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VERMICOMPOSTING OF MUNICIPAL SOLID WASTE WITH AN EPIGEIC EARTHWORM, *EISENIA FETIDA*

KARUNAI SELVI. B[1], AROCKIA JOHN PAUL.J[2] AND KARMEGAM.N[3]

[1]Department of Botany, V.V. Vanniaperumal College for Women, Virudhunagar
[2]Department of Zoology, Arumugam Pillai Seethai Ammal College, Tiruppattur
[3]Department of Botany, Government Arts College, Salem
Tamil Nadu, INDIA.

ABSTRACT

Municipal solid waste (MSW) was vermicomposted in combination with cowdung (CD) using *Eiseniafetida*. The decomposition rate of 58-83% was observed in different vermibed substrates, the highest being CD followed by 10:1 CD+MSW. The C/N ratio was reduced from 37 to 14 in MSW+CD (10:1). The important nutrients, NPK showed significantly ($p < 0.05$) higher contents in vermicomposts than composts. The cellulose degradation rate of 44% was observed in 10:1 vermibed mix. The bacterial, fungal and actinomycetes population in vermicompost was significantly higher than in compost. The biomass, number and cocoons of the earthworm species collected after 50 days increased with the increase of CD incorporation in MSW.

Key Words: Waste decomposition, *Eiseniafetida*, Municipal solid waste, Vermicompost.

INTRODUCTION

Total municipal solid waste generation in Madhya Pradesh is 4461.08 MT per day in which the organic municipal solid waste accounts 2288.61 MT per day. The recent report showed that MSW management in the majority of cities and towns are non-systematic and unscientific, involving dumping in low lying areas in the outskirt of the towns (Lal and Rajnikant, 2010). However, there is an urgent need to reduce MSW loadings into landfill, because landfill sites are known to produce leachate that carries both organic and inorganic contaminants (Bou-Zeid and

El- Fadel, 2004). Cocomposting municipal organic waste (MOW) with biosolids greatly improved MOW compost quality by increasing organic matter, total Kjeldhalnitrogen, and extractable P concentrations; whereas, the direct action of worms (*Eiseniafetida*), measured by comparing ground beds with and without worms, improved final product quality by increasing nitrate nitrogen in MOW/biosolid mixtures and extractable P concentrations in the 3:1 mixture (Tognetti et al., 2007).

Vermicomposting is one of the approaches for mobilizing the organic fraction of municipal solid wastes for meeting crop nutritional needs and thus constitutes a productive wastemanagement strategy. A study by Kaviraj and Sharma (2003) reported that on the basis of chemical analysis of MSW vermicompost, *E. fetida*to be superior in performance over *L. mauritii*, in terms of loss of total organic carbon, reduction in carbon to nitrogen ratio, increase in electrical conductivity and total Kjeldhal nitrogen. Vermicomposting of MSW along with other organic wastes, lime and the free-living N-fixer (*Bacillus polymyxa*) using *E. fetida*showed increased nutrient contents in vermicompost (Pramanik et al.,2007). Not only for stabilization of MSW organic fraction, but for variety of organic materials such as vegetable market solid waste (Suthar, 2009), silkworm litter (Raja Sekar and Karmegam, 2009), toxic paper mill sludge (Kaur et al.,2010), septic tank sludge (Rodríguez-Canché et al.,2010), biogas plant slurry with crop residues (Suthar, 2010), sago industrial wastes (Subramanian et al.,2010), bio-sludge of beverage industry (Singh et al. 2010), and many other organic materials were reported to be successfully vermicomposted with *E. fetida*. Hence, the present study has been aimed to study the vermicomposting efficiency of the popularly used exotic worm, *E. fetida* in various combinations of MSW and CD (cowdung).

MATERIALS AND METHODS

Exotic earthworm species, *E. fetida*was originally obtained from Dr. Radha D. Kale, Department of Zoology, University of Agricultural Sciences, Bangalore, Karnataka. These earthworm species were mass cultured using CD as the medium and maintained in the Department of Biology, Gandhigram Rural University, Gandhigram, Tamil Nadu, were used in the present study. Clitellate worms of uniform size were selected from among the mass multiplied organisms and used for the vermicomposting experiment. MSW from Dindigul town was collected, the organic materials were separated and air dried, chopped in to 3-5 cm size and subjected to pre-decomposition in cement tanks by sprinkling water and turning for 15 days.

Plastic containers of 45 × 35 × 15 cm size were filled with 2 kg of predecomposed MSW. CD was mixed with pre-decomposed MSW in different ratios as indicated in the experimental design along with physico-chemical characteristics (Table 1). MSW and CD were mixed on dry weight basis (w/w). CD was made into slurry with water in 1:1 ratio (w/v) and mixed with MSW finally before adding to vermibeds. The vermibed was allowed 24 h for stabilization. The number of earthworms to be introduced was fixed based on the rate of growth, reproduction and decomposition of organic wastes (Reinecke and Viljoen, 1990). Accordingly, 85 preweighed clitellate *E. fetida*of uniform size were introduced in the respective containers. The containers without earthworms served as the control. The average moisture content of the vermibed was maintained at 75% and the substrate was turned once in a week and the experimental setups were maintained in a controlled environment for 50 days. Three replicates were maintained for each treatment. Samples were collected at the initial and, after 50 days, the vermicomposts were removed and sieved through a 2 mm sieve to exclude the worms.

Determination of pH was done by a digital pH meter, electrical conductivity by a conductivity meter (Elico) using 1:10 (w/v) compost-water (double distilled) suspension. The moisture content was determined after drying at 105°C for 24 hrs. Total organic carbon (TOC) and organic matter content (OMC) were measured using the method (Walkley and Black, 1934). Total Kjeldhal Nitrogen (TKN) was determined after digesting the sample with concentrated H2SO4 and concentrated HClO4 (9:1, v/v) (Tandon, 1993). Total phosphorus (TP) was analysed using colorimetric method with molybdenum in sulphuric acid (Tandon, 1993). Total potassium (TK) and total calcium (Ca) were determined after digesting the samples in concentrated HNO3: HClO4 (4:1 v/v), by flame photometer (Tandon, 1993). The C/N and C/P were calculated with the results of TOC, TKN and TK. The cellulose and lignin contents were analysed by adopting the methods of Updegraff (1971) and Chesson (1978) respectively. The percent increase/decrease of various physico-chemical (nutrient) parameters over the worm-unworked substrates was calculated [(A-B/A) x 100; where A= values in the worm-worked substrate, B= values in the worm-unworked substrate].

One gram of each sample was transferred to test tubes containing sterilized water after thorough mixing with a vortex mixer for 20 minutes, and serial dilutions were made. This was used as inoculum and 1.0 ml was plated in triplicate on Nutrient agar media, Rose Bengal agar and Kenknight's media for the enumeration of bacteria, fungi and actinomycetes, respectively using pour plate method, and incubated for 24, 72 h and one week.

The statistical difference of the above parameters was carried out (ANOVA) using Microsoft Excel Computer Software (Version 2007).

The rate of reproduction of the earthworm species was observed in terms of increase in worm number and number of cocoons recovered. The adult and the young worms in each container were counted and weighed separately. To find out the biomass, the worms in each container were hand sorted, washed with water, blotted using Whatman No. 1. filter paper, and weighed in a monopan balance. The effect of various combinations of MSW and CD on the total biomass and total number of *E. fetida* were statistically interpreted (ANOVA) using Microsoft Excel Computer Software (Version 2007).

RESULTS AND DISCUSSION

The percentage decomposition of the eight different combinations of MSW and CD treated with *E. fetida*is given in Fig. 1. As given in the Fig. 1, the percentage decomposition showed a steady increase with increase in the incorporation of CD. It was high in the treatment, which contained CD only i.e., 82.98% followed by 75.67% in MSW+CD (10:1). The composts (without worms) of MSW and CD showed low rate of decomposition which ranged from 25-30%. Similar studies suggest that the decomposition rate depends on the efficiency of earthworm species and the nature of organic material mix used for vermicomposting (Karmegam and Daniel, 2009a; Prakash and Karmegam, 2010b).

The initial values of physico-chemical parameters in different combination of substrates showed variation. However, the variation in pH, EC, TOC, cellulose, lignin, TKN, TK and Ca between different combinations did not differ statistically (Table 1). In all the substrates, pH showed decrease in compost and vermicompost from the initial values. The pH in 100:10 and 0:100 (MSW: CD) significantly differed from composts, and vermicomposts obtained from other treatments. The EC, TKN, TP, TK and Ca in vermicomposts of 100: 10

MSW+CD, and sole CD showed significantly higher increase over composts (Table 2). The parameters such as TOC, OMC, C/N and C/P showed decrease in all substrates. The increase of EC was 12.17% in 100: 2 MSW +CD combination which increased up to 23.05% in 100:10 MSW+CD.

The cellulose content decreased from initial amounts and the higher decline was observed in vermicompost obtained from CD (90.62%). However, 100: 10 MSW+CD showed significantly lower percentage of cellulose degradation (44.35%). Only low percentage of reduction in lignin (7-21%) was observed in the present study. The percent decrease in the C/N ratio of the vermicompost clearly showed the addition of CD as its increasing proportion resulted in higher decrease (Fig. 1). The reduction of C/N ratio ranged from 28.32 to 14.35% in different substrates used. Since the C/N ratio of the MSW was high, an attempt was made in the present study to reduce the C/N ratio by minimal incorporation of CD, which is a good source of nitrogen, in order to make the waste mixture suitable for decomposition using earthworms. Similar reduction was observed for C/P also. Several researchers have used different ratios of organic materials such as leaf litter, pressmud, MSW and vegetable market waste with CD for vermicomposting (Kaviraj and Sharma, 2003; Suthar, 2009; Karmegam and Daniel, 2009a; Prakash and Karmegam, 2010a). The generation of compostable organic material in Dindigul Town is 49.896 tons/day and it requires a minimum of 16.632 tons of CD/day to prepare a 3:1 ratio mixture and it is very difficult to collect 16.632 tons of CD/day which forces indirectly again the disposal problem of MSW and adoption of unscientific disposal methods (John Paul, 2005). Hence, in the present study, minimum incorporation of CD with MSW has been worked out to elucidate the possibility of converting MSW into resourceful vermicompost. The present study reveals that the ratio of 100:8 and 100: 10 MSW+CD is suitable for vermicomposting using *E. fetida*. For decline in C/N ratio, loss of carbon during vermicomposting could be due to mineralization and due to CO_2 production during respiration, nitrogen on the other hand is fixed by microbes as well as it is also added in the form of mucus, nitrogenous excretory substances, hormones and enzymes by the worms (Garg and Kaushik, 2005; Hobson et al., 2005; Suthar, 2009).

The higher percent increase of NPK in WOW vermicompost produced by *E.fetida*than in the WUW compost in this study may be attributed to the mineralization process caused by earthworm action along with microorganisms on organic materials. Irrespective of the treatment used for earthworm feeding, the TKN content in organic wastes consistently increased during vermicomposting. After initial steady increase, the growth curve of TKN content had shown steep slope after 30 days of vermicomposting. The rate of increase in TKN content gradually slowed down near about 60 days and ultimately become constant at completion (Pramanik, 2010). Increased level of P during vermicomposting is due to earthworm-gut derived phosphatase activity and also increased microbial activity in the cast (Lee and Foster, 1991). The P content rise during vermicomposting is probably attributed to mineralization and mobilization of P due to bacterial and faecal phosphatase activity of earthworms. Total K content was higher in vermicomposted MSW than initial level. Kale et al. (1982)concluded that when organic waste passes through the gut of worm; some organic forms of nutrients are then converted into more plant available forms. The results of this study agree with previous reports that the vermicomposting process accelerates the microbial populations in waste and subsequently enriches the end product with more available forms of plant nutrients.

The results of the enumeration of the total colony forming units (CFU) of bacteria, fungi and actinomycetes in the initial vermibed substrates, the worm-unworked compost and the worm-worked compost of *E. fetida*are given Table 3. The total CFU were higher in the final vermicompost and in the compost than in the initial vermibed mixtures. The CFU of the microorganisms in the worm-worked vermicompost was significantly higher in the treatments with *E.fetida*than those in the worm-unworked compost. CD contains a number of fungal strains and greater population of other microbes, such as bacteria, protozoa, nematodes, fungi, actinomycets, which play an important role in organic matter decomposition by providing extra-cellular enzymes in vermibeds (Suthar, 2010). This might be the reason for increased microbial population in the vermibeds with higher proportion of CD. John Paul et al. (2011) recorded significant increase in the microflora of MSW vermicompost by an indigenous earthworm *Perionyxceylanensis*.

The total biomass of the worms recovered from the various combinations of MSW and CD after 50 days of vermicomposting is given in Table 4. The total biomass of worms recovered was high in the treatment, which contained only CD. It significantly differed between the percent incorporation of CD ($p < 0.005$). The total number of worms and the cocoons recovered from the vermicompost of the MSW and CD after 50 days of vermicomposting is given in Table 3. The total number of worms and the cocoons recovered were high in the treatment, which contained only CD. The total number of worms recovered in each treatment significantly differed (at 0.1% level) between the percent incorporation of CD.

Kaur et al. (2010) reported that cattle dung increased suitability of paper mill sludge as feed for both microbes and the earthworm (*E. fetida*) which is evident from higher nutrient content and better population buildup in the mixtures over 100% paper mill sludge. They also suggested that the ideal ratio of paper mill sludge with cattle dung was 25:75 as compost started granulating on its surface earliest (100–110 days), and this mixture was found to be best for growth and population buildup of *E. fetida*. In another study, Singh et al. (2010) reported that minimum mortality and maximum population buildup of *E. fetida*were observed in 50:50 mixture of biosludge and cattle dung. The recovery of a high number of earthworms in the treatment inoculated with *E. fetida*showed the short life cycle of this earthworm species which is an essential characteristic of vermicomposting species (Karmegam and Daniel, 2009b).

CONCLUSION

Based on the observations of percentage incorporation of CD, worm biomass, number of worms recovered, nutrient status, C/N ratio and microbial load of vermicompost, the efficiency of *E. fetida*are found to be suitable candidates for the vermiconversion of MSW with minimal incorporation of CD to MSW, i.e., 100:10 (10:1). The ratio, 10:1 did not show significant difference in nutrient and microbial population with that of CD vermicompost and this ration can be used for large scale vermicomposting of MSW which requires further insight into scalability to the field.

Fig. 1. The rate of decomposition (%) of MSW and CD treated with *E.fetida*and percent decrease of C/N ratio of vermibed materials over the initial values. Trend lines show the logarithmic increase/decrease. Error bars indicate standard deviation.

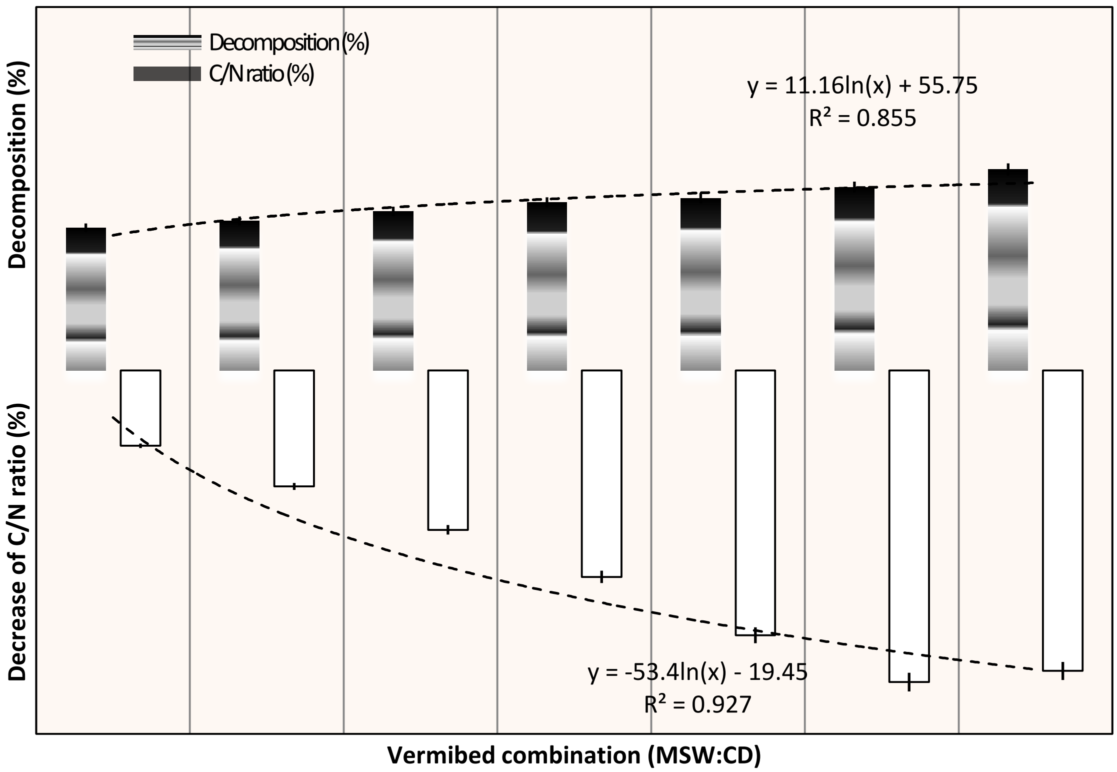

Table 1. Experimental design of vermicomposting of MSW (15 days pre-decomposed) in combination with CD and their physicochemical characteristics

Treatments	pH*	EC (dS/m)	TOC* (%)	OMC (%)	Cellulose* (%)	Lignin* (%)	TKN* (%)	TP (%)	TK* (%)	Ca* (%)	C/N	C/P
No worms MSW (M_1)	7.41	1.98	36.27	62.53a	24.31	27.64	0.78	0.39a	0.65	0.85	46.50a	93.00a
No worms CD (C_1)	7.29	2.16	33.39	57.56b	27.58	25.03	0.86	0.57b	0.69	0.83	38.83b	58.58b
MSW:CD 100:0	7.41	1.98	36.27	62.53a	24.31	27.64	0.78	0.39a	0.65	0.85	46.50a	93.00a
MSW:CD 100:2	7.40	2.00	36.10	62.24a	24.79	27.31	0.78	0.40a	0.65	0.85	46.28a	90.25a
MSW:CD 100:4	7.38	2.04	35.33	60.91a,b	25.33	27.05	0.80	0.40a	0.65	0.86	44.16a,b	88.33a
MSW:CD 100:6	7.35	2.07	35.06	60.44a,b	25.89	26.88	0.82	0.41a	0.66	0.82	42.76a,b	85.51a
MSW:CD 100:8	7.34	2.09	34.58	59.62a,b	26.02	26.56	0.82	0.43a	0.67	0.82	42.17a,b	80.42c
MSW:CD 100:10	7.32	2.12	34.25	59.05a,b	26.10	26.51	0.82	0.46a,b	0.67	0.82	41.77a,b	74.46c
MSW:CD 0:100	7.36	2.16	33.39	57.56b	27.58	25.03	0.86	0.57b	0.69	0.80	38.83b	58.58b

*The values of each parameter between treatments did not differ significantly at $P<0.05$ by ANOVA. The same alphabets in each parameter between treatments did not differ significantly at $P<0.05$ by ANOVA.

Table 2.Physico-chemical characteristics of composts with and without *E. fetida*(50 days). Values are mean of three replicates. The same alphabets between columns did not differ significantly at $p < 0.05$ by ANOVA.

Parameters	Composts		Vermicomposts						
	M_1	C_1	MSW:CD (100:0)	MSW:CD (100:2)	MSW:CD (100:4)	MSW:CD (100:6)	MSW:CD (100:8)	MSW:CD (100:10)	MSW:CD (0:100)
pH	7.39a	7.26a	7.33a	7.27a	7.23a,b	7.20a,b	7.12a,b	7.11b	7.08b
EC (dS/m)	2.02a	2.21a,b	2.30a,b	2.38a,b	2.45b	2.50b,c	2.59b,c	2.64c	2.87c
TOC (%)	33.05a	30.54a,b	30.02a,b	29.63a,c	28.00b,c	27.67b,c	26.96b,c	26.14b,c	25.25c
OMC (%)	56.98a	52.65a,b	51.75a,b	51.08a,b	48.27b,c	47.70b,c	46.48b,c	45.07c	45.53c
Cellulose (%)	23.27a,b	26.02b	21.00a,c	19.51c,d	19.02c,d	17.31d	16.80d,e	16.12d,e	13.65e
Lignin (%)	26.86a	23.08a,b	25.07a,b	24.85a,b	24.18a,b	23.54a,c	22.36b,c	22.08b,c	20.13c
TKN (%)	0.89a	0.95a,c	1.06b,c	1.18b,c	1.25c	1.38c,d	1.52c,d	1.61d	1.76d
TP (%)	0.42a	0.62b	0.70b,c	0.71b,c	0.75b,c	0.81c,d	0.86c,d	0.91d,e	1.04e
TK (%)	0.67a	0.70a,b	0.83b,c	0.86b,c	0.89c,d	0.92c,d	0.96c,d	1.02d,e	1.10e
Ca (%)	0.92a,b	0.84a	1.00a,b	1.09b,c	1.14b,c	1.20c	1.28c,d	1.32c,d	1.39d
C/N	37.13a	32.15a,b	28.32a,b,c	25.11b,d	22.40b,d	20.05c,d	17.74c,d	16.24c,d	14.35d
C/P	78.69a	49.26b	42.89b,c	41.73b,c	37.33c	34.16c,d	30.40c,d	29.63d,e	24.28e

Table 3. Microbial load at the commencement and at the end of vermicomposting of various combinations of the municipal solid waste and cowdung slurry treated with *E.fetida*(50 d)

Treatments	Bacteria (X10^7 g^{-1})		Fungi (X10^4 g^{-1})		Actinomycetes (X10^4 g^{-1})	
	Initial	Final	Initial	Final	Initial	Final
Composts						
No worms MSW (M_1)	$135.33\pm9.45^{A,a}$	$170.58\pm13.37^{A,b}$	$102.68\pm8.79^{A,a}$	$132.25\pm10.25^{A,b}$	$155.57\pm12.66^{A,a}$	$186.49\pm12.63^{A,b}$
No worms CD (C_1)	$160.95\pm14.34^{B,a}$	$196.25\pm15.51^{B,b}$	$130.07\pm9.13^{B,a}$	$149.38\pm12.36^{A,B,b}$	$170.57\pm15.96^{B,a}$	$204.75\pm17.92^{B,b}$
Vermicomposts						
MSW:CD 100:0	$135.33\pm9.45^{A,a}$	$181.75\pm17.86^{A,a}$	$102.68\pm8.79^{A,a}$	$149.66\pm13.48^{A,b}$	$155.57\pm12.66^{A,a}$	$209.29\pm18.30^{A,b}$
MSW:CD 100:2	$147.65\pm12.65^{A,B,a}$	$198.49\pm18.37^{B,b}$	$124.97\pm10.29^{B,a}$	$161.33\pm14.69^{B,b}$	$161.66\pm15.84^{A,B,a}$	$225.00\pm21.66^{B,b}$
MSW:CD 100:4	$156.87\pm14.24^{C,a}$	$216.78\pm19.53^{C,b}$	$130.35\pm11.89^{B,a}$	$169.58\pm13.84^{B,b}$	$167.99\pm15.51^{B,C,a}$	$248.32\pm19.35^{C,b}$
MSW:CD 100:6	$161.60\pm14.85^{C,D,a}$	$234.52\pm18.42^{D,b}$	$137.32\pm12.76^{B,C,a}$	$180.10\pm16.09^{C,b}$	$171.33\pm15.65^{B,C,a}$	$263.55\pm25.16^{D,b}$
MSW:CD 100:8	$168.94\pm14.69^{D,a}$	$265.39\pm24.15^{E,b}$	$140.00\pm13.08^{C,a}$	$191.07\pm18.94^{D,b}$	$175.74\pm16.24^{C,D,a}$	$284.91\pm26.78^{E,b}$
MSW:CD 100:10	$172.59\pm15.38^{D,a}$	$278.33\pm24.31^{F,b}$	$145.45\pm12.73^{C,a}$	$193.22\pm18.00^{D,b}$	$183.62\pm17.53^{D,a}$	$290.40\pm28.29^{E,b}$
MSW:CD 0:100	$160.95\pm14.34^{C,D,a}$	$294.89\pm28.84^{G,b}$	$130.07\pm9.13^{B,a}$	$198.46\pm18.54^{D,E,b}$	$170.57\pm15.96^{C,a}$	$311.40\pm29.38^{F,b}$

Values are mean ± S.D; The difference in mean values between rows (Capital letters) and between columns (small letters) followed by the same letter are not significant at 5 % level (p=0.05) by one-way ANOVA.

Table 4. Number of worms, biomass and cocoons of *E. fetida*recovered after 50 days of vermicomposting MSW + CD combinations. Values are mean ± SE. The same alphabets between vermibed combinations did not differ significantly at $p < 0.05$ by ANOVA.

Vermibed combinations (MSW:CD)	Worms recovered (No./trough)	Worm biomass (g/trough)	Cocoons recovered (No./trough)
100:0	111.5±1.0a	43.5±0.8a	60.8±0.7a
100:2	129.3±1.0b	46.8±0.6a,b	68.3±0.9a,c
100:4	141.2±1.2b	48.2±0.9a,b	73.8±0.8b
100:6	160.8±1.3c	52.3±0.8b	62.7±0.8c
100:8	175.6±1.3d	54.1±0.7b	75.3±0.8a,d
100:10	189.3±1.3e	56.92±0.7c	81.0±0.9d
0:100	255.9±1.5f	72.85±0.8d	102.5±1.0e

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