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RESEARCH ARTICLE

EFFECT OF DIFFERENT ANIMAL MANURE ON VERMICOMPOSTING OF MIXED LEAVES LITTER BY UTILIZING AN EXOTIC EARTHWORM, *EUDRILUS EUGENIAE*

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Abstract

The main objective of this research work is effect of two different animal dung *viz.*, goat dung and cow dung on vermicomposting of mixed leaves litter by utilizing an exotic earthworm, *Eudrilus eugeniae*. Of the two animal dung used in the present study *i.e.*, cow dung and goat dung the percentage of decomposition was appeared to be high in Experiment I (mixed leaves litter treated with cow dung in 1:2 ratio) over other two experiments. Number of adult worms was found to be comparatively little higher in the experiment I (Mixed leaves litter + cow dung in 1:2 ratio) than other two experiments. The physico-chemical and biological parameters of the vermicompost obtained from Experiment I (mixed leaves litter treated with cow dung in 1:2 ratio) was seemed to be good followed by Experiment III (mixed leaves litter treated with cow dung and goat dung in 1:1:1 ratio) and Experiment II (mixed leaves litter treated with goat dung in 1:2 ratio). Hence cow dung may be used for the production of vermicompost. Therefore it may be concluded that the mixed leaves litter must be mixed with cow dung in 1:2 ratio and it must be converted into vermicompost by utilizing *E. eugeniae* under monoculture conditions.

INTRODUCTION

Abundant uses of chemical fertilizers have not only caused the loss of soil fertility but also increase the large amount of agro wastes. The production of cow dung and goat dung are 11.6 and 0.70 kg/animal/day, respectively, in India (Garg *et al.*, 2006). The presence of abundant agro wastes and animal dung causes serious problems to animals as well as to human beings if there is improper management of these wastes. So, it becomes essential to retain the soil fertility as well the handling of abundant production of agro and animal wastes in productive ways.

Animal manure is one of the major underutilized resources in many countries. Animal manure mainly refers to excreta (dung) and urine along with the bedding material mixed with soil. Animal manure is available either in dairies, slaughterhouses or at the backyards of the houses (Mukund and Chavan, 2007). Along with other animal wastes and agro-industrial wastes create environmental problems like, dispensing foul odors, occupying vast areas, ground and surface water pollution *etc.* The manure generated by livestock is currently receiving a great deal of attention in the water quality arena. Adoption of better animal waste management practices can reduce the transport of nutrients and pathogens from animal farms to ground and surface water, which could improve the water quality. Though the food production has been improved significantly since 1960's by successful implementation of high yielding variety seeds, fertilizers, pesticides and farm machineries, in the recent past farmers are facing problem of stagnant productivity due to deteriorated soil organic carbon status. To improve the organic status of the soil, farmers are now turning towards the age old practices of organic farming *i.e.* managing the crops without the use of chemical fertilizers and pesticides.

Most animal manure is the excreta (variously called "droppings" or "crap" *etc.*) of plant-eating animals (herbivores) and poultry mixed with bedding material (often straw) and thus is heavily contaminated with their faeces and urine. Animal excreta differ according to species, diet, environment and productivity of the animal. The amount of excreta produced by different species of animals ranges from 0.12-1.9 tons /year/animal.

Animal wastes are the valuable sources of organic matter and plant nutrient such as nitrogen. Though these animal wastes are utilized as compost to sustain agriculture in the past, they are not fully exploited until recently due to non-availability of viable, eco-friendly, socially acceptable and farmer friendly technology. In the last few decades vermicomposting has been arising as a sustainable tool for the efficient utilization of agro-industrial and animal wastes, and to convert them into value added products for land restoration practices. Among the microbial fertilizer, bio-fertilizer and vermicompost, the use of vermicompost as an organic manure has become popular owing to its simple preparation, eco-friendly nature and easily available raw material (Balasubramanian *et al.*, 2009).

Table 1: Dung production per animal per year (Dry weight basis)

S. No.	Species	Dung Production (tons / year)
1	Buffalo	0.80 – 1.90 (1.39)
2	Cattle	0.40 – 1.80 (1.10)
3	Horse	0.40 – 0.60 (0.50)
4	Pig	0.20 – 0.30 (0.25)
5	Sheep and Goat	0.10 – 0.20 (0.15)
6	Poultry	0.12 – 0.16 (0.14)

Source: Mukund and Chavan (2007); Figures within the parenthesis indicate mean values.

Table 2: Nutrient composition in excreta of different species of animals

S.No.	Types of live stocks	Dry Matter (%)	Ca (%)	Mg (%)	N (%)	P_2O_5 (%)	K_2O (%)
1	Cattle	18	0.37	0.53	1.74	1.70	0.60
2	Swine	18	0.21	0.54	2.27	3.10	1.80
3	Poultry	45	2.28	1.39	2.17	2.00	4.20
4	Sheep & Goat	-	-	-	0.65	0.50	0.03
5	**Horse**	**-**	**0.26**	**0.49**	**1.07**	**2.10**	**3.60**

Source: Mukund and Chavan (2007)

The role of earthworms in organic matter decomposition, nutrient cycling, soil structure and plant productivity has been studied by several authors (Lavelle 1988; Scheu and Wolters, 1991; Zhang and Schrader, 1993; Blair *et al.,* 1994 and Stephens *et al.*, 1995). Use of earthworms for waste conditioning is widely practiced all over the world as vermicomposting technology Epigeic earthworms like *Eudrilus eugeniae*, *Perionyx excavatus* and *Eisenia fetida* are some of the popularly used earthworms for vermicomposting (Kale *et al*., 1982). *E. eugeniae*, a tropical earthworms commonly called African Night Crawler, is large in size grows rapidly, breeds fast and is capable of decomposing large quantities of organic materials into usable vermicompost (Kale and Bano, 1988). *E. eugneiae* has been utilized for vermicomposting of leaves litter (Daniel and Karmegam, 1999).

The present study aims at finding out the effect of different animal manures *viz.*, goat dung and cow dung on vermicomposting of mixed leaves litter by utilizing an exotic earthworm, *Eudrilus eugeniae*.

Materials and Methods

Collection of plant and animal waste

The selected mixed leaves litter was collected from our college campus. The animal dung such as cow dung and goat manure was collected from nearby dairy yard and transported to Vermished of our college.

Collection of Earthworm Species

The vermicomposting earthworm species *viz., Eudrilus eugeniae* were collected from Vermiyard of Nehru Memorial College, Puthanampatti, Tiruchirappalli District, Tamil Nadu, India and mass cultured in cow dung medium for further study. The species were identified and confirmed by using morphological characters given by Talashilkar and Dosani (2005) and Blakemore (2010).

Pre-digestion of the chosen Organic wastes

The mixed leaves litter was spread on a clean floor, which was open to sunlight for 5 days. Watering was done regularly twice in a day on the mixed leaves litter. Similar method was adopted for curing cow dung and goat dung. The sun dried mixed leaves litter; cow dung and goat dung were transferred to a shady place where it was cured for 5 days. The shade dried mixed leaves litter made as heap. The water was sprinkled periodically over the heap of mixed leaves litter to accelerate natural microflora in pre-decomposition of mixed leaves litter. The moisture content in the heap was maintained at about 60-70% by sprinkling water. All these layers were covered by wet pieces of jute bags in order to maintain the moisture content. This set up was maintained for 30 days.

Preparation of Experimental Trays

Plastic trays are considered to be advantageous because there are more durable lighter in weight and could be easily arranged one above the other in vertical rows in limited space and hence used during the present study. Plastic trays of 45 cm (l) × 15 cm (h) × 30 cm (w) were bought and holes were made at the bottom to drain the excess water in the experimental medium. Vermibeds were prepared by mixing the pre-decomposed mixed leaves litter along with cow dung and goat dung separately in 1:2 (2000g of mixed leaves litter:4000g of cow dung and 2000g of mixed leaves litter: 4000g of goat dung) and 1:1:1 (2000g of mixed leaves litter:2000g of cow dung:2000g of goat dung) ratio. The exotic earthworm *E. eugeniae* was inoculated (20 nos. / kg. substrate) in each tray except control and the whole set-up was maintained in triplicates. Water was sprinkled regularly to keep the vermibed with moisture and care was taken not to soak the substrate with excess water. The vermibed substrate were also mixed periodically and maintained for 45 days. The experimental design was given in Table 3.

Table 3: Experimental Design

Experiment No.	Specifications	Weight of the organic wastes taken	Number of earthworms introduced
Control – I	Leaves litter + Cow dung (1:2)	2000g of mixed leaves litter : 4000g of cow dung	-
Experiment – I	Leaves litter + Cow dung (1:2) + Earthworm	2000g of mixed leaves litter : 4000g of cow dung	120
Control – II	Leaves litter + Goat manure (1:2)	2000g of mixed leaves litter : 4000g of goat dung	-
Experiment – II	Leaves litter + Goat manure (1:2) + Earthworm	2000g of mixed leaves litter : 4000g of goat dung	120
Control – III	Leaves litter + Cow dung + Goat manure (1:1:1)	2000g of mixed leaves litter : 2000g of cow dung:2000g of goat dung	-
Experiment – III	Leaves litter + Cow dung + Goat manure (1:1:1) + Earthworm	2000g of mixed leaves litter : 2000g of cow dung:2000g of goat dung	120

Earthworms – 20nos./kg of substrate

The experimental trays were kept undisturbed in the shady place. Watering was done regularly twice in a day in order to maintain the optimum temperature and moisture content of the medium during the entire composting period.

Harvesting of Vermicompost and Compost

The vermicompost produced from leaves litter along with animal manures such as cow dung and goat manure were collected at every 7days interval up to 28 days, sieved (3mm mesh size sieve) and air dried. Simultaneously, control medium also was collected and air dried. All the samples were subjected to various physico-chemical nutrient analyses and microbial load. Further, after the harvest in each tray the numbers of earthworms were estimated. The percentage of decomposition in each tray was also calculated.

Analysis of Physico-Chemical Characteristics of Vermicompost and Compost

The leaves litter with animal manure was allowed to decompose for a period of 28 days after 7^{th}, 14^{th} and 21^{st} days and 28^{th} days, the samples were taken and analyse the various physico-chemical nutrients.

Table 4: Methods used for analysing various physico-chemical parameters of the vermicompost and compost

S. No.	Parameter analysed	Methodology	Reference
1	pH	Digital pH meter (Elico)	Tandon (2005)
2	Electrical Conductivity	Electrical Conductivity Meter (Elico)	Tandon (2005)
3	Total Nitrogen	Micro Kjeldahl Method	Tandon (2005)
4	Organic Carbon	Potassium Dichromate Oxidation Method	Walkely and Black (1934)
5	Total Phosphorus	Spectrophotometric Method	Tandon (2005)
6	Total Potassium	Flame Photometric Method	Tandon (2005)
7	C:N ratio	-	Anon (2006)

Enumeration of microbial counts in vermicompost and compost

The total number of microbial colonies in the vermicompost and compost sample was counted by utilizing standard plate count method (Rao, 1995 and Kannan, 1996).

Data Analysis

The values obtained from all experiments carried out in the present investigation in triplicates were converted into Mean ± Standard Deviation values and the same are presented in Tables. One way analysis of variance was done to analyse the significant difference between the different experiments and worms count at 0.05% level of significance. Paired samples "t" test was used to determine any significant difference between compost and vermicompost in each treatment at 0.05%, 0.01% and 0.001% level of significance. All these analyses were done by using SPSS (Statistical Package for Social Science) program version 16.0 for windows.

Results and Discussion

The pH, OC and C:N ratio decreased in the vermicompost when compared to the compost. The percentage of pH decrease in the vermicompost was not significant, whereas the reduction in OC and C:N ratio was significant when compared to that of compost. A highly significant ($p<0.001$) enhancement of N, P and K contents was found in the vermicompost when compared to compost except 28^{th} day of analyses (Table 6).

Table 5: The propensity of physico-chemical nutrients and biological composition of vermibed at initial day

S. No.	Parameters	Experiment I Mean ± S.D.	Experiment II Mean ± S.D.	Experiment III Mean ± S.D.
1	pH	8.01 ± 0.06	8.29 ± 0.07	7.92 ± 0.10
2	Electrical Conductivity (dSm-1)	4.89 ± 0.01	4.21 ± 0.05	4.15 ± 1.10
3	Organic Carbon (%)	40.21 ± 1.16	42.16 ± 0.01	49.15 ± 0.02
4	Total Nitrogen (%)	0.51 ± 0.01	0.63 ± 0.09	0.45 ± 0.01
5	Total Phosphorus (%)	0.45 ± 0.06	0.32 ± 0.06	0.35 ± 0.07
6	Total Potassium (%)	0.32 ± 0.03	0.38 ± 0.05	0.39 ± 0.07
7	C:N ratio	78:1	66:1	45:1
8	Bacteria × 10^6CFU /g	75 ± 0.01	76 ± 0.02	65 ± 0.02
9	Fungi × 10^4CFU /g	76 ± 0.05	65 ± 0.03	68 ± 0.05
10	Actinomycetes × 10^3CFU /g	57 ± 0.06	58 ± 0.02	64 ± 0.05

Mean ± S.D. values were obtained from three individual observations.

Table 6: The quantity of chemical constituents of vermicompost produced by *E. eugeniae* under monoculture conditions utilizing mixed leaves litter and cow dung in 1:2 concentration and compost at different time intervals

S. No.	Parameters	7th day		% increase (+)/decrease (-)	14th day		% increase (+)/decrease (-)
		Compost Mean ± S.D.	V.compost Mean ± S.D.		Compost Mean ± S.D.	V.compost Mean ± S.D.	
1	pH	7.46 ± 0.50	7.53 ± 0.65	+0.93^NS	7.02 ± 0.54	6.66 ± 0.51	-5.40^NS
2	Electrical Conductivity (dSm-1)	1.08 ± 0.02	1.71 ± 0.03	+58.33**	1.08 ± 0.02	1.71 ± 0.03	+36***
3	Organic Carbon (%)	35.46 ± 0.35	35.44 ± 0.43	-0.05***	34.61 ± 0.30	32.24 ± 0.39	-7.35**
4	Total Nitrogen (%)	0.91 ± 0.09	0.95 ± 0.03	+4.2***	0.98 ± 0.07	1.08 ± 0.02	+9.25***
5	Total Phosphorus (%)	0.89 ± 0.04	0.92 ± 0.03	+3.37***	1.09 ± 0.04	1.16 ± 0.05	+6.03***
6	Total Potassium (%)	0.54 ± 0.03	0.57 ± 0.02	+5.26***	0.57 ± 0.03	0.60 ± 0.01	+5***
7	C:N ratio	37:1	37:1	0	35:1	29:1	-20.68*
S. No.	**Parameters**	**21st day**		**% increase (+)/decrease (-)**	**28th day**		**% increase (+)/decrease (-)**
		Compost Mean ± S.D.	**V.compost Mean ± S.D.**		**Compost Mean ± S.D.**	**V.compost Mean ± S.D.**	
1	pH	6.68 ± 0.57	6.38 ± 0.42	-4.70^NS	6.54 ± 0.67	6.30 ± 0.41	-3.80^NS
2	Electrical Conductivity (dSm-1)	2.52 ± 0.02	2.78 ± 0.16	+9.35**	3.2 ± 0.10	3.83 ± 0.07	+16.44*
3	Organic Carbon (%)	31.57 ± 0.29	28.53 ± 0.38	-10.65***	30.16 ± 0.27	26.14 ± 0.35	-15.37^NS
4	Total Nitrogen (%)	1.10 ± 0.07	2.16 ± 0.04	+5.17***	1.03 ± 0.11	2.30 ± 0.08	+20.76^NS
5	Total Phosphorus (%)	1.22 ± 0.05	2.20 ± 0.05	-1.66***	1.37 ± 0.03	2.43 ± 0.04	+4.19^NS
6	Total Potassium (%)	0.76 ± 0.03	1.82 ± 0.02	+7.3***	1.05 ± 0.04	2.10 ± 0.01	+4.54***
7	C:N ratio	28:1	24:1	-16.66*	26:1	19:1	-36.84*

Mean ± S.D. values were obtained from three individual observations.
*,**,*** and NS indicates statistically significant differences at p<0.05, p<0.01, p<0.001 and not significant by "t" test

The population of microorganisms *viz.*, bacteria, fungi and actinomycetes was increased when compared to compost. A highly significant (p<0.001) increased population of bacteria, fungi and actinomycetes was found in vermicompost harvested from different time intervals than the compost (Table 7).

Table 7: The propensity of biological composition of vermicompost produced by *E. eugeniae* under monoculture conditions utilizing mixed leaves litter and cow dung in 1:2 ratio and compost at different time intervals

S. No.	Parameters	7th day		% increase (+)/decrease (-)	14th day		% increase (+)/decrease (-)
		Compost Mean ± S.D.	V.compost Mean ± S.D.		Compost Mean ± S.D.	V.compost Mean ± S.D.	
1	Bacteria× 10^6CFU /g	87.33 ± 3.05	87.33 ± 3.05	0***	114.33 ± 3.05	140.33 ± 33	+18.52***
2	Fungi× 10^4CFU /g	87 ± 1.73	88 ± 1.00	+1.13***	98 ± 1.00	119.00 ± 2.00	+17.64***
3	Actinomycetes × 10^3CFU /g	103.00 ± 3.60	102.67 ± 2.08	-0.32***	123.67 ± 4.04	163 ± 1.00	+24.12***
S. No.	**Parameters**	**21st day**		**% increase (+)/decrease (-)**	**28th day**		**% increase (+)/decrease (-)**
		Compost Mean ± S.D.	**V.compost Mean ± S.D.**		**Compost Mean ± S.D.**	**V.compost Mean ± S.D.**	
1	Bacteria× 10^6CFU /g	153.67 ± 4.04	218.33 ± 2.08	+13.82***	185.33 ± 3.05	255.33 ± 5.03	+9.74***
2	Fungi × 10^4CFU /g	106.33 ± 1.52	142.33 ± 3.21	+13.07***	113.33 ± 3.05	159 ± 4	+15.42***
3	Actinomycetes× 10^3CFU /g	103.00 ± 3.60	262.67 ± 2.08	+35.32***	188 ± 3.00	281.33 ± 1.52	+22.09***

Mean ± S.D. values were obtained from three individual observations.
*,**,*** and NS indicates statistically significant differences at $p<0.05$, $p<0.01$, $p<0.001$ and not significant by "t" test.

A highly significant ($p<0.001$) reduction was observed in pH, OC and C:N ratio of the vermicompost obtained from different time intervals than the compost. A non-significant ($p>0.001$) reduction was observed in Electrical conductivity harvested from different time intervals as compared to compost. A highly significant increase ($p<0.001$) in Total Nitrogen, Total Phosphorus and Total Potassium was recorded in vermicompost obtained from different time intervals than compost (Table 8).

Table 8: The extent of chemical constituents of vermicompost produced by *E. eugeniae* under monoculture conditions utilizing mixed leaves litter and goat dung in 1:2 ratio and compost at different time intervals

S. No.	Parameters	7th day		% increase (+)/decrease (-)	14th day		% increase (+)/decrease (-)
		Compost Mean ± S.D.	**V.compost Mean ± S.D.**		**Compost Mean ± S.D.**	**V.compost Mean ± S.D.**	
1	pH	7.53 ± 0.64	7.61 ± 0.77	+1.06***	7.40 ± 0.62	7.23 ± 0.69	-15.00***
2	Electrical Conductivity (dSm-1)	1.30 ± 0.05	1.75 ± 0.22	+34.6***	1.54 ± 0.04	2.19 ± 0.23	+29.68^{NS}
3	Organic Carbon (%)	36.57 ± 0.43	36.03 ± 0.05	-1.95***	33.03 ± 0.01	35.00 ± 0.40	+5.62***
4	Total Nitrogen (%)	0.95 ± 0.13	0.92 ± 0.04	-3.26***	0.92 ± 0.06	1.04 ± 0.04	+11.53***
5	Total Phosphorus (%)	0.85 ± 0.04	0.86 ± 0.04	+1.16***	1.05 ± 0.04	1.18 ± 0.04	+11.01***
6	Total Potassium (%)	0.56 ± 0.05	0.65 ± 0.03	+13.8***	0.60 ± 0.02	0.65 ± 0.01	+7.69***
7	C:N ratio	39:1	38:1	-2.63***	38:1	31:1	-22.58***
S. No.	**Parameters**	**21st day**		**% increase (+)/decrease (-)**	**28th day**		**% increase (+)/decrease (-)**
		Compost Mean ± S.D.	**V.compost Mean ± S.D.**		**Compost Mean ± S.D.**	**V.compost Mean ± S.D.**	
1	pH	7.29 ± 0.52	7.11 ± 0.62	-13.90***	7.79 ± 0.50	7.17 ± 0.65	-5.10***
2	Electrical Conductivity (dSm-1)	2.67 ± 0.07	3.10 ± 0.25	+13.87^{NS}	3.20 ± 0.01	3.36 ± 0.28	+1.22^{NS}
3	Organic Carbon (%)	31.58 ± 0.37	30.07 ± 0.05	-5.02**	30.09 ± 0.34	28.52 ± 0.08	-5.50***
4	Total Nitrogen (%)	0.98 ± 0.07	1.15 ± 0.03	+14.78***	1.05 ± 0.04	1.23 ± 0.045	+14.6***
5	Total Phosphorus (%)	1.18 ± 0.04	1.24 ± 0.04	+4.83***	1.30 ± 0.05	1.55 ± 0.04	+16.12***
6	Total Potassium (%)	0.87 ± 0.03	1.16 ± 0.04	+25***	1.12 ± 0.02	1.38 ± 0.01	+18.84***
7	C:N ratio	31:1	25:1	-24***	34:1	30:1	-13.33***

Mean ± S.D. values were obtained from three individual observations.
*,**,*** and NS indicates statistically significant differences at p<0.05, p<0.01, p<0.001 and not significant by "t" test.

A highly significant ($p<0.001$) increase in population of microorganisms *viz.*, bacteria, fungi and actinomycetes was registered in the vermicompost harvested from all the time intervals except fungi at 7th day of experiment when compared to compost (Table 9).

Table 9: The magnitude of biological composition of vermicompost produced by *E. eugeniae* under monoculture conditions utilizing mixed leaves litter and goat dung in 1:2 ratio and compost at different time intervals.

S. No.	Parameters	7th day		% increase (+)/decrease (-)	14th day		% increase (+)/decrease (-)
		Compost Mean ± S.D.	V.compost Mean ± S.D.		Compost Mean ± S.D.	V.compost Mean ± S.D.	
1	Bacteria× 10^6CFU /g	80.33 ± 1.52	82.00 ± 5.29	+2.43***	110.33 ± 2.51	133.33 ± 4.16	+17.25***
2	Fungi× 10^4CFU /g	85.66 ± 2.08	85.33 ± 3.51	-0.38***	90.00 ± 2.00	105.33 ± 4.04	+14.55***
3	Actinomycetes× 10^3CFU /g	92.66 ± 2.51	93.00 ± 3.00	+0.36***	116.33 ± 3.78	145.33 ± 3.05	+19.95***
S. No.	**Parameters**	**21st day**		**% increase (+)/decrease (-)**	**28th day**		**% increase (+)/decrease (-)**
		Compost Mean ± S.D.	**V.compost Mean ± S.D.**		**Compost Mean ± S.D.**	**V.compost Mean ± S.D.**	
1	Bacteria× 10^6CFU /g	133.67 ± 4.04	172.00 ± 2.64	+22.28***	155.33 ± 5.03	185.00 ± 3.60	+16.03***
2	Fungi× 10^4CFU /g	99.00 ± 3.00	117.67 ± 1.52	+15.86***	101.67 ± 2.08	124.00 ± 2.64	+18.00***
3	Actinomycetes× 10^3CFU /g	125.33 ± 2.51	190.67 ± 2.08	+34.26***	164.33 ± 3.05	221.33 ± 3.21	+25.75***

Mean ± S.D. values were obtained from three individual observations.

*,**,*** and NS indicates statistically significant differences at $p<0.05$, $p<0.01$, $p<0.001$ and not significant by "t" test

A highly significant ($p<0.001$) reduction in pH was recorded in vermicompost obtained from all the time intervals except 7th day of experiment as compared to control and initial vermibed. The electrical conductivity of the vermicompost from different time intervals showed non-significant ($p<0.001$) reduction when compared to initial vermibed and compost as per "t" test analysis. A highly significant ($p<0.001$) increase in Total Nitrogen, Total Phosphorus and Total Potassium was observed in vermicompost obtained from different time intervals except total phosphorus in 21st and 28th day of experiment. A highly significant ($p<0.001$) decrease in C:N ratio was registered in the vermicompost obtained from different time intervals except 7th day of experiment when compared to compost (Table 10).

Table 10: The quantity of chemical constituents of vermicompost produced by *E. eugeniae* under monoculture conditions utilizing mixed leaves litter, cow dung and goat dung in 1:1:1 ratio at different time intervals

S. No.	Parameters	7th day		% increase (+)/decrease (-)	14th day		% increase (+)/decrease (-)
		Compost Mean ± S.D.	V.compost Mean ± S.D.		Compost Mean ± S.D.	V.compost Mean ± S.D.	
1	pH	7.36 ± 0.65	7.63 ± 0.77	+3.53***	7.40 ± 0.62	6.90 ± 0.72	-7.24***
2	Electrical Conductivity (dSm-1)	2.26 ± 0.16	1.95 ± 0.08	-15.89 NS	3.32 ± 0.27	3.13 ± 0.12	-6.07 NS
3	Organic Carbon (%)	30.98 ± 0.30	34.37 ± 0.36	+9.86***	25.41 ± 0.23	27.90 ± 0.26	+8.92***
4	Total Nitrogen (%)	0.93 ± 0.05	0.93 ± 0.05	0***	0.94 ± 0.07	1.13 ± 0.04	+16.81***
5	Total Phosphorus (%)	0.86 ± 0.04	0.90 ± 0.06	+4.44***	1.02 ± 0.04	1.22 ± 0.05	+16.39**
6	Total Potassium (%)	0.54 ± 0.02	0.55 ± 0.02	+1.81***	0.61 ± 0.05	0.58 ± 0.03	-5.17***
7	C:N ratio	32:1	36:1	+11.11***	27:1	24:1	-12.5***
S. No.	**Parameters**	**21st day**		**% increase (+)/decrease (-)**	**28th day**		**% increase (+)/decrease (-)**
		Compost Mean ± S.D.	**V.compost Mean ± S.D.**		**Compost Mean ± S.D.**	**V.compost Mean ± S.D.**	
1	pH	7.28 ± 0.60	6.55 ± 0.58	-11.14***	6.56 ± 0.40	6.36 ± 0.56	-3.14***
2	Electrical Conductivity (dSm-1)	1.94 ± 0.05	1.54 ± 0.05	-25.97***	3.73 ± 0.04	2.72 ± 0.20	-37.13***
3	Organic Carbon (%)	33.46 ± 0.49	34.47 ± 0.51	+2.93***	29.92 ± 0.33	30.16 ± 0.35	+0.79***
4	Total Nitrogen (%)	0.98 ± 0.07	1.20 ± 0.01	+18.33**	1.05 ± 0.04	1.35 ± 0.08	+22.22*
5	Total Phosphorus (%)	1.31 ± 0.04	1.16 ± 0.04	-12.93 NS	1.39 ± 0.04	1.63 ± 0.05	+14.72 NS
6	Total Potassium (%)	0.77 ± 0.03	0.79 ± 0.01	+2.53***	1.10 ± 0.03	1.08 ± 0.01	-1.85***
7	C:N ratio	34:1	28 :1	-21.42***	27:1	22:1	-22.72**

Mean ± S.D. values were obtained from three individual observations.
*,**,*** and NS indicates statistically significant differences at p<0.05, p<0.01, p<0.001 and not significant by "t" test.

A highly significant (p<0.001) increase in population of bacteria, fungi and actinomycetes was observed in the vermicompost harvested from different time intervals than compost (Table 11).

Table 11: The propensity of biological composition of vermicompost produced by *E. eugeniae* under monoculture conditions utilizing mixed leaves litter, cow dung and goat dung in 1:1:1 ratio at different time intervals.

S. No.	Parameters	7th day		% increase (+)/decrease (-)	14th day		% increase (+)/decrease (-)
		Compost Mean ± S.D.	V.compost Mean ± S.D.		Compost Mean ± S.D.	V.compost Mean ± S.D.	
1	Bacteria × 10^6CFU /g	92.66± 3.05	93.66 ± 4.72	+1.06***	124.33 ± 4.04	145.67 ± 2.08	+14.64***
2	Fungi × 10^4CFU /g	88.66 ±1.52	89.00 ± 3.00	+0.38***	112.67 ± 2.08	111.33 ± 3.21	-1.20***
3	Actinomycetes × 10^3CFU /g	99.33 ± 4.04	107.00 ± 6.24	+7.16***	125.00 ± 4.00	168.00 ± 2.64	+25.59***
S. No.	**Parameters**	**21st day**		**% increase (+)/decrease (-)**	**28th day**		**% increase (+)/decrease (-)**
		Compost Mean ± S.D.	**V.compost Mean ± S.D.**		**Compost Mean ± S.D.**	**V.compost Mean ± S.D.**	
1	Bacteria × 10^6CFU /g	160.00 ± 2.00	185.67 ± 3.21	+13.82***	189.00 ± 3.60	210.33 ± 4.50	+10.14***
2	Fungi × 10^4CFU /g	99.00 ± 3.00	124.33 ± 4.16	+20.37***	119.67 ± 1.52	135.67 ± 4.16	+11.79***
3	Actinomycetes × 10^3CFU /g	159.67 ± 2.51	230.00 ± 2.00	+30.57***	191.00 ± 3.60	255.00 ± 2.00	+25.09***

Mean ± S.D. values were obtained from three individual observations.

*,**,*** and NS indicates statistically significant differences at p<0.05, p<0.01, p<0.001 and not significant by "t" test

Table 12: Percentage decomposition of mixed leaves litter treated with cow dung and goat dung in 1:2 and 1:1:1 ratio. Each value represents the mean value of three observations.

S. No.	Name of the Experiments	With earthworms Mean ± S.D.	Without earthworms Mean ± S.D.
1	Mixed leaves litter : Cow dung (1:2 ratio)	62.30 ±1.62	16.73 ±1.33
2	Mixed leaves litter : Goat dung (1:2 ratio)	37.00 ± 2.21	17.15 ± 2.03
3	Mixed leaves litter : Cow dung : Goat dung (1:1:1 ratio)	54.20 ± 2.60	23.37 ± 1.63

Table 13: One way ANOVA table showing the effect of the cow dung and goat dung on the percentage decomposition of mixed leaves litter after 28 days

S. No.	Sources of variation	SS	df	MS	F	Significance	Significance Level (%)
1	Between groups	5716.100	5	1143.220	299.297	0.000	0.1
2	Within groups	45.836	12	3.820			
3	Total	5761.936	17				

The maximum percentage of decomposition *i.e.*, 62.30 ±1.62% was observed in Experiment I (mixed leaves litter + cow dung) and *E. eugeniae* whereas the minimum percentage of decomposition *i.e.*, 16.73 ±1.33% was found in control of mixed leaves litter treated with cow dung in 1:2 ratio (Table 12 and 13).

Table 14: Total Number of *E. eugeniae* recovered after 28 days of vermicomposting of different organic substrates. Each value represents the mean of three observations.

S. No.	Name of the Experiments	Total Number of worms	
		Initial	Final
1	Mixed leaves litter : Cow dung (1:2 ratio)	120	120
2	Mixed leaves litter : Goat dung (1:2 ratio)	120	106
3	Mixed leaves litter : Cow dung : Goat dung (1:1:1 ratio)	120	101

Table 15: One way ANOVA table showing the effect of the cow dung and goat dung on the total number of E. eugeniae recovered after 28 days

S. No.	Sources of variation	SS	df	MS	F	Significance	Significance Level (%)
1	Between groups	150.944	5	30.189	12.637	.000	0.1
2	Within groups	28.667	12	2.389			
3	Total	179.611	17				

The total number of adult *E. eugeniae* observed were to the tune of 120 (Mixed leaves litter + cow dung); 106 (Mixed leaves litter + goat dung) and 101 (mixed leaves litter + cow dung + goat dung) (Table 14 and 15).

pH

The reduction in pH in the final products could also have been due to the production of CO_2 and organic acids by microbial activity during the process of bioconversion of the different substrates in the beds (Haimi and Huhta, 1986). A decrease in the pH is an important factor in nitrogen retention, as this element is lost as volatile ammonia at pH values Reduction in pH towards neutrality is an important factor in retaining nitrogen, for it seems to promote the nutrient availability for plants (Hartenstein and Hartenstein 1981). Similar results on vermicomposting of textile sludge, institutional waste, kitchen waste, agro-residues, coir waste, leaves litter, water hyacinth and cattle waste have been reported by Garg *et al.*, (2006); Suthar (2007b,c); Gupta *et al.*, (2007); Suthar (2009a); Murali *et al.*, (2011) and Selvamuthukumaran and Neelanarayanan (2012a).

Electrical Conductivity

The electrical conductivity has shown significant increase in the vermicompost over the compost. This shows that during vermicomposting process, the soluble salt level increases because of the mineralization activity of earthworms and microorganisms in the organic substance and as well as in the gut of earthworms. Joshi and Kelkar (1952) have reported a higher electrical conductivity of casts, which denotes an increase in the level of soluble salts in the soil. These findings are well supported by the results of the previous work conducted in this laboratory with other earthworm species during the vermicomposting of leaf litter, weeds and agricultural residues (Karmegam and Daniel, 2000).

Organic Carbon

According to Dominguez (2004), vermicomposting is a combined operation of earthworm and microorganisms in which earthworm fragments and homogenizes the ingested material through muscular action of their foregut and also adds mucus and enzymes to ingested material and thereby increases the surface area for microbial action while, microorganisms perform the biochemical degradation of waste material providing some extra-cellular enzymes required for organic waste decomposition within the worm's gut. Moreover, this biological mutuality caused OC loss in the form of CO_2 from the substrates during the decomposition and mineralization of organic waste (Suthar, 2007a, b). Aira *et al.* (2007a,b), demonstrated that earthworm improves the structure and metabolic capabilities of microbial communities involving in OC mineralization during vermicomposting. Apart from decomposition within earthworm's gut some part of organic fractions is mineralized and associated decomposers (bacteria, protozoa, nematodes, fungi and actinomycetes) in casts. These microbial communities are primarily responsible for OC loss through respiration rate. The conversion of some part of organic fractions of waste into worm biomass can also reduce the OC loss from the substrate. Kale *et al.* (1982); Elvira *et al.* (1998); Kaviraj and Sharma (2003); Suthar (2007c); Khwairakpam and Bhargava (2009a,b); Prakash and Karmegem (2010a,b) and Kaur *et al.* (2010) reported that significant decline in organic C content after worms' inoculation.

Total Nitrogen

The enhancement of total N in vermicompost was probably due to mineralization of the organic matter containing proteins (Bansal and Kapoor, 2000 and Kaushik and Garg, 2003); total amount of N present in the feed materials (Kale, 1998 and Suthar 2007a) and conversion of ammonium nitrogen into nitrate (Atiyeh *et al.*, 2000 and Suthar and Singh, 2008a,b,c)**.** Earthworms can boost the nitrogen levels of the substrate during digestion in their gut adding their nitrogenous excretory products, mucus, body fluid, enzymes, and even through the decaying dead tissues of worms in vermicomposting subsystem (Suthar, 2007a). The increasing trend in total N in the vermicompost was also proposed by various researchers (Kale *et al.*, 1982; Elvira *et al.*, 1998; Balamurugan *et al.*, 1999; Paredes *et al.*, 2002; Tripathi and Bharadwaj, 2004a,b; Bhattacharya and Chattopadhyay, 2004; Kaushik and Garg, 2004; Khwairakpam and Bhargava, 2009a; Alburquerque *et al.*, 2009 and Subramanian *et al.*, 2010). The results of the present investigation are in agreement with these earlier observations.

In contrast, Hobson *et al.* (2005) reported that the reductions in N concentrations in vermicomposting due to *in vivo* denitrification within the worm's digestive tract. Part of the N-content in the initial substrate is also transformed into earthworm protein.

Total Phosphorus

The enhanced total P level in vermicompost suggests phosphorous mineralization during the process. The worms during vermicomposting converted the insoluble P into soluble forms with the help of P solubilizing microorganisms through phosphatases present in the gut, making it more available to plants (Ghosh *et al.*, 1999; Suthar and Singh, 2008a,b and Padmavathiamma *et al.*, 2008). Edwards and Lofty (1972); Martin and Dale (1980); Jambhekar (1992); Lee, (1992); Delgado *et al.*(1995); Ghosh *et al.*(1999); Vinotha *et al.* (2000); Kaushik and Garg (2003); Manna *et al.*(2003); Aira *et al.*(2005); Suthar (2007b) and Sangwan *et al.*(2010) reported significant increase in Total P content after worm inoculation in the vermicompost. The results observed in this study are consistent with these previous works. Bayon and Binet (2006) correlated the increase in phosphate content during vermicomposting to the presence of alkaline phosphatases in the worm casts.

Total Potassium

Earlier, Delgado *et al.*, (1995); Orozco *et al.*, (1996); Dominguez and Edwards (1997); Selvamuthukumaran and Neelanarayanan (2012a,b); Viji and Neelanarayanan (2013 and 2014); reported the general rise of total potassium in the final product. Large number of symbiotic micro flora present in the gut and the cast of earthworms in collaboration with secreted mucus and water might increase the degradation of ingested organic matter and the release of metabolites. These metabolites enhance the enrichment of the vermicompost with total potassium (Kaviraj and Sharma, 2003). The results of the present investigation are in conformity with these earlier works. In contrast, some researchers also reported lower content of TK in vermicompost (Elvira *et al.*, 1998; Sangwan *et al.*, 2008a,b and Ananthakrishnasamy *et al.*, 2009). This is probably due to leaching of this soluble element by the excess water that drained through the mass. Benitez *et al.*, (1999) pointed out that the leachates collected during vermicomposting process had higher potassium concentrations.

C:N ratio

In general, C:N ratio of vermicompost reflects the waste mineralization rate and N enrichment process of material (Suthar and Singh, 2008a,b). It is suggested that in vermicomposting sub system, the loss of carbon as carbon dioxide due to respiratory activities of earthworms and associated microflora, and simultaneously adding of nitrogen in substrate material by inoculated earthworms (through production of mucus, enzymes and nitrogenous excrements) lowers the C:N ratio of waste mixtures. The parameter traditionally considered determining the degree of maturity of compost and to define its agronomic quality is the C:N ratio. Plants cannot assimilate mineral N unless the C:N ratio is≤ 20:1, and this ratio is also an indicative of acceptable maturity of compost (Morais and Queda, 2003). The C:N ratio of 20 or lower being preferable for agronomic use of composts. Dash and Senapathi (1986); Thalalshikar *et al.* (1999); Kaushik and Garg (2004); Kristiana *et al.* (2005); Suthar (2007); Chandra *et al.* (2007); Suthar and Singh (2008a,b) and Yadav and Garg (2011), that reported a significant decline in C:N ratio after worm inoculation. Similar trend in C:N ratio could be observed in the present investigation.

Microbial Population

Availability of half-digested nutrient rich organic wastes by earthworm activity contributed for the proliferation of aerobic decomposing heterotrophic microbes. These results are in conformity with the results of earlier works like Kale *et al.* (1988) who had reported higher counts of actinomycetes and bacteria when the *E. eugeniae* and *P. excavatus* worked organic waste mixed with soil. Jambhekar (1992) noticed a considerable increase in total viable counts of actinomycetes and bacteria in the vermicompost than the control. Parthasarathi and Ranganathan (2000) had reported an increase of bacterial population in *L. mauritii* and *E. eugeniae* worked vermicompost when compared to control. The observed increase in microbial population in the vermicompost may be due to the nutrient rich organic wastes which were utilized for the vermicomposting process during the present study. Similar observations have been reported by Tiwari *et al.* (1989); Parthasarathi (2007); Pramanik *et al.* (2007); Karmegam and Daniel (2008 and 2009); Prakash *et al.* (2009); Prakash and Karmegam (2010a,b); John Paul *et al.* (2011) and Selvamuthukumaran and Neelanarayanan (2012a).

Suthar (2010a,b) suggested that cow dung contains a number of fungal strains and higher population of other detritus feeders, such as bacteria, protozoa, nematodes, actinomycetes, which play an important role in microbial enhancement of vermibeds.

Conclusion

The physico-chemical and biological parameters of the vermicompost obtained from Experiment I (mixed leaves litter treated with cow dung in 1:2 ratio) was seemed to be good followed by Experiment III (mixed leaves litter treated with cow dung and goat dung in 1:1:1 ratio) and Experiment II (mixed leaves litter treated with goat dung in 1:2 ratio). Of the two animal manure used in the present study *i.e.*, cow dung and goat dung the percentage of decomposition was appeared to be high in Experiment I (mixed leaves litter treated with cow dung in 1:2 ratio) over other two experiments, hence cow dung may be suggested to farming community for adoption. Number of adult worms was found to be comparatively little higher in the experiment I (Mixed leaves litter + cow dung in 1:2 ratio) than other two experiments. The quantity of macro nutrients and biological composition of vermicompost obtained from E I experiment was appeared to be better for plant growth. Hence cow dung may be used for the production of vermicompost. Therefore it may be concluded that the mixed leaves litter must be mixed with cow dung in 1:2 ratio and it must be converted into vermicompost by utilizing *E. eugeniae* under monoculture conditions.

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