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High Rate Vermicomposting of Coral Vine by Employing Three Epigeic Earthworm Species

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ABSTRACT

Use of the high-rate vermicomposting system and its relevant technology were successfully applied to accomplish direct vermicomposting of coral vine leaves - devoid of any pre-treatment/composting or amended with cow dung as earlier proclaimed protocols for the vermicomposting of various phytomass had necessitated. Three earthworm species tested were *Eisenia fetida, Eudrilus eugeniae* and *Perionyx excavatus,* and they had shown efficient vermicast recovery with few instances of mortality and good reproduction over the 150-day experiment. In this duration, all vermireactors were run in semi-continuous mode at the solid retention time of 15 days. This process enabled us to improve process efficacy of the reactor by the required pointers and systematic process monitoring. This paper substantiates the potential of the high-rate vermicomposting system in direct and potential vermicomposting of coral vine without any pre-treatment/composting or cow dung amendments. The observations have significance for enhancing process economics and therefore, process utility.

INTRODUCTION

Thermophilic composting technology has been progressively popular for large-scale disposal and utilization of different types of organic wastes, in response to the enormous amounts of organic wastes being generated every day. However, this technology does not always guarantee the high-quality products that have the potential for reclamation of soil and plants' growth, eventually, it leads to the loss of economic viability. Over the past three decades, interest towards mesophilic composting by employing earthworm to utilize degradable organic wastes into useful value-added end-product has been dramatically increased. Vermicomposting is an aerobic process in which earthworms are involved in turning waste to ensure proper stabilization, and aerobic condition thereby, lessening the need for expensive engineering to accomplish these objectives. However, the study on the efficiency of earthworms in degrading organic materials into vermicompost has been in the increasing trend, and exploration in more depth on commercial ventures is in progress (Edwards et al. 2011). The vermicompost, an end-product of the vermicomposting process, is a toxic-free material with excellent structure and stability. Thereby, it has been used as a fertilizer for plant growth hence, its economic value (Hemalatha 2013). Moreover, vermicomposts are believed to contain enzymes, hormones, and it has good porosity, bulk density, and water-holding capacity, providing an appropriate nutrient balance and improves its availability to the soil, and hence better plants' growth (Edwards & Burrows 1988, Edwards & Arancon 2004).

Conventional Versus High-rate Vermicomposting

Traditional vermicomposting, whether it is down with 'low-technology' windrow-based systems or with mechanized container-based systems (Edwards et al. 2011), is a slow process that takes 3-4 months for a given quantity of feed to be converted into vermicast. This aspect has so far governed the economics as well as the range of application of vermicomposting technology, by-and-large affecting it unfavourably. In an attempt to break free from this constraint, the hypothesis of the high-rate vermicomposting system has been employed. This led to a design process that can translate the concept into practice (Tauseef et al. 2013, Gajalakshmi et al. 2002, SankarGanesh et al. 2009). The essence of the idea is in the following attributes:

(i) The low-aspect-ratio helps earthworm feeding as well as cast deposition. Moreover, it enables harvesting of vermicompost much easier.

(ii) The low-substrate-column-height enables it to keep evenness in the moisture all over the reactor depth. Nutrient wash off is prevented because there is little scope for water collecting at the bottom and what does get collected is re-sprayed.

(iii) The sand-gravel as vermibed, which lodges in over 25% space in almost all traditional vermireactors, is replaced by wet jute cloth, which maximizes the available space of reactor, proportionately cutting down the system cost.

(iv) Earthworm numbers were increased to achieve the sustainable population growth of earthworms for a given feed. Besides, the high-density earthworm: feed ratio helps to mix causing aeration of the feed due to copious earthworm movement.

Since earthworms' metabolism relies on carbon to the maximum extent, it sequesters nearly all the carbon from the substrate as an attractive feature in one among the various merits of vermicomposting option (Banupriya et al. 2014).

The use of weed phytomass as feedstock in vermicomposting is due to the reasons like the high productivity, low input requirements, and invasive characteristics (Barney et al. 2008). However, there is no commercial facility available so far, which processes phytomass based organic wastes, such as weeds, leaf litter, or crop waste, directly into vermicompost (Tauseef et al. 2013). In this paper, we report on the attempts to generate organic fertilizer from the coral vine by employing earthworms *E. fetida*, *E. eugeniae*, and *P. excavatus*. In our earlier attempts, we have successfully achieved the sustainable, direct, and rapid vermicomposting of coral vine over the period of 150-day duration. Whereas, all the past efforts in vermicomposting different phytomass have relied on blending the plant-biomass with 30 % or more of cow dung, often with pre-composting (Rajiv et al. 2013, Vasanthi et al. 2013, Ansari & Rajpersaud 2012, Chauhan & Joshi 2010). However, we have succeeded in achieving direct and efficient vermicomposting of coral vine. Moreover, the economic and environmental obstacles to using animal manure lies on two different lines: Unlike waste biomass, cow dung is not available free of cost due to its numerous competitive applications already in existence (Abbasi et al. 2014). Collection and transport of cow dung are among the operations, which led to the emissions of CO_2, CH_4, and N_2O (Abbasi et al. 2014).

In the present study, the quantity of substrate was strengthened to the extent of four kg dry weight equivalent, to evaluate the process efficiency of vermireactors in vermicomposting of coral vine. The basic factor that controls vermireactor efficiency is the extent to which earthworms can feed upon a substrate per unit time. If vermireactors are operated such that much greater quantities of the substrates are available in the reactors than the capacity of earthworms to feed, it can be possible to know the limits of consumption. By this approach, it can also be seen whether the extent of feeding varies with the substrate or the earthworms eventually adapt to all feeds equally. With three different epigeic species of earthworm in semi-continuously operated vermireactors, the reactor operation was carried out for a 150-day duration.

MATERIALS AND METHODS

Vermireactors which are fabricated with rectangular containers made of the aluminium sheet, of length 152 cm, breadth 61.5 cm, and depth 9.7 cm, and effective volume 74.9 litres were employed. The reactors were lined with a 2 mm thick plastic sheet. The bottom of each reactor was covered with a 1 cm layer of jute cloth; as it is made of cellulose, it absorbs water quickly, facilities to breathe easily, retain moisture, and caters a favourable condition so as the earthworms can survive and function properly. The reactor was added with 15.4 kg of fresh coral vine leaves. The dry weight of the feed, achieved by oven drying to constant weight at 105 °C, was 4 kg. To each reactor, 1500 individuals of *E. fetida, E. eugeniae,* and *P. excavatus* were added. These were healthy, adult earthworms, which had been cultured in cow manure, and were picked randomly from a large population. The reactors were maintained under same favourable conditions during which daytime temperatures were 32 ± 3°C and night temperatures 29 ± 2°C. The relative humidity varied in the range 55-70%. The reactor feed was always maintained at 70 ± 10% moisture content. There was never any excess water collecting at the reactor bottom that would have needed draining. The reactors were run in semi-continuous mode, fresh weight of substrate was added with an equivalent to the dry weight of vermicast harvested. Since the reactor content was greater in an amount to handle at a single time, the grid method of harvesting was carried out throughout the experiment. A thread was used to mark the line to divide reactor into eight equal grids but was not done physically. Once every 15 days, the two grids were selected randomly to harvest vermicast. The vermicast recovered from two grids was estimated and used to calculate the whole reactor recovery in the manner of extrapolation. Moreover, this method of harvesting is easy and quick to handle, so the reactor content does not get disturbed. Equivalent quantities of fresh feed were introduced to restore the feed mass to its original level. A 3-mm mesh was used to sieve/refine castings to remove other particles. Having cocoons and juveniles not removed from the reactor the efficiency of the reactor concerning vermicast output would have been doubled and keep on increasing since those juveniles produced have started growing to become the adult to do so.

RESULTS AND DISCUSSION

The findings, encompassing five months of reactor operation in 15-day interval pulse-feed mode, are summarized in Table 1. The median/average values are given in the Table 1; the replicates agreed to within ± 10%, which may be considered adequately precise given the heterogeneity nature of the reactor feed. In the first 30 days of the reactor operation, the efficiency of vermicomposting was low. Then the rate started to increase consistently throughout the experimental period. The rate of earthworm reproduction, as reflected by the juveniles and cocoons that were generated, was also picked up after the initial lull. By the time about three months had elapsed, some of the juveniles began attaining adulthood; this was manifested in the form of appearance of a well-formed clitellum in them. As the number of adults increased from the end of the fourth month onwards, there was a dramatic rise in vermiconversion efficiency by the end of 150 days. It was sustained at that level until the completion of experiment exactly five months after the start. Overall, the vermicast output increased with respect to time in a linear fashion (Fig. 1).

The findings establish the fact that, even with the sole fresh leaves of coral vine plant, very rapid and sustained vermiconversion is achievable if the technology based on the approach of high-rate vermicomposting is employed

Table 1: Vermicast production in pre-pilot scale reactors with *E. fetida, E. eugeniae* and *P. excavatus* charged with coral vine as feed.

Days	*E. fetida*			*E. eugeniae*			*P. excavatus*		
	Vermicast production								
	(%)	Per day (g)	Per litre (g)	(%)	Per day (g)	Per litre(g)	(%)	Per day (g)	Per litre (g)
15	22.3	59.6	11.9	25.3	67.6	13.5	21.6	57.6	11.5
30	30.1	80.1	16.0	36.3	96.9	19.4	30.5	81.3	16.3
45	35.1	93.7	18.7	42.4	112.9	22.6	36.6	97.6	19.5
60	42.5	113.4	22.7	48.7	129.9	26.0	44.4	118.4	23.7
75	46.2	123.3	24.7	54.1	144.3	28.9	50.1	133.6	26.7
90	49.1	131.0	26.2	56.8	151.3	30.3	52.8	140.8	28.2
105	53.5	142.7	28.5	60.2	160.5	32.1	48.6	129.6	25.9
120	55.2	147.3	29.5	65.0	173.2	34.6	54.3	144.8	29.0
135	58.0	154.8	31.0	67.2	179.1	35.8	49.3	131.5	26.3
150	60.7	161.8	32.4	68.8	183.4	36.7	52.0	138.7	27.7
Average	50.1±8.5	133.5	26.7	57.9±9.3	154.3	30.0	48.5±5.7	129.4	25.9

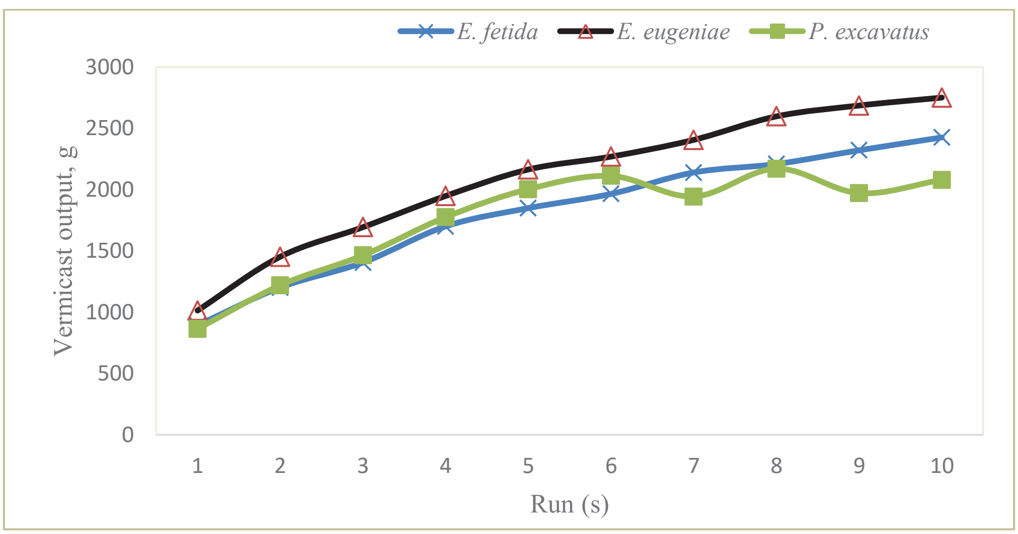

Fig. 1: Vermicast recovery (g), in pre-pilot scale reactors with *E. fetida*, *E. eugeniae*, *P. excavatus* charged with coral vine as feed.

for the purpose. The earthworms have demonstrated high reproductive rate, which has led to a linear rise in vermicast output. The pulse-fed operation eventually led to near quantitative vermiconversion of coral vine-fed vermireactors at an SRT of a mere 30, 26, 31 days from the average vermicast production of *E. fetida, E. eugeniae* and *P. excavatus* respectively, which is many times quicker than the rate achievable in conventional systems. Moreover, the latter need much higher (50% or greater) supplementation of cow dung, and other preconditioning methods. Had the juveniles produced during the experimental period—168 by *E. fetida*, 181 by *P. excavatus* and 225 by *E. eugeniae* —not been removed, the vermiconversion rate is set to be increasing consistently in every run (Table 2). It is expected that as the juveniles approach adulthood, they would begin consuming the substantial quantity of feed, thereby pushing the vermicast recovery above the plateau, which may continue until the death of the 'parent' worms that may cause a temporary lowering of production.

In fact, in view of the fast rate juvenile production, which has an average of 11, 15 and 12 earthworms per day in reactors with *E. fetida*, *E. eugeniae* and *P. excavatus*, respectively (Table 2), the feed utilization rate is probably to have been close to 100 % at the solid retention time of 28-day had the offspring been put back in the reactor. There was mortality in all the reactors, which might be due to the ageing of earthworm species. There was no significant difference, $F(2, 27)=1.287$, $P=0.293$, observed between any reactors in vermicast production. The statistical method was used to confirm this observation. One-way ANOVA was conducted to examine the significance difference between different earthworm species in vermicast production.

SUMMARY AND CONCLUSIONS

Coral vine, as a sole feed is vermicomposted by employing three epigeic species of earthworm, *E. fetida*, *E. eugeniae* and *P. excavatus*, without any pre-conditioning of feed, over a five-month span. All the three earthworm species consistently generated vermicast: *E. eugeniae* produced higher vermicast than *E. fetida* and *P. excavatus*. The average vermicast production, based on steady-state conversion from 45th day onwards, per animal per day, was 50.1 %, 57.9 % and 48.5 % with *E. fetida*, *E. eugeniae*, and *P. excavatus* respectively. All the species of earthworms reproduced successfully in the reactors. The number of juveniles produced was 168, 225 and 181; in the case of cocoons, it was 454, 500 and 591. Notwithstanding the morality in all the reactors, the vermiconversion rate was incessantly increasing in each run as the juveniles, and cocoons were not removed from the reactors. This study also describes the efficiency of vermireactors operated in the semi-continuous mode. This has enabled to demonstrate the fact that use of the high-rate vermicomposting system and relevant technology ensure the efficient and sustainable vermicomposting of coral vine leaves.

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Table 2: Reproduction and mortality, in pre-pilot scale reactors with *E. fetida, E. eugeniae* and *P. excavatus* charged with coral vine as feed.

Days	*E. fetida*			*E. eugeniae*			*P. excavatus*		
	Mortality	Juvenile	Cocoon	Mortality	Juvenile	Cocoon	Mortality	Juvenile	Cocoon
15	3	0	15	0	0	16	15	0	12
30	0	22	31	0	34	26	3	5	32
45	0	6	54	0	15	53	0	28	63
60	0	25	35	0	32	43	0	14	38
75	0	14	64	0	14	71	11	26	79
90	1	23	30	1	31	39	0	15	43
105	1	8	69	2	16	74	8	32	88
120	3	32	39	0	27	36	0	29	80
135	4	12	43	4	18	78	3	7	67
150	1	26	74	2	38	64	0	25	89
Total	13	168	454	9	225	500	40	181	591

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