermicomposting (Yadav and Garg 2010). In India, due to lack of knowledge about vermicomposting, the people usually use simple dung for composting in which has low quality than the vermicompost. The present study was designed to investigate and assess the reproduction rate of the cocoons and hatchling emergence as well to determine growth of *E. fetida* in different combinations and to evaluate the pH, C/N ratio, electrical conductivity (EC), total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total potassium (TK), total available phosphorus (TAP), and total calcium (TCa) in the pre- and final vermibed. The present study is important not only to the small farmers but also to the large-scale farmers in informing them on the production of large amount and potent vermicompost for agricultural crops and enhancement of the epigeic earthworm population during the management of agricultural-organic wastes.

Methods

Collection of earthworm *E. fetida,* animal dung, bran, and agrowastes

The culture of the earthworm *E. fetida* used during the entire experiment was procured from the Vermiculture Research Centre, Department of Zoology, DDU Gorakhpur University, Gorakhpur, UP, India.

Fresh dung of cow and goat was collected from different farmhouses of Gorakhpur City. The agrowastes, such as wheat straw and banana pills and different brans of barley, gram and rice, were collected from rice mills, pulse mill, and fruit seller in different parts of Gorakhpur City.

Experimental setup

The experiment was conducted on a cemented earth surface. Two kilograms of each of the 14 different combinations were CD (cow dung control), CWBr (cow dung + wheat straw + barley bran), CWRr (cow dung + wheat straw + rice bran), CWGr (cow dung + wheat straw + gram bran), CBBr (cow dung + banana pills + barley bran), CBRr (cow dung + banana pills + rice bran), CBGr (cow dung + banana pills + gram bran), GD (goat dung control), GWBr (goat dung + wheat straw + barley bran), GWRr (goat dung + wheat straw + rice bran), GWGr (goat dung + wheat straw + gram bran), GBBr (goat dung + banana pills + barley bran), GBRr (goat dung + banana pills + rice bran), and GBGr (goat dung + banana pills + gram bran) made in ratio of 1:1:1 (w/w) on $30 \times 30 \times 10$ cm^3 made in bed form at room temperature (28 ± 2°C). The experiment to study the growth and development of earthworm *E. fetida* was performed by the method of Garg et al. (2005). The vermicomposting beds were turned over manually every 24 h for 2 weeks in order to eliminate volatile substances. After this, 20 adult non-clitallated individuals (average weight 238.14 to 252.82 mg) of *E. fetida* were introduced in each vermibed. Biomass gained and cocoon production were recorded up to 90 days every 15 days in bed. After isolation, each cocoon was freshly laid inside a Petri dish which contains a moist filtered paper at 30 ± 2°C and 70 ± 5% RH. The hatching of cocoons was determined to stipulated incubation, and the number of progeny emerged per cocoon was recorded. Each experiment was replicated six times.

Chemical analysis

The pH and electrical conductivity were determined using a double-distilled water suspension of each waste in the ratio of 1:10 (w/v) that has been agitated mechanically for 30 min and filtered through Whatmann no.1 filter paper; TOC was measured after igniting the sample in a Muffle furnace at 550°C for 50 min by the method of Nelson and Sommers (1982). TKN was determined after digesting the sample with concentration (conc.) of H_2SO_4 and $HClO_4$, (9:1 v/v) according to the method of Bremner and Mulvaney (1982). TAP was analyzed using the colorimetric method with molybdenum in sulfuric acid, and TK was determined after digesting the sample in diacid mixture conc. of HNO_3:$HClO_4$, 4:1 (v/v) using a flame photometer (Garg et al. 2005).

Statistical analysis

All the experiments were replicated six times for the purpose of obtaining consistency in the result and finding out the mean with standard error. Analysis of variance was used to analyze the significant difference between the combinations; t test ($P < 0.05$) was performed to identify the homogenous type of bedding with respect to reproduction and growth from the control.

Results and discussion

During vermicomposting, firstly, there was a decrease in the odors from the pretreated bed and then an improvement in the growth and reproduction of the earthworm population. Vermicompost has better quality than the traditional compost concerning the potent nutrient. The food source, due to the presence of different physicochemical parameters, influences not only the size of the earthworm population but also affects its growth and reproduction.

Table 1 Effect of tertiary combinations of animal dung with biowastes on the reproduction of *Eisenia fetida*

Combinations	Initiation of clitellum development (in day)	Initiation of cocoon production (in week)	Rate of reproduction	
			Cocoons/worm/2 weeks	Number of hatchling/cocoon
CD	26.4 ± 3.0	6th	3.2 ± 0.02b	1.6 ± 0.02b
CWBr	18.4 ± 1.9	5th	3.8 ± 0.03b	*1.9 ± 0.03e*
CWRr	20.2 ± 2.0	5th	*5.9 ± 0.01e*	1.7 ± 0.02c
CWGr	16.9 ± 2.0	5th	4.3 ± 0.02c	1.8 ± 0.02d
CBBr	19.6 ± 2.1	5th	5.1 ± 0.03d	1.7 ± 0.03c
CBRr	20.7 ± 2.0	5th	4.2 ± 0.02c	1.7 ± 0.03c
CBGr	18.9 ± 1.7	5th	4.8 ± 0.05c	1.8 ± 0.02d
GD	24.6 ± 3.0	6th	2.7 ± 0.03a	1.5 ± 0.02a
GWBr	14.4 ± 2.0	5th	5.1 ± 0.02d	1.8 ± 0.02d
GWRr	22.6 ± 2.1	6th	4.2 ± 0.03c	1.7 ± 0.01c
GWGr	20.4 ± 2.2	6th	5.3 ± 0.04c	1.7 ± 0.02c
GBPBr	20.8 ± 2.1	5th	4.9 ± 0.03d	1.6 ± 0.02b
GBRr	20.1 ± 1.9	5th	3.8 ± 0.04b	1.6 ± 0.02b
GBGr	19.8 ± 2.1.	5th	4.6 ± 0.02d	1.7 ± 0.01c

Each value is the mean ± SE of six replicates. One way ANOVA was used for the significant combinations and *t* test for significant reproduction rate of the mean value of the different letters (at $P < 0.05$). Earthworm was grown in a 30.0 × 30.0 × 30.0 cm^3 area of vermicomposting bed. Mean values followed by common letters are not significantly different at $P < 0.05$ (*t* test).

Growth and reproduction of *E. fetida*

The different tertiary combinations of cow and goat dung with agrowastes, i.e., wheat straw, banana pills, and different brans of barley, gram, and rice, caused a significant reproduction and growth rate of the earthworm *E. fetida*. There was a significant cocoon production and hatchling per cocoons in different combinations (Table 1). The significant highest production was 5.92 ± 0.01 cocoons/worm/2 weeks production in CWRr, and then 5.3 ± 0.04 cocoons/worm/2 weeks in GWGr combinations. The reproduction rate as the number of hatchling emerged per cocoon was significantly highest which was 1.9 ± 0.03 in CWBr. The differences of growth and reproduction in various combinations were dependent in the quality of dung and wastes. According to Suthar and Ram (2008), the growth and cocoon production was affected also by the C/N ratio in the feed material as better growth and reproduction in high C/N ratio. The dung, which is an important and a unique factor for the earthworm maturation and for the production of cocoons and hatchling from the cocoons (Garg et al. 2005), increases the growth and reproduction of earthworm by the different agrowastes in the animal dung with different ratios (Suthar 2007; Chauhan and Singh 2012). Kale et al. (1982) observed a mean cocoon production of 0.15 cocoons/worm/day. The growth pattern of *E. fetida* in different tertiary combinations was described (Figure 1 and Table 2), and Figure 1 shows that rapid biomass gained after the 2nd week and then slightly decreased at the end of the experiment. The maximum

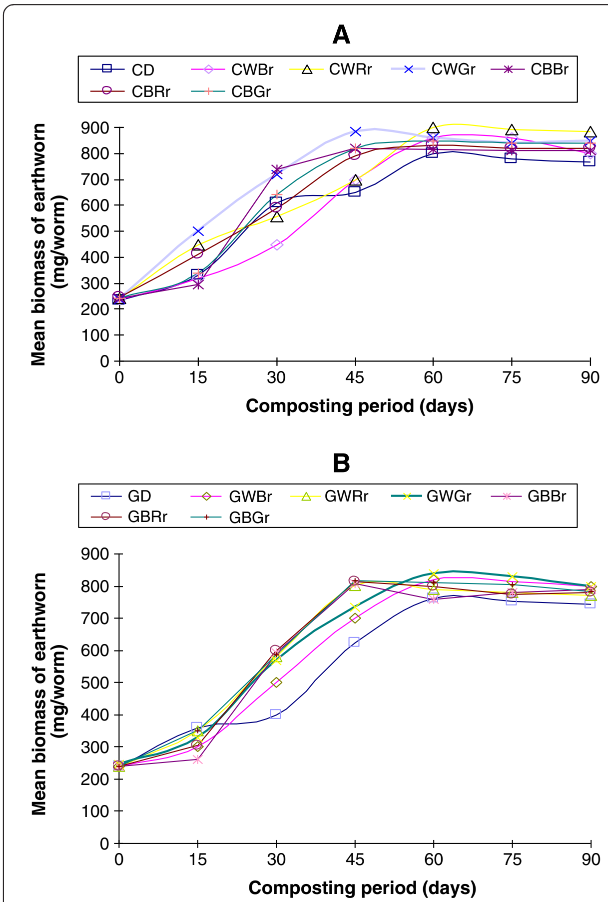

Figure 1 Growth rate of *Eisenia fetida* in cow dung (A) and goat dung (B) with different agrowastes.

Table 2 Growth rate of *Eisenia fetida* in different tertiary combinations of animal dung with agrowastes

Combinations	Mean initial weight (mg/worm)	Maximum weight achieved (mg/worm)	Net weight gain (mg/worm)	Growth rate (mg/worm/day)
CD	235 ± 3.15	798 ± 2.22	572 ± 1.32	6 ± 0.02a
CWBr	239 ± 3.57	861 ± 3.43	618 ± 1.12	6 ± 0.03c
CWRr	240 ± 3.46	883 ± 2.30	641 ± 1.41	7 ± 0.03d
CWGr	242 ± 3.51	898 ± 2.04	655 ± 1.23	7 ± 0.02d
CBBr	241 ± 3.74	821 ± 2.13	589 ± 1.03	6 ± 0.03bc
CBRr	246 ± 3.81	832 ± 2.14	595 ± 1.40	6 ± 0.03c
CBGr	244 ± 3.64	846 ± 2.29	600 ± 1.09	6 ± 0.02c
GD	238 ± 3.49	761 ± 1.51	525 ± 1.35	5 ± 0.04a
GWBr	241 ± 3.87	820 ± 2.19	580 ± 1.25	6 ± 0.02ab
GWRr	239 ±4.04	801 ± 2.14	564 ± 1.24	6 ± 0.01a
GWGr	246 ± 4.13	840 ± 2.98	596 ± 1.17	6 ± 0.02bc
GBBr	239 ± 4.60	809 ± 1.61	572 ± 1.34	6 ± 0.04b
GBRr	240 ± 4.25	812 ± 2.12	574 ± 1.37	6 ± 0.04bc
GBGr	240 ± 4.64	818 ± 2.42	580 ± 1.43	6 ± 0.03b

Each value is the mean ± SE of six replicates. One way ANOVA was used for the significant combinations and *t* test for the significant ($P < 0.05$) growth rate of the mean value of the different letters. Earthworm was grown in a 30.0 × 30.0 × 30.0 cm^3 area of vermicomposting bed. Mean values followed by common letters are not significantly different at $P < 0.05$ (*t* test).

biomasses gained which was 898.67 ± 2.04 mg/worm, and also, a significant growth rate occurred which was 7.18 ± 0.42 mg/worm/ day in CWGr combination. The growth rate which was 6.64 ± 0.02 mg/worm/day in GWGr combination was also significant than that of the CD (cow dung control). The different biomasses gained due to the different combinations during vermicomposting (Table 2). According to Garg et al. (2005), the maximum individual body mass was 800 to 1,290 mg in an animal dung vermibed. The growth rate of *E. fetida* in cow and goat dungs was recorded as 16.3 ± 0.52 and 16.5 ± 3.54 mg/worm/day, respectively (Garg et al. 2005).

Physicochemical analysis

During vermicomposting, the final pH of all the vermibed reactors was significantly decreased with respect to the initial feed mixture (Table 3). The significant lowest pH was observed as 6.2 ± 0.03 in CWBr combination which is suitable for earthworm development. These changes in pH may be due to the degradation of organic solid wastes, and during this process, formation of humic acid and ammonium ions occurred; similar results were supported by Short et al. (1999). The low pH in vermicompost may be due to the production of fulvic acid and humic acid (Chauhan and Singh 2012). During vermicomposting process, there was a trend to the neutral pH in the vermicompost (Singh et al. 2005). The C/N ratio is an important factor to determine the growth and reproduction of the vermicomposting earthworm (Suthar and Ram 2008; Chauhan and Singh 2012). The significant lowest C/N ratio of 9.58 ± 1.61 in CWBr combination may be due to the decrease in organic carbon and increase in nitrogen in the final vermicompost. Similar results were reported during the experiment of vermicomposting by Garg et al. (2006). Suthar (2010) has reported that loss of carbon during vermicomposting is due to the digestion of carbohydrate and other polysaccharide from initial substrate material. Also, some part of organic carbon may be assimilated by the earthworm as the biomass increases. Increase in nitrogen is responsible for the reduced C/N ratio by the change of ammonium nitrogen to nitrate.

In the experiment, the electrical conductivity of initial feed mixtures ranged from 2.10 to 2.40 dS/m; while after the vermicomposting, a significant decrease of 1.10 to 1.29 dS/m may be due to high organic matter loss consequently and release of different mineral salts. Garg et al. (2006) reported that there is 28% to 46% reduced EC in the final vermicompost. Singh et al. (2010) observed that EC significantly declined (28.69%) in the final vermicompost during the management of bio sludge of the beverage industry. In the present study, the TOC content was reduced during vermicomposting (Table 3.).

The significant reduction of TOC in CWRr was about 38% (598.63 ± 1.17 to 231.68 ± 1.41 gm/kg). The organic carbon content declined drastically from the substrate up to 90 days (Suthar 2007). In all of the chemical parameters in the vermicompost, TOC was the most important for the growth and development of the earthworm which may be due to its use in the metabolism, thus a reduction in the final vermicompost. The organic content was lost in the form of CO_2 by the earthworm activity, thus, also a decline from initial feed mixture as well as increase the

Table 3 Different physical parameters in initial feed mixture and final vermicompost of different tertiary combinations of animal dung with agrowastes

Combinations	pH		C/N ratio		EC (dS/m)	
	IM	FV	IM	FV	IM	FV
CD	7.8 ± 0.05[a]	6.8 ± 0.04*[a]	47.8 ± 1.41*	12.7 ± 1.18*[a]	2.10 ± 0.06*	1.13 ± 0.07*[a]
CWBr	7.5 ± 0.03	6.2 ± 0.03*	35.42 ± 1.22	9.58 ± 1.61*	2.15 ± 0.09	1.14 ± 0.03*
CWRr	7.3 ± 0.06	6.3 ± 0.02*	49.54 ± 1.72	10.02 ± 1.72*	2.14 ± 0.07	1.16 ± 0.02*
CWGr	7.6 ± 0.04	6.1 ± 0.01*	44.21 ± 1.68	9.94 ± 1.65*	2.22 ± 0.09	1.23 ± 0.04*
CBBr	7.6 ± 0.04	6.7 ± 0.02*	59.05 ± 1.69	11.23 ± 1.67*	2.24 ± 0.06	1.25 ± 0.05*
CBRr	7.2 ± 0.03	6.4 ± 0.03*	53.22 ± 1.42	10.58 ± 1.42*	2.23 ± 0.09	1.24 ± 0.04*
CBGr	7.4 ± 0.06	6.2 ± 0.02*	46.26 ± 1.54	10.69 ± 1.60*	2.21 ± 0.08	1.22 ± 0.02*
GD	8.5 ± 0.04[a]	6.7 ± 0.05*[a]	52.14 ± 1.64[a]	19.65 ± 1.40*[a]	2.25 ± 0.10[a]	1.18 ± 0.08*[a]
GWBr	8.1 ± 0.01	6.5 ± 0.03*	46.08 ± 1.82	9.94 ± 1.52*	2.42 ± 0.12	1.18 ± 0.06*
GWRr	8.2 ± 0.02	6.4 ± 0.02*	48.43 ± 1.72	9.18 ± 1.64*	2.29 ± 0.08	1.20 ± 0.08*
GWGr	7.9 ± 0.02	6.3 ± 0.04*	46.89 ± 1.61	8.50 ± 1.57*	2.33 ± 0.10	1.29 ± 0.06*
GBBr	8.4 ± 0.01	6.6 ± 0.03*	47.57 ± 1.84	10.21 ± 1.64*	2.32 ± 0.11	1.24 ± 0.07*
GBRr	8.1 ± 0.04	6.4 ± 0.02*	45.80 ± 1.61	9.98 ± 1.47*	2.29 ± 0.08	1.22 ± 0.06*
GBGr	8.2 ± 0.02	6.4 ± 0.02*	44.61 ± 1.57	9.15 ± 1.53*	2.23 ± 0.09	1.20 ± 0.05*

IM initial feed mixture, *FV* final vermicompost, each value is the mean ± SE of six replicates. [a]Two-way ANOVA for significant combination difference ($P < 0.05$) in each mean value of physical parameter in the column from treated combinations.[*]Statistically significant ($P < 0.05$) difference of the chemical parameter of final vermicompost from the initial feed mixture.

stabilization process of wastes. The TOC reduction during vermicomposting was observed 24% to 60% in the different combinations of vermibed in an earlier research (Yadav and Garg 2010). The total TKN content was significantly highest at 53.80% which increased (12.48 ± 0.03 to 26.21 ± 0.09 gm/kg) in the final vermicompost of GWGr combination. The TKN increase in the final vermicompost may be due to mineralization and addition of some byproduct or assimilatory product by the earthworm (Chauhan and Singh 2012). In spite of all, the TKN conc. in the vermicompost depends on the combination of initial feed mixture. According to Kale et al. (1982), nitrogen content accumulated in the earthworm cast after the digestion wastes of the earthworm. During vermicomposting, there was a significant increase (11% to 83%) in the TK in all the final vermicomposts. The significant highest TK is 9.61 gm/kg in GWGr combination, in which significantly increased to 83% then 8.92 gm/kg (53% increase) in CBRr. The TK increased in all vermibeds after 150 days (Suthar, 2007). Similar result was found in vermicomposting of sewage sludge by using red worm. According to Barois and Lavelle (1986), symbiotic association of microorganism in earthworm gut and secreted mucus water helps in increasing the degradation of organic matter. The TAP content was significantly increased in the final vermicompost (Table 4). The increase in TAP was the highest in CWRr (67%), then in CD (60%), which may be due to the phosphorus mineralization by the earthworm. Lee (1992) suggested that unavailable phosphorus was converted in the earthworm intestine to an available form and also by solublization by the microorganism in their casts. This result was supported by Vinotha et al. (2000) as it is the major role of the microflora due to the increase of phosphatase activity. Total calcium is significant in all of the final vermicompost compared to the initial feed mixture. The highest TCa which is 3.68 ± 0.04 gm/kg significantly increased in the final vermicompost of GBRr and then 3.68 ± 0.02 gm/kg in GBGr combination; similar results were observed by Garg et al. (2006). According to Hartenstein and Hartenstin (1981), calcium metabolism in the earthworm gut was primary responsible for the increase of inorganic calcium in the worm cast. The total nutrient content in the vermicompost for plant depends on the nature of the initial feed mixture, about 2.0 to 2.6 times (on a dry weight basis) in the final vermicompost. The phosphorus and potassium contents were 1.36 and 2.14 times, respectively, greater than the raw material for vermicomposting (Tripathi and Bhardwaj 2004).

Conclusions

The vermicomposting of different biological wastes by the *E. fetida* showed significant changes in the physicochemical properties of wastes into a potent vermicompost. The vermicompost has an intrinsic potency for the nourishment of crops and plants, which also provides a sound environment as well as to protect diversity. From the present study, it may be concluded that the quality of different combinations of food materials influenced the reproduction and growth of the earthworm. The tertiary combinations of dung and bran with agrowastes used were

Table 4 Different chemical parameters in initial feed mixture and final vermicompost of different tertiary combinations of animal dung with agrowastes

Combinations	TOC		TKN		TK		TAP		TCa	
	IM	FV	IM	FV	IM	FV	IM	FV	IM	FV
CD	423.12 ± 1.45[a]	187.61 ±1.57[a]*	8.70 ± 0.04[a]	15.7 ± 0.02[a]*	5.21 ± 0.05[a]	6.6 ± 0.04[a]*	5.62 ± 0.05[a]	9.01 ± 0.04[a]*	1.4 ± 0.02[a]	2.0 ± 0.04[a]*
CWBr	442.81 ± 1.10	221.54 ± 1.61*	12.46 ± 0.05	23.42 ± 0.01*	6.52 ± 0.04	8.57 ± 0.03*	6.89 ± 0.04	10.02 ± 0.05*	2.39 ± 0.04	3.48 ± 0.03*
CWRr	598.63 ± 1.17	231.68 ± 1.41*	12.03 ± 0.04	22.98 ± 0.01*	6.14 ± 0.03	8.02 ± 0.03*	7.08 ± 0.05	10.48 ± 0.02*	2.34 ± 0.03	3.62 ± 0.02*
CWGr	571.74 ± 1.02	226.28 ± 1.24*	12.75 ± 0.06	23.28 ± 0.09*	6.24 ± 0.06	8.34 ± 0.03*	6.10 ± 0.03	10.21 ± 0.03*	2.45 ± 0.04	3.56 ± 0.04*
CBBr	582.63 ± 1.14	252.42 ± 1.71*	9.98 ± 0.05	20.46 ± 0.03*	5.62 ± 0.04	8.24 ± 0.04*	7.42 ± 0.03	9.87 ± 0.03*	2.84 ± 0.05	3.60 ± 0.05*
CBRr	589.62 ± 1.60	243.26 ± 1.73*	11.01 ± 0.04	22.75 ± 0.08*	5.83 ± 0.02	8.92 ± 0.04*	7.28 ± 0.04	10.79 ± 0.04*	2.42 ± 0.03	3.48 ± 0.04 *
CBGr	564.22 ± 1.13	237.69 ± 1.51*	11.57 ± 0.05	21.97 ± 0.02*	5.48 ± 0.04	7.17 ± 0.05*	6.91 ± 0.04	9.45 ± 0.04*	2.52 ± 0.04	3.42 ± 0.06*
GD	438.64 ± 1.51[a]	220.61 ± 1.57[a]*	8.21 ± 0.05[a]	11.05 ± 0.04[a]*	5.19 ± 0.03[a]	6.65 ± 0.04[a]*	4.82 ± 0.03[a]	7.84 ± 0.03[a]*	2.21 ± 0.03[a]	3.02 ± 0.04[a]
GWBr	572.62 ± 1.07	240.53 ± 1.64*	12.32 ± 0.04	25.87 ± 0.02*	6.10 ± 0.04	7.26 ± 0.04*	5.70 ± 0.04	8.58 ± 0.02*	2.29 ± 0.03	3.41 ± 0.04 *
GWRr	576.17 ± 1.02	232.86 ± 1.61*	12.25 ± 0.02	25.49 ± 0.03*	6.01 ± 0.03	7.08 ± 0.05*	5.84 ± 0.03	8.71 ± 0.05*	2.52 ± 0.04	3.54 ± 0.02*
GWGr	549.19 ± 1.04	221.74 ± 1.72*	12.48 ± 0.03	26.21 ± 0.09*	5.24 ± 0.04	9.61 ± 0.03*	5.76 ± 0.03	8.62 ± 0.03*	2.43 ± 0.04	3.42 ± 0.03*
GBBr	566.82 ± 1.43	242.57 ± 1.41*	11.67 ± 0.05	23.21 ± 0.01*	5.70 ± 0.02	7.41 ± 0.05*	6.21 ± 0.05	9.30 ± 0.04*	2.66 ± 0.02	3.75 ± 0.03*
GBRr	554.32 ± 1.61	238.51 ± 1.42*	11.89 ± 0.04	23.48 ± 0.02*	5.98 ± 0.02	7.87 ± 0.06*	6.32 ± 0.05	9.09 ± 0.06*	2.64 ± 0.02	3.89 ± 0.04*
GBGr	542.64 ± 1.51	231.69 ± 1.79*	12.42 ± 0.04	25.14 ± 0.02*	5.52 ± 0.04	7.34 ± 0.04*	6.50 ± 0.04	9.18 ± 0.04*	2.80 ± 0.03	3.68 ± 0.02*

All units in g/kg, *IM* initial feed mixture, *FV* final vermicompost, *TOC* total organic carbon, *TKN* total Kjeldahl nitrogen, *TK* total potassium, *TAP* total available phosphorous, *TCa* total calcium. Each value is the mean ± SE of six replicates. [a]Two-way ANOVA for significant combinations difference ($P < 0.05$) in each mean value of chemical parameter in the column from the treated combinations. [*]Statistically significant ($P < 0.05$) difference of the chemical parameter of final vermicompost from the initial feed mixture.

effective and efficient culture media for the large-scale production of *E. fetida*. The healthy and large number of earthworms will be the best converters of organic wastes into a potent biofertilizer. This work is important not only to the small farmers but also to the large-scale farmers in informing them on the production of large amount and potent vermicompost for agricultural crops and enhancement of the epigeic earthworm population during the management of agricultural-organic wastes.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
The KS is the corresponding author. HKC is main author, who performed laboratory task and drafted the manuscript. HKC also designed the experiment under the supervision of KS. KS participated in the correction of manuscript. Both authors read and approved the final manuscript.

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