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Bio-conversion of banana waste (Pseudostem and leaves) and mango leaf litter into vermicompost by *Eudrilus eugeniae* and *Eisenia foetida*

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Abstract
Recycling of organic wastes is a challenging problem in India. Vermitechnology can be effectively utilized to convert waste into valuable compost. Therefore, the bio-conversion of banana waste and mango leaf litter through vermicomposting by the two species of earthworm *i.e. Eudrilus eugeniae and Eisenia foetida* was undertaken at Krishibhavan, Elamkunnapuzha, Ernakulam District, Kerala. The composting duration, biomass and cocoon production of both species were studied in two substrates mixed with cow-dung in 60:40 with the different treatments- $T_{1:}$banana waste + cowdung + *E.eugeniae (25 Nos./kg of waste);*T_2 - Mango leaf litter + cowdung + *E eugeniae (25 Nos./kg of waste);* T_{3} - banana waste + cowdung + *E.foetida (25 Nos./kg of waste);* T_4 - Mango leaf litter + cowdung + *E foetida (25 Nos./kg of waste);* T_5 - banana waste + cowdung without worms and T_{6} - Mango leaf litter + cowdung without worms. The physical and chemical parameters, such as, pH, EC, C,N,P,K, Ca, Mg, Zn, Mn, Cu, Cd and Pb of the vermi-composts produced were also quantified. The data collected were subjected to analysis of variance and mean values were compared using Duncan's Multiple Range Test. Of the two substrates, banana waste was found to be a better substrate as compared to mango leaf litter in terms of time taken for composting, quantity of compost produced and per cent conversion. On the other hand, when progeny production of the earth worm species is considered, mango leaf litter was found to be a better substrate. The nutrient elements were higher in vermicomposts than in control treatments. The present study clearly suggests that *E. eugeniae* and *E. foetida* efficient species which can be effectively for recycling of banana and mango wastes and production of vermicompost.

Keywords: Banana wastes, *Eisenia foetid, Eudrilus eugeniae,* mango litter, vermicompost

Introduction
Banana is a very important horticultural crop of the state of Kerala and Tamil Nadu. India produces around 3000 million tons of organic wastes annually of which the banana wastes come, approximately to 0.5 million tonnes [1]. Tamil Nadu is the largest producer of bananas in the country cultivating around 9 million metric tonnes (MT) annually, but inefficient postharvest practices lead to massive waste every year. An average of 30% or 2.7 million MT of Tamil Nadu's bananas currently goes to waste largely due to the absence of integrated cold chain infrastructure. Banana cultivation produces a huge amount of waste: approximately 30 tonnes of waste is generated per acre in one crop season from banana stem alone. In addition to home stead farming especially in Kerala, the crop is cultivated commercially in large areas in the state. Abundant quantities of banana waste in the forms of leaves and pseudo-stems are available for composting. Similarly, mango (*Mangifera indica*) trees are long-lived and are also commonly cultivated in many parts of the country. The litter of the mango trees is another major organic waste are available.

Several methods have been developed to convert agro-waste into organic manure to replace chemical fertilizers. Of these methods, vermicompost is one of the better methods of converting organic waste into nutrient rich manure [2, 3]. Earthworms, with their diverse utilization in waste management, sustainable agriculture and fisheries, become promising soil-macro invertebrate species over the world. In recent years, many earthworm species have been identified as important organisms to process bio-degradable organic matters. An important feature of vermicompost is that during the processing of various organic wastes by earthworms, many of the nutrients that the wastes contain are changed to forms that are available to plants [4]. Application of vermi-compost to crop fields can improve the physical, chemical and biological properties of the soil [5].

The role of earthworm species in vermicomposting for organic agriculture have been well reported by many authors. Though there are about 4000 species of earthworms, only few species are used for composting world-wide. Among various earthworm species; *Eisenia foetida*, *Eisenia andrei*, *Eudrilus eugeniae* and *Perionyx excavatus* are reported as the most promising earthworm species used for vermicomposting [6].

Hence, it is important to understand the comparative efficiency of the two species of earthworms, *Eudrilus eugeniae* and *Eisenia foetida,* in bio-conversion of the two abundantly available substrates in the state, banana wastes (leaves and pseudo-stems) and mango leaf litter into vermicompost. The aim of the study to evaluate the efficiency of the two earthworm species *E. eugeniae* and *E. foetida* in bio-conversion of banana wastes and mango leaf litter into vermi-compost and to study the physical and nutrient status of composts produced from both the substrates by the two species.

Materials and Methods

This study was conducted at Krishibhavan, Elamkunnapuzha, Ernakulam District, Kerala during 2017-18 for 120 days. Fresh cow dung and organic waste (banana wastes and mango leaf litter) collected from Elamkunnapuzha village, Ernakulam District, Kerala, India. They were chopped and spread over in a clean terrain and allowed for 3 to 5 days. Simultaneously, cow dung was also dried and powdered. The banana wastes and the mango leaf litter were mixed separately with the dried and powdered cow dung in the ratio, 40:60 (40% cow dung and 60% organic wastes) cured for 30 days under shady place as suggested by Murali *et al.* (2011) [7] and water was sprinkled every day to maintain the moisture. The mixtures were covered with cotton cloths.

Vermicomposting was performed in plastic trays (45×15×30 cm size). The trays were first thoroughly cleaned with water and holes were kept at the bottom side for drainage purpose. The trays containing the mixture were kept in a shed to avoid direct sunlight, to prevent excess moisture loss and to protect the worms from attack of predators. Banana wastes and the mango leaf litter were used as a main substrate and cow dung waste was used as a waste material in different combinations for preparation of vermicompost as follows, $T_{1:}$ banana waste + cow dung +*E.eugeniae*, T_2 - Mango leaf litter +cow dung +*E eugeniae*, $T_{3\text{ -}}$ banana waste + cow dung +*E.foetida*, T_4 - Mango leaf litter +cow dung +*E foetida*, T_5 - banana waste + cow dung without worms, $T_{6\text{ -}}$ Mango leaf litter +cow dung without worms. The vermibeds were prepared by filling about three fourth of each tray as detailed in the treatments. All the above experiments were repeated in triplicate. After 15 days of the preparation of the experimental media in the trays, 25 clitellate *E. eugeniae and E. foetida* adult earthworms were inoculated into each of these trays separately according to treatments. The earthworm, *E. eugeniae* was procured from Welfare Society, Ponnurunni, Vytilla and *E. foetida* was collected from College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur. These trays were kept undisturbed in shade. Watering was done regularly twice in a day in order to maintain the temperature and moisture content of the medium during the entire composting period.

The vermicompost was collected, sieved, air dried and weighed separately from each tray at the end of the experiments. The vermicompost was then analysed to quantify its chemical nutrients composition. Further, in each tray the number of cocoons and young ones were counted and recorded. Various chemical parameters such as pH, EC (dsm^{-1}), Carbon%, Nitrogen%, Phosphorus%, Potassium%, Calcium (ppm), Magnesium (ppm), Zinc (ppm), Copper (ppm), Manganese (ppm), Cadmium (ppm) and Lead (ppm). Were analysed in the laboratory of Rice Research Station, Vytila, Ernakulam. The data were subjected to statistical analysis to derive useful inferences.

Results and Discussion

The mean values (Mean +/ - SE) on composting duration, quantity of compost produced and per cent conversion of the banana waste (pseudostem and leaves) and mango leaf litter by the earthworm species *viz.*, *E. eugeniae* and *E. foetida* are presented in Table 1. Banana waste was converted into vermicompost by the two species in lesser time (36.3 days and 36.6 days respectively) as compared to the mango leaf litter indicating that the former is a better substrate than the latter for the worms. With regard to mango leaf litter, *E. foetida* showed better efficiency (45.3 days) in conversion than *E. eugeniae* (48.6 days).

Table 1: Bioconversion of banana wastes and mango leaf litter by the two species *Eudrilus eugineae* and *Eisenia foetida*.

Treatments	Composting duration (days)	Compost harvested (Kg)	Bio-conversion of vermicompost (%)
T1- Banana waste + *E.eugeniae*	36.3 ± 1.33^c	4.4 ± 0.33^a	84.6 ±2.02
T2- Mango waste + *E.eugeniae*	48.6 ± 0.33^a	4.1 ± 0.09^b	84.0 ±2.08
T3- Banana waste + *E. foetida*	36.6 ± 0.88^c	4.3 ± 0.05^a	86.0 ±1.52
T4- Mango waste + *E. foetida*	45.3 ± 0.33^b	4.1 ± 0.1^b	82.6 ±1.2
T5 - banana waste + cow dung without worms	65 ± 0.43^d	2.6 ± 0.3^d	52 ± 2.33
T6 - Mango leaf litter +cow dung without worms	70 ± 0.39^d	2.3 ± 0.30^d	45 ± 2.73

Each value represents the mean of three replications (Mean ± S.E); Treatment followed by the same column with superscript letters are significantly different ($p \leq 0.05$) by Duncan test.

The quantities of vermicompost produced also showed the same trend. Both the species produced higher quantities from banana waste than from mango leaf litter when the same quantities of both the substrates (5 kilograms each) were provided initially. The highest per cent conversion into vermicompost was observed in banana waste by the species, *E. foetida*, whereas the lowest conversion was in mango leaf litter by the same species. The earth worm species *E eugeniae* showed almost the same percentage conversion of both the substrates. Singh *et al.* (2010) [8] also has reported that the processing time and quality of the end product vary according to the composition of the initial mixture being processed. In the present investigation, banana waste seems to be the better substrate in terms of composting duration, quantity produced and percent conversion.

The mean number of young ones and cocoons produced by the earthworms was found to be 336.3 ± 7.21 and 125.0 ±2.72 (T1); 420.0 ± 11.01 and 145.0 ±2.64 (T2); 343.6 ± 9.7 and 90.0 ±1.15 (T3); 429.0 ± 4.93 and 141.0 ± 1.52 (T4), respectively during the composting period (Table 2). The young ones and cocoons production by both the species of earth worms were found to be higher in the mango leaf litter as compared to those produced from banana waste. The results indicate that the substrate, mango leaf litter is a better medium for progeny production for both the species, in spite of the fact that banana waste was found to be the better choice in terms of duration of composting, quantity and conversion percentage by the two species. Edwards *et al*. (1998) [9] observed that the important difference between the rates of cocoon production in the organic wastes must be related to the quality of the waste material. Suthar (2005) [10] also stated that chemical nature of the feeding stock may be of primary importance in rearing earthworms on organic wastes. Hence, the difference in cocoon production in the investigation could be due to variation in quality of the substrates. Evans and Guild (1948) [11] observed that nitrogen rich diets help in rapid growth of earthworms and facilitate more cocoon production than those with little nitrogen available. The reason for this apparent anomaly may be that the tissues of mango leaf litter are harder as compared to banana waste and that the latter is more amenable to easy break down by the earth worms. It may also be due to the differences in the contents of materials including nutrients, in the substrates, required for progeny production. The contention that mango leaf litter is a better substrate for the two species for progeny production due to the nutritional superiority of the substrate is speculative in nature at the moment as there are no references to authenticate the inference.

Table 2: Number of juveniles and cocoons produced by the two species, *Eudrilus eugineae* and *Eisenia foetida* on the two substrates

Treatments	No. of Juveniles	No. of Cocoon
T1- Banana + *E. eugeniae*	336.3 ± 7.21^{b}	125.0 ± 2.72^{b}
T2- Mango + *E. eugeniae*	420.0 ± 11.01^{a}	145.0 ± 2.64^{a}
T3- Mango + *E. foetida*	429.0 ± 4.93^{a}	141.0 ± 1.52^{a}
T4- Banana + *E. foetida*	343.6 ± 9.7^{b}	90.0 ± 1.15^{c}

Each value represents the mean of three replications (Mean ± S.E); Treatment followed by the same column with superscript letters are significantly different ($p \leq 0.05$)

Chemical composition of vermicompost

The results of the chemical analysis of different vermicompost of manago and banana wastes are provided in Fig 1-5 & Table 3. The ANOVA results shows that the vermicompost differed significantly (P=0.05) in all the chemical parameters assessed. The vermicomposting activities of both species of earthworms increased the nutrient composition of the vermicompost as compared to non-treated wastes.

Table 3: Quantity of various chemical constituents of in different treatments

Parameter	T1	T2	T3	T4	T5	T6
pH	7.01	7.42	7.08	7.70	7.33	7.82
EC(Dsm)$^{-1}$	2.6	1.9	4.6	1.6	1.1	2.3
Carbon %	5.8	11	9.9	10.8	6.4	7.8
Nitrogen (%)	0.74	1.3	0.82	1.2	0.39	0.9
Phosphorus (%)	0.29	0.8	0.30	0.7	0.21	0.6
Pottasium (%)	0.56	0.53	0.54	0.57	0.30	0.29
Calcium (ppm)	4.42	5.96	7.29	7.38	1.24	2.28
Magnesium (ppm)	5.64	6.21	4.43	5.29	2.23	1.12
Cadmium (ppm)	0.062	0.099	0.084	0.0716	BDL *	0.0046
Lead (ppm)	0.0044	0.0032	0.0091	0.0048	0.0003	BDL *
Zinc (ppm)	0.169	0.293	0.385	0.252	0.093	0.086
Copper (ppm)	0.375	0.294	0.281	0.249	0.100	0.187
Manganese (ppm)	4.24	3.92	4.33	3.49	1.55	1.26

*Below detectable level
T1 Banana waste + *E. eugineae* T2 Mango leaf litter + *E. eugineae*
T3 Banana waste + *E. foetida* T4 Mango leaf litter + *E. foetida*
T5 Banana waste cow dung mixture T6 Mango leaf litter cow dung mixture

pH, electrical conductivity and carbon content

The pH values of all the treatments can be considered more or less on the alkaline side. The pH values of vermin composts varied from 7.01 (banana waste + *E.eudrilus*) to 7.70 (mango leaf litter + *E. foetida*). The composts from mango leaf litter by both the species had higher values (7.42 and 7.70) as compared to those from banana waste (7.01 and 7.08). The treatments without worms, banana waste + cow dung and mango leaf litter + cow dung, had pH values, 7.33 and 7.82. Similar results on vermicomposting of leaf litters, poultry waste and paddy straw have been reported by Selvamuthukumaran and Neelanarayanan (2012) and Viji and Neelanarayanan (2013) [12, 13]. The results of the present experiment indicate that the pH values of vermicomposts depend to a great extent on the substrate rather than on the species of earth worms. Decrease in pH may be owing to the mineralization of nitrogen and phosphorus into nitrites/nitrates and orthophosphates and transformation of organic waste into organic acids [14].

Values of Electrical conductivity (E C) showed variations between treatments. The EC value has increased in all the earthworm treated experiment than the untreated compost. The vermi-compost produced by *E. foetida* from banana waste showed the highest value of 4.6 dS/m and second highest value (2.6 dS/m) was in the vermi-compost produced by *E. eugeniae* from banana waste. The lowest EC value (1.1 dS/m**)** was recorded in the control treatment, banana waste and cow dung mixture. Irshad *et al.* (2013) [15] reported that higher EC values in composted manures could be attributed to the release of salts from the manure with the passage of time. The banana wastes and mango leaf litter were collected from the coastal region of the state and the soils in the coastal region contain high salt contents. This may be the reason for the high EC values in the samples.

Organic Carbon

The organic content among the different treatments differed significantly (P=0.05 (Fig.1). Higher organic carbon contents (11% and 10.8%) were recorded in composts from mango leaf litter produced by both the species. Slightly lesser percentage of organic carbon (5.8%) was recorded in compost from banana waste produced by *E. eugineae*. The control treatments, banana waste cow dung mixture and mango leaf litter cow dung mixture and the compost from banana waste by *E.eugeniae* had comparatively lower organic carbon contents (6.4%, 7.8% and 5.8% respectively). There are reports that continuous and adequate use of vermi-compost with proper management practices can increase soil organic carbon, soil water retention and improvement in other physical properties of soil like bulk density, penetration resistance and aggregation [16].

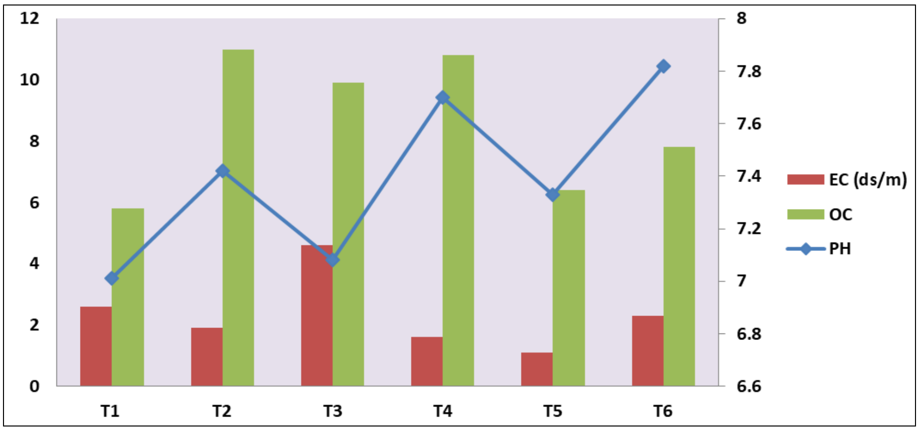

Fig 1: Effect of Banana and mango wastes on PH, EC, and Carbon concentration

Nitrogen

The N values of the vermicompost treated with two different species and wastes was significant (P=0.05). The N values of T2 (Mango leaf litter + *E. eugineae*) and T4 (Mango leaf litter + *E. foetida)* vermicomposts were higher than that of the T1 and T3 vermicomposts. The order of increase in N of the vermicompost were T2, T4, T6, T3, T1, T5 (Fig. 2). Overall assessment indicates that there is a variation in nitrogen content between the composts produced from the two substrates and the substrates without vermicomposting. The studies by Suthar (2007) [17] showed that the inoculation of worms in waste material considerably enhances the amount of N due to earthworm mediated nitrogen mineralization of wastes. It also suggested that the earthworm enhances the nitrogen levels of the substrate by adding their excretory products, mucus, body fluid, enzymes and even through the decaying tissues of dead worms in vermicomposting sub-system.

Phosphorus

The total phosphorus content was significantly higher in vermicompost than untreated waste composts (ANOVA: $p<0.05$). The available P was greatest in T2 (0.8%) and T4 (0.7%). While banana wastes the available P was 0.29% (T1) and 0.30% (T3) than the control 0.21% (T5) (Fig.2). The enhanced P level in vermicompost suggests phosphorous mineralization during vermi-composting process [18]. Acid production during organic matter decomposition by the microorganisms is a major mechanism for solubility of insoluble phosphorous also; the percentage of large number of micro flora in the gut of earthworms might play an important role in increasing P in the process of vermicomposting [19]. The present finding was agree with the reports of Kaushik and Garg, (2003), Suthar (2007) and Manna *et al.* (2003) [17, 20, 21] who demonstrated similar increase in total phosphorus of vermicomposted materials.

Potassium

Vermicomposts produced from the two substrates by the two species showed higher values of potassium contents in T1=0.56% and T4=0.579% as compared those in the control treatments (T5=0.300% and T6=0.293%). Some previous studies also indicated enhanced potassium content in vermi-compost [17, 21].

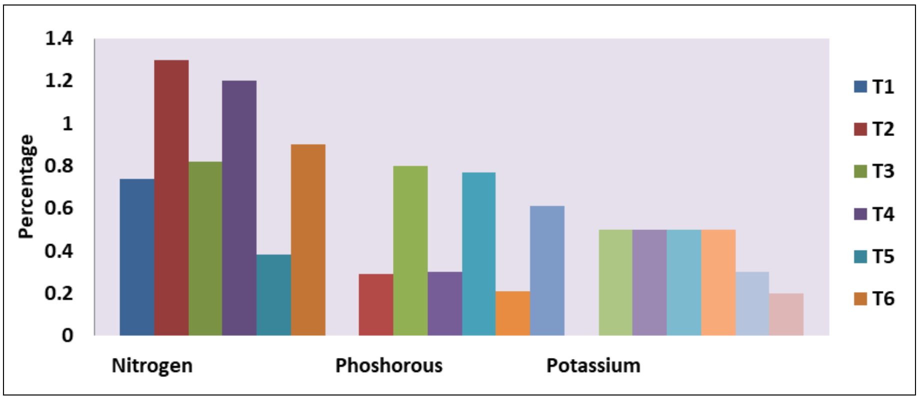

Fig 2: Effect of different treatments on N available P and K

Calcium and magnesium contents (ppm)

Calcium contents (ppm) in the vermicomposts produced by the two species from both the substrates recorded much higher (T4=7.38 > T3=7.29 > T2=5.96 > T1 =4.42) than from the control treatments T5 (1.25) & T6 (2.28). The higher values of calcium content were in the vermicomposts produced by *E. foetida* from the two substrates indicating that the earthworm species had a role in enhancing calcium content. Similar trend were recorded in magnesium contents (ppm) in the vermicomposts produced by the two species from both the substrates. The values were T2=6.21> T1=5.64>T4=5.29 >T3=4.43>T5=2.23>T6=1.12 (Fig. 3). The findings were in agreement with the findings of Suthar and Singh (2008) and Swathi and Vikram Reddy (2010) [18, 22].

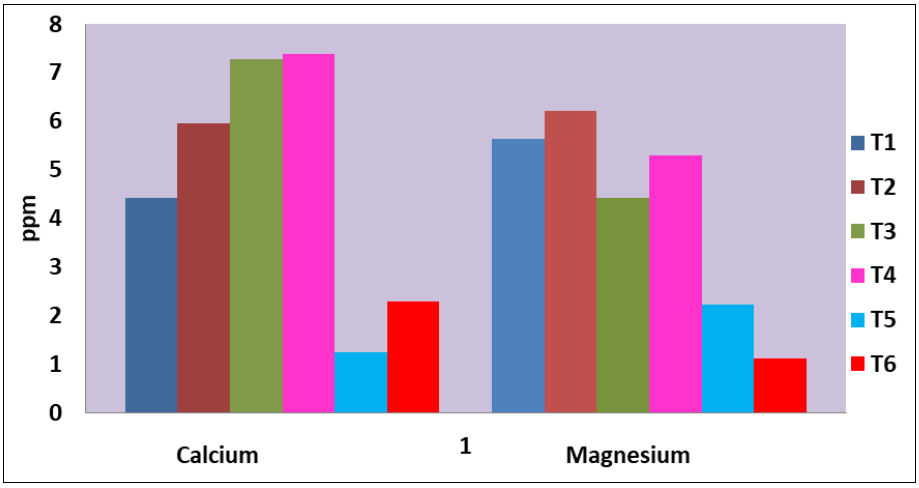

Fig 3: Comparative value of banana and mango wastes compost with respect to calcuim and Magnesium

Copper, zinc and manganese contents (ppm)
The vermicomposts showed higher levels of copper, zinc and manganese as compared to the control treatments. The highest level of copper, zinc and manganese was recorded in T1 (0.375), T3 (0.385), T3 (4.33), respectively (Fig. 4). Reddy and Reddy (1999) [23] reported similar results that significant increases in micronutrient content were found in field soils after application of vermicompost.

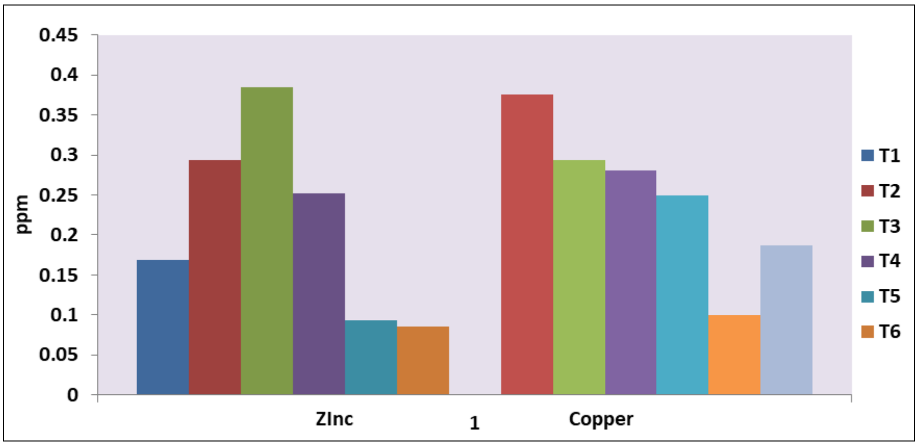

Fig 4: Conncentration of zinc and copper

Heavy metal contents (ppm)
The results revealed the presence of minute quantities of lead and cadmium in vermi-composts and the waste cow dung mixtures as shown in Fig. 5. According to the WHO and FAO guidelines, the maximum allowable limits for Cadmium and Lead are 3 and 100 microgram per gram respectively. The values of Cadmium and Lead obtained in the current studies are much below the maximum allowable limits. Asghar *et al*. (2006) [24] reported that the presence of heavy metals and other toxic substances were very low in vermi-composts.

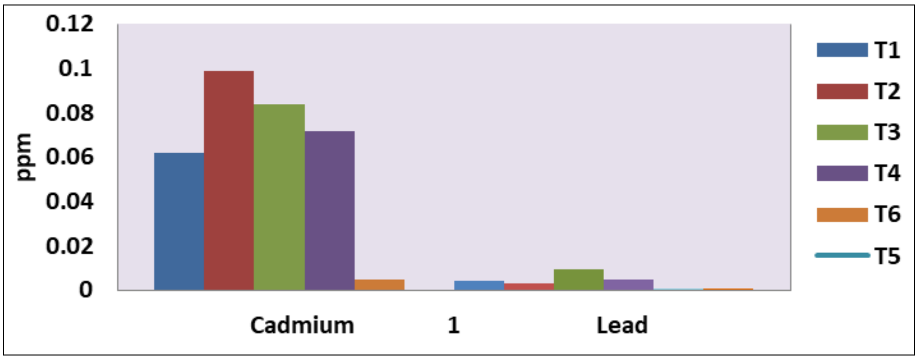

Fig 5: Heavy metal valuve of different samples

Conclusion
From the results of the experiment, it is inferred that the composting efficiency of two commonly distributed epigeic earthworms such as *E. eugeniae* and *E. foetida* can be used for vermicomposting of banana wastes and mango leaf litter wastes as well. Vermicomposting of banana wastes with two species significantly reduces the time of composting with highest compost recovery than the mango waste. However, on basis of reproduction performance and nutrient contents of the vemicomposts produced by the two species, the mango leaf

litter substrate is better one in producing more number of young ones, cocoon and high nutrient element as compared to banana wastes.

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