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BIOREMEDIATION OF TEMPLE WASTES (NIRMALAYA) BY EMPLOYING *EUDRILUS EUGENIAE*

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ABSTRACT

In India, million tons of temple waste (nirmalya) is produced every day. The waste collected from temple mainly consists of flowers, leaves, fruits, honey, coconuts, camphor, jaggery, milk etc. which is released in the water bodies or dumped at the available land spaces, thereby leading to severe environmental pollution and health hazards. Bioremediation of nirmalya can be carried out by vermicomposting. In the present study a successful attempt was made to convert temple waste into vermicompost. The temple waste was mixed with cow dung in two different proportions (1:1 and 2:1) to make it suitable for culture of selected earthworm, *Eudrilus eugeniae* and detailed experiments were conducted in plastic containers. In our work the nirmalya was taken from a temple in South Tenkasi, which was pre-composted at 26°C and used as a substrate for vermicomposting by earthworm species *Eudrilus eugeniae* for 60 days. The chemical analysis of the vermicompost showed its pH (7.26), the organic carbon content (14.51%), N (57.6%), total P (47.8%), K (1.24%), C: N ratio (11.65) and also contained sufficient concentration of macro elements like calcium, magnesium and sulphur. The cocoon production and growth rate (biomass gain worm $^{-1}$ day $^{-1}$) were maximum in T_1 mixture containing temple waste and cowdung in (1:1) ratio followed by T_2 and T_O respectively. Results of the study are highly encouraging and is concluded that the temple waste can be managed, through vermicomposting in an eco-friendly manner by mixing equal ratio of cow dung.

KEY WORDS : *Eudrilus eugeniae*, Temple waste, Vermicomposting, Physico-chemical analysis of vermicompost, Worm growth and fecundity study.

INTRODUCTION

Deterioration of environmental quality, climate change, disposal and management of waste and sustainable development are the major issues to human society. One of the major causes of environmental pollution is mis-management of organic waste including temple waste. The waste management system followed in near Courtallam temple is a traditional method of dumping the waste in landfills and water bodies. The solid waste dumps/dump sites are known to generate global warming gases like methane and nitrous oxide besides polluting the water table through the percolation of its leachate into the soil / groundwater. Improper decomposition of such organic wastes that finally end up in water bodies emit a foul odour, affecting aquatic life and pose environmental and public health risks (Singh *et al.*, 2011).

Flowers come as waste from various sources like hotels, marriages, gardens, temples, churches, *Dargah* and various other cultural and religious ceremonies. In India, religion is a path of life. It is an intrinsic element of the entire Indian culture. People worship God and are accustomed to go to the temples offering flowers, fruits, coconuts and sweets, *etc.* The bulk of the flowers, leaves of

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different plants, coconut shells, milk and curd are piled up and then disposed off exclusively in water bodies (Singh and Singh, 2007). Every day, these flowers are offered by devotees in temples and are left unused and therefore become waste. India is a country of festivals and many occasions are celebrated round the year that eventually leads to generation of solid waste. This proportion of waste is generally neglected and requires due consideration. Because of our religious beliefs, many of us avoid throwing flowers and other items that are used for prayers in the garbage, and instead put them in the plastic bags and throw them directly in the water bodies. Apart from this; flowers are also kept under the sacred trees and thus there is no suitable mode of disposal. For instance, Banaras, one of the holiest cities of the country, has no policy for disposal of the tonnes of waste that comes from its many temples. Each day waste material weighing 3.5 - 4 tonnes is left behind in the city of temples (Mishra, 2013).

Degradation of floral waste is a very slow process as compared to kitchen waste degradation (Jadhav *et al.*, 2013). Therefore, there is a need for proper and ecofriendly process of floral waste treatment. Management and utilization of flower waste has been carried out in some studies. One such example is the Kashi Vishwanath temple which draws maximum devotees all round the year, especially in the month of *Shravan*. It has its own system for disposal of hundreds of kilograms of waste resulting from offerings by devotees; the floral waste generated in the temple is converted into manure (Mishra, 2013).

Present investigation is an attempt to utilize temple waste for vermicomposting by using earthworm species *Eudrilus eugeniae*. It was found that vermicompost obtained by temple waste was rich in carbon, Nitrogen, Phosphorus and Potassium content. Thus, Vermicomposting of temple waste is an excellent and ecofriendly method of temple waste management**.** In the present work nirmalya (temple waste) was used as a substrate for vermicomposting and the worm growth and fecundity of *E .eugeniae* were observed along with the chemical analysis of vermicompost.

MATERIALS AND METHODS

Cow dung

Urine free cow dung (CD) was collected from the local areas in quantities enough for the experiment, were sun dried and powdered.

Earthworm cultures

Earthworms belong to phylum- Annelida, subclass- Oligochaeta. In this study the well known epigeic species of earthworm *Eudrilus eugeniae* was obtained from a vermicomposting unit of Sri Parasakthi College for Women, Courtallam. The stock culture of the earthworm was maintained in plastic containers using partially decomposed biowaste and cow dung as growth medium in laboratory condition for further use in the vermicomposting experiment. Vasanthi *et al*., (2013b) reported that *E. eugeniae* is a fast-growing and productive earthworm in animal waste that is ideally suited as a source of animal feed protein as well as for rapid organic waste conversion.

Collection of substrate

Garlands, and other flower types, were collected from various temple waste bins. The collected materials were segregated and the flowers were washed and dried in a hot air dryer at 50 °C.

Addition of nirmalya

After collection of flower waste from temples non-biodegradable part was removed by hand sorting and the biodegradable waste i.e garlands and flowers were segregated and shredded into small pieces. The segregated floral waste was air dried by spreading over paper for 48 hours. Initially three kg of freshly collected and finely chopped and dried nirmalya pieces were added into the kit. Smaller size of the feed is favourable to worms growth and also provides more surface area per volume, which facilitates microbial activities as well as moisture availability. The physico-chemical characteristics of CD and temple wastes are given in Table 2.

Experimental setup

Temple waste (nirmalya) and cow dung was used as substrate for the pre-decomposition studies. Pre-decomposition of the temple waste was done in plastic containers. Three treatments were established having feed mixture containing CD alone and others mixed with Temple waste in two different proportions (1:1 and 2:1) in plastic containers (Table 1). Each treatment was established in triplicate. For mesophilic aerobic digestion, turning was done manually every 4 days and the temperature was not allowed to exceed 26 °C by maintaining the moisture by adding water when necessary. The mixtures were left undisturbed for about 15 days in order to semi – compost the feed so that it becomes palatable to worms. After 15 days, 25 unclitellated *Eudrilus eugeniae* were introduced in each vermicomposting treatment. All the treatments were kept in dark at room temperature. The moisture content was maintained at 60 – 70% during the experiment . The zero days refers to the day of inoculation of earthworms after the pre – composting period of 15 days.

Physico – chemical analysis of vermicompost

About 110 g of homogenized samples (free from earthworms, hatchlings and cocoons) were drawn at 0 (initial day) and after 60 days (at the end of experiment). Each samples were air dried, ground to pass to 0.2-mm sieve and stored for further analysis. The samples was analyzed for the following parameters: pH and electrical conductivity (EC) (1:10 w/v waste: water extract), Total nitrogen (TN) using Kjeldahl method, ammonical nitrogen (NH_4–N) and nitrate nitrogen (NO_3–N) using KCL extraction, total organic carbon (TOC) determined by Shimadzu solid sample module (SSM- 5000A), total phosphorus (TP) by acid digestion using stannous chloride method (APHA, 1998), potassium (K), calcium (Ca) and Magnesium (Mg) by acid digestion using flame photometer APHA, (1998). In addition earthworm growth related parameters like earthworm biomass; and fecundity were measured at the end of the vermicomposting process. All the samples were analyzed in triplicate and results were averaged.

Worm growth and Fecundity

Biomass gain, clitellum development and cocoon production by worms in each treatment were recorded periodically for 60 day. The feed in the container was turned out, then earthworms and cocoons were separated from the feed by hand sorting, after which they were counted and weighed after washing with water. Then all the earthworms were returned to their respective container. The earthworms were weighed with full gut. At the end of the experiment, earthworms and cocoons were separated and the final vermicompost from each treatment was air – dried at room temperature and packed in airtight plastic containers for further physico – chemical analysis.

Statistical analysis

The probability levels used for statistical significance were $p< 0.05$ for the tests. All the results reported in the text are the mean of three replicates.

RESULTS AND DISCUSSION

Physico-Chemical changes in quality of vermicompost

The end product (i.e. vermicompost) significantly differs from the initial feed mixtures in pH , EC,TOC and macronutrients composition. There was a decrease in pH in all the feed mixtures during vermicomposting (Table 2).

In our work the pH value of vermicompost was found to be 7.26. These results are in agreement with the results of Aruna *et al.,* (2016) and Kohli and Hussain (2016) who reported that pH of floral vermicompost was 7.2 and 7.53 respectively. Makhania and Upadhyay (2015) also reported that the pH of the vermicompost from nirmalaya or temple solid waste varies between 7.9 to 8.48 which are slightly higher than our studies. The decrease in pH may be due to mineralization of nitrogen and phosphorus into nitrites / nitrates and orthophosphates and bio-conversion of the organic material into intermediate species of organic acids (Ndegwa and Thompson, 2000). However , pH shift during vermicomposting is dynamic and substrates specific as different substrates make different intermediate species of the organic acids (Gupta and Garg, 2008).

There was a significant increase in Electrical Conductivity (EC) values as compared to the initial level of all the treatments, (Table 2). EC reflects the salinity of an organic amendment. The EC of vermicomposts ranged from 2.46 ± 0.03 (T_1) to 0.96± 0.04 (T_0). The difference in EC value in vermicompost and control was found statistically

Table 1. The Composition of Cow dung (CD) and temple wastes in different treatments

Treatment No	Description	CD[kg]	Temple waste[kg]
T_0	CD (100%)	1	-
T_1	CD + Temple waste (1:1)	1	1
T_2	CD + Temple waste (2:1)	2	1

significant (P<0.05). (Yadav and Garg, 2011) have emphasized that higher EC in vermicompost may be due to the presence of more soluble salts in final products after earthworm activities.

Total Organic Carbon (TOC) was lower in all the treatments by the end of vermicomposting. TOC loss was observed highest in treatment T_1 and lowest in control T_0. A large fraction of TOC was lost in all the treatments by the end of experiment. Elvira *et al.* (1998) have reported that 20 – 43% fraction of organic matter present in the initial feed substrates is lost as CO_2 during vermicomposting. The value of TOC obtained from T_1 was 14.51% which is significantly different from other treatments (P < 0.05). The incorporation of floral waste vermicompost has been shown to increase organic carbon content in the soil (Nelson and Sommers, 1982).

Macronutrients composition (N, P, K, Ca, Mg and S)

The macronutrients composition of the initial feed mixture TW + CD and vermicompost are presented in (Table 2). All the macronutrients were significantly enriched in vermicompost sample than the initial feed mixture. The composition of the macronutrients were found significantly higher in vermicompost sample (P < 0.05). There was 57.6% increase in TN content in the end products than the initial level of the TW + CD mixture after 60 days of vermicomposting process. Many factors such as N status of the feed mixture; excretory products, mucus, body fluid, enzyme and even decaying tissue of the death earthworms are associated with the higher level of N in vermicompost (Vasanthi *et al*., (2013a). Soluble Phosphorus of vermicompost value varies from 0.9-1.02% (Kohli and Hussain, (2016). The concentration of soluble phosphorous was found to be 47.8% in the vermicompost in the current study and 13.2% in the control. The present findings corroborate the results of the earlier workers (Fernandez – Gomez *et al*., 2010) which reports upto 97.9% increase in available P due to mineralization of phosphorus in biowaste materials. Similar result was also reported from vermicompost obtained from grass waste where phosphorous level was 0.2-0.6% (Ansari and Rajpersaud, 2012).

Table 2. Comparison of physico-chemical characteristics of initial mixtures and vermicomposts obtained from different treatments (Mean ± SD, n = 3)

Parameters	Control (T_0)		T_1		T_2	
	Initial (0 day)	Final (60th day)	Initial (0 day)	Final (60th day)	Initial (0 day)	Final (60th day)
P^H	7.35±0.01	7.31±0.02	7.64±0.02	7.26±0.01	7.53±0.02	7.28±0.02
Electrical conductivity (mS cm^{-1})	0.73 ± 0.09*	0.96± 0.04	0.83 ± 0.09*	2.46 ± 0.03	0.81 ± 0.06	1.73 ± 0.05
TOC %	33.72± 0.09*	31.89±0.03	39.71±0.08*	27.26 ± 0.01	37.00± 0.08*	29.21±0.02
TN %	0.89±0.03	0.99 ± 0.01	1.47±0.02	2.34± 0.01	1.49 ± 0.03	1.84 ± 0.01
TP %	0.46 ± 0.09*	0.61 ± 0.03	0.69 ± 0.01	2.20 ± 0.03	0.59 ± 0.01	1.84±0.01
TK %	1.12 ± 0.07*	1.29 ± 0.03	1.60 ± 0.03	2.84 ± 0.02	1.64±0.01	2.32±0.02
Calcium %	1.20 ± 0.03	1.46 ± 0.01	1.41 ± 0.03	3.20 ± 0.01	1.26 ± 0.01	2.79 ± 0.04
Magnesium %	0.64 ± 0.09*	0.82 ± 0.05	0.66 ± 0.06*	2.76±0.03	0.74 ± 0.09*	2.15±0.03
Sulphur %	0.11 ± 0.06*	0.24 ± 0.05	0.18 ± 0.01	1.23 ± 0.01	0.19 ± 0.09*	0.93 ± 0.02
C/N ratio	37.89± 0.06*	32.21± 0.04	27.01± 0.04	11.65± 0.01	24.83± 0.03	15.87± 0.02

* non-significant
Mean values are statistically significant (P< 0.05)

Table 3. Growth of *Eudrilus eugeniae* in different treatments (Mean ± SD, n = 3)

Treatments	Mean Initial biomass/ earthworm (mg)	Maximum biomass achieved/ worm (mg)	Maximum biomass achieved on	Net biomass gain/worm (mg)	Growth rate/ worm/day/ (mg)
T_0	134±0.09	318±0.07	6th week	184±0.05	4.30±0.07^{NS}
T_1	137±0.07	918±0.03	5th week	781±0.02	22.31±0.02*
T_2	135±0.05	820±0.02	5th week	685±0.04	19.57±0.03*

Mean values are statistically significant (P< 0.05); ^{NS}- Not significant;*-Significant

Vermicomposting resulted in significant increase in TN in different treatments. The final TN content in vermicompost is dependent on the initial nitrogen present in the feed material and the degree of decomposition (Crawford, 1983). Furthermore, losses in organic carbon, decreases in pH (Yadav and Garg, 2011) mineralization of the organic matter containing proteins and conversation of ammonium nitrogen into nitrate (Atiyeh *et al*., 2000) may be responsible for nitrogen addition in vermicompost. There was increase in total potassium (TK) level in T_1 although the control T_0 did not show any significant changes over the initial value of the mixture (Table 2). The concentration of the total potassium (TK) greatly increased in treatment T_1 as compared to control in our studies. The TK content of the vermicompost in the present study was found to be 1.24% which is in accordance with the results of (Narkhede *et al*., 2011) and (Ansari and Rajpersaud, 2012) who reported the TK level 1.4% and 3% respectively. However, TK in vermicompost prepared from temple waste was reported to be 0.28% (Gurav and Pathade, 2011). The change in the distribution of potassium between exchangeable and non exchangeable forms may lead to an increase in the potassium content in the vermicompost. The earthworm processed waste material which contains high concentration of exchangeable potassium, due to enhanced microbial activity during the vermicomposting process consequently enhances the rate of mineralization (Achsah and Prabha, 2013).

The total Ca and Mg increased by 40.86% and 21.15% in T_1 treatment respectively after vermicomposting of TW+CD mixtures. Senthilkumari *et al*., (2013) have stated that the activity of earthworm's drives the mineralization process efficiently and transforms a large proportion of Ca and Mg from bind to free form which results in increased Ca and Mg level in the final product. Similarly there is considerable increase in the level of sulphur (S) in vermicompost T_1 prepared using temple waste when compared to control. As a whole, the overall increase in total nutrient contents in the vermicompost as revealed from the present study is mainly due to the earthworms that reduce the waste mass thereby enhancing the organic matter mineralization rate (Fernandez-Gomez *et al*., 2010). Furthermore, it can also be hypothesized that the concentration of the elements like K, Ca , Mg and S may be enhanced in the end product due to dead and decomposition of the old earthworms although a planned experiment is still needed to prove this hypothesis.

C/N ratio

The results of the present findings clearly show that there was significant decrease in the C/N value at the end of the vermicomposting process. The C:N ratio of vermicompost in the current studies was found to be 11.65 in T_1 as compared to 32.21 in T_0 from the initial level of the TW + CD mixture. These results are in accordance with the results of Mistry *et al*., (2015). Similar results of C: N ratio 15.54 and 16.03 in the vermicompost obtained from vegetable wastes are present (Kapoor *et al*., 2015). Vermicompost obtained from flower waste has C: N ratio 12.3 (Kohli and Hussain, 2016). C: N ratio is one of the most widely used indicators of vermicompost maturation, which declines during the vermicomposting process (Kale, 1998; Gupta and Garg, 2008). The C/N ratio below 20 is indicative of an advanced degree of stabilization and acceptable maturity, while a ratio of 15 or less being preferable for agronomic use of compost (Morais and Queda, 2003). Likewise , in the present study the vermicompost sample was found to meet this requirement thereby indicating high degree of organic matter stabilization and agronomic potentiality.

Earthworm population and biomass

Table 3 Summarizes the weight gain biomass of

Table 4. Fertility of *E. eugeniae* in different treatments (Mean ± SD, n = 3)

Treatment No	Clitellum development started in (week)	Cocoon production started in (week)	Total no of cocoons after 60 days	Reproduction rate (cocoons/ worm)	No of cocoons produced/ earthworm/ day	Total No of hatchlings
T_0	4th	6th	210 ± 1.01	8.4 ± 0.60	0.14 ± 0.08^{NS}	189 ± 0.07
T_1	3rd	5th	970 ± 0.05	38.8±0.02	0.64 ± 0.04*	1084 ± 0.01
T_2	3rd	5th	780 ±0.03	31.2±0.04	0.52 ± 0.01*	810 ± 0.03

Mean values are statistically significant (P< 0.05); ^{NS}- Not significant;*-Significant

E.eugeniae in temple wastes mixed with cowdung in different ratios 1:1 and 2:1. Maximum weight gain was observed in T_1 followed by T_2 and T_0. From the study, the maximum biomass gain was recorded in T_1 (918±0.03mg/worm) followed by T_2 (820±0.02 mg/worm) treatments. Similarly, the maximum growth rate was achieved in T_1 (22.31±0.02 mg/ worm/day) and T_2 (19.57±0.03mg/worm/day) than the control. There was no statistical significant difference among T_1 and T_2 treatments for biomass gained per worm ($P < 0.05$). The growth rate has been considered as a good comparative index to compare the growth of earthworms in different feeds (Edwards *et al.*, 1998). Growth and reproduction in earthworms require OC, N and P which are obtained from litter, grit and microbes (Edwards *et al*., 1985). Thus from the present study it is clear that *E.eugeniae* preferred treatment T_1 containing equal proportion of temple waste and cowdung (1:1) than the control containing cow dung alone which resulted in increased biomass of the worms throughout the study period with no mortality.

Sexual development and cocoon production

Data on the sexual development and cocoon production of *E. eugeniae* in different treatments with and without temple wastes are presented in (Table 4). The individuals developed clitellum in the feeds on the 3rd and 4th week after the onset of the experiment. The cocoon production started in the 5th week in treatment T_1 and T_2 and in 6th week in T_0. After vermicomposting maximum cocoons were counted in T_1 (970 ± 0.05) and T_2 (780 ±0.03) treatment than control. Similarly, the maximum number of hatchlings were produced in T_1 (1084 ± 0.01) and T2 (810 ± 0.03) treatment but the difference was not statistically significant. The difference between the rates of cocoons and hatchlings production in different treatments could be related to the nutrient quality of the feed mixtures, which is one of the important factors in determining the onset of cocoon production (Gupta *et al*., 2007). Edwards *et al* (1998) have also reported that the important difference among the rates of cocoon production in different organic wastes is related to the quality of the waste material used as feed. Thus in the present study treatment T_1 (1:1) containing equal proportion of temple waste and cow dung shows enhanced reproduction, cocoon production and hatchability rate revealing the suitability of the substrate supporting the growth and reproduction rate of *E.eugeniae*. The present study concludes that the utilization of temple wastes in the culture of earthworm could enhance the worm's reproductive potential and which in turn will produce a high amount of young ones and a greater quantity of vermicomposts, vermicast etc.

CONCLUSION

The present study was conducted to manage and utilize the temple waste generated by temples of South Tenkasi. The process of vermicomposting was carried out in different ratios of temple waste and cowdung like 1:1 and 2:1 for 60 days. Earthworm species *Eudrilus eugeniae* was used because of its adaptability to varied conditions. This sustainable waste technique can be implemented on a larger scale and this will eliminate their waste products which have adverse environmental impacts and would help to promote the concept of "Green Temples" through Zero Waste management. The temple waste would not only ease the burden on the environment that is caused by the volume of waste that they produce and the uninspiring methods of its disposal but would rather create value in terms of vermicompost, which enriches the soil, hence benefitting the environment.

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