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INFLUENCE OF INDIGENOUS EARTHWORM ON MAJOR NUTRIENT CHANGES DURING DEGRADATION OF DIFFERENT ORGANIC WASTE

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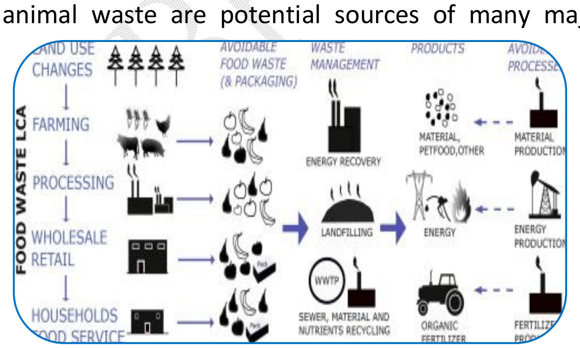
ABSTRACT :

Organic waste bioconversion through vermicomposting is a widely used method for disposal of organic wastes for nutrients recovery. Application of fresh organic wastes or non-stabilized compost to soil may leads to immobilization of plant nutrients and cause phytotoxicity. The aim of this study was poultry droppings (PD) mixed with rice husk (RH) and sugar cane press mud (SPM) at various proportions to make different treatments and kept for natural stabilization for 15 days and subsequently vermicomposted using native earthworm species P. ceylanensis for a period of 75 days under laboratory conditions in order to produce stabilized organic fertilizer. The vermicompost were sampled at 0, 25, 50 and 75 days for the assessment of temporal changes in nutritional properties. Results revealed that nutrient contents during vermicomposting showed a significant variation in all the treatments ($p<0.05$) for all the sampling days. Among the different treatments, maximum increase was observed in VCPT2, VCPT3, VCPT6 and VCPT7 for P. ceylanensis after experimentation, respectively and were not significantly significant different from ($P < 0.05$) each other, while significantly different with other worm composting treatments and without worm treatments. Therefore producing nutrient rich stabilized product from PD, RH and SPM useful for sustaining high crop yield and minimizing soil depletion.

KEYWORDS : *Vermicomposting, poultry droppings, press mud, Nutrients.*

INTRODUCTION

Biomass generation has increased in recent years due to increased agricultural and agro-industrial production and its processing is a serious problem for present society (Amir et al., 2005). With the increase in organic wastes, landfill space has become the limiting factor for disposal as a result recycling through available local earthworms species has become an attractive option for the treatment of these residues. Poultry and livestock industries are growing rapidly along with the human population and production of animal waste are potential sources of many major environmental problems. India is one of the main producers of poultry in the world and the poultry manure availability is estimated to be 12.1 million tons (The week end leader, 2014). In the poultry farm large amount of droppings that accumulated in the litter turns it into importance sources of contamination i.e. odorous gases including amines, amides, mercaptans, sulphides and disulphides. These noxious gases can cause respiratory disease in animals and humans (Schiffamn and Williams, 2005). However, poultry droppings along with litter has useful nutrients, and is



therefore used as organic fertilizer but uncontrolled decomposition and excess applications to soil can cause environmental problems due to their extremely high levels of nitrogen as ammonia, low pH, and heat generation (Moore *et al.,* 1995).

In addition, India is one of the primary growers of sugarcane with an estimated production of approximately 300 million tons in the marketing for every year. Huge amount of solid waste streams generated during sugar manufacturing process including sugarcane trash, press mud and bagasse. Mostly sugarcane industry generates enormous amount of residue after the sugarcane juice has been clarified commonly known as press mud. For about 134 million tons of sugarcane crushed, 4.0 million tons of filter mud are produced (Manivannan *et al.,* 2004). There is a major disposal problem for the filter mud although it is fairly rich in organic nutrients; it finds little use as bio-fertilizer (Sen and Chandra, 2007). Similarly, rice husk as by-product of the rice milling and is extensively available in rice producing country like India (Soltani *et al.,* 2015). Approximately 500 million tons paddy produced by world every year and 120 million tones of paddy produced by India, it gives around 24 million tones of RH per year (Sinha, 2010).

Therefore, there is an urgent need to recycle the RH, PD and SPM without environmental impact. Numerous technologies are harnessed to deal with the organics that have the feasible to pollute the environment. Existing technologies concentrate to oxidize the organics in the waste producing a new stream that has its own disposal problems. The need of the hour is to develop close loop technologies which harness the renewable energy and nutrient of these waste organics to fuel amend the soil. Vermicomposting process is a stabilization of organic waste involving the joint action of earthworms and microorganisms (Khwairakpam and Bhargava, 2009). Epigeic earthworms have been used as an alternative tool to convert different types of organic waste resource into a product with relatively higher concentration of plant nutrients. Hence, the present work is aimed to study the nutrient changes during vermicomposting by local earthworm's *P. ceylanensis* using RH, PD and SPM in different ratios in order to agronomic utilization.

MATERIALS AND METHODS

Collection of organic wastes

The poultry droppings (PD) were collected from Indian feeds farm, Perumal kovilmedu, Namakkal district, Tamil Nadu, India. Sugar cane press mud (SPM) was obtained from Thiru Arooran Sugars Limited, located at Tirumandangudi, Thanjavur district, Taminadu, India. Rice Husk (RH) was collected from a modern rice mill, Vandikkara Street, Thanjavur, Tamil Nadu, India. The poultry droppings were transported to the laboratory using sterile plastic bags. PD and SPM were sundried separately for 15 days to remove the odor and noxious gases.

Selection of earthworms

Indigenous, efficient epigeic species *Perionyx ceylanensis* were selected for their survival and obtained from the stock culture which was cultivated in cow dung in the laboratory, Department of Zoology, Annamalai University, India. The worms were stocked in cement tank and one month old cow dung was used as substrate to maintain the earthworms.

Experimental design

In the present study, different treatments containing different ratios of poultry droppings (PD) with bulking material Sugar industry press mud (SPM) and rice husk (RH) mixtures were prepared (Table 1). Each was weighed (dry weight) in the above said description and treatments of VCPT1, VCPT2, VCPT3, VCPT4, VCPT5, VCPT6 and VCPT7 were composed of different proportions of PD, RH and SPM with *P. ceylanensis*. The waste mixtures were transferred to separate plastic troughs with 40cm diameter x 60cm depth, respectively. The troughs were filled with 5kg substrate per troughs in above combinations. After transferred in the plastic troughs all the mixture compositions of PD, RH and SPM were allowed for seven days of initial natural decomposition. All the experimental treatments were kept in six replicate for each treatment in a completely randomized block design. The above treatments were kept under shade and irrigated with equal quantity of water to ensure that the substrate moisture content was maintained at approximately 65-75%. After the completion of pre-inoculation period of 7days, *P. ceylanensis* were weighed and inoculated in to respective each treatment (Manivannan *et al.,* 2004). Controls for the above treatments CT1, CT2, CT3, CT4, CT5, CT6 and CT7 were also included without the inoculation of *P. ceylanensis*. Periodically the samples in each treatment was collected on day 25, 50 and 75 were used to nutrient analysis.

Nutrient analysis

The pH and electrical conductivity (EC dSm^{-1}) were determined using a double distilled water suspension in the ratio of 1:10 (W/V) using a digital pH and conductivity meter. Total organic carbon (TOC) content in the sample was determined by chromic oxidation method (Jackson, 1973). Furthermore total Kjeldhal nitrogen (TKN) was measured by micro Kjeldhal method (Jackson, 1973). Total phosphorus (TP) was estimated by vanadomolybdo phosphoric acid yellow colour method using a colorimeter (Model 115, Systronics, India) (Jackson,1973).While Total potassium (TK) was detected by the method of Jackson (1973) using flame photometer (Model 128, Systronics, India). C: N was considered from the measured value of C and N. Results are the means of the three replicates. Two way analysis of variance was performed by using the SPSS software.

RESULTS AND DISCUSSION

In this study the nutritional value of vermicompost depends on several factors viz., characters of feed substrate, surrounding environmental factors (aeration, humidity and temperature), and earthworm species used in the worm composting process. Therefore, it is essential to specify various nutritional characters to enumerate the dynamics of worm composting process (Tables 2- 8). The pH of final substrate was significantly different than initial substrate material and the changes of pH in the vermicompost produced by *P.ceylanensis* are given in Table 2. However, there were slight changes in the pH of vermicompost produced by *P. ceylanensis* as compared to initial values. The pH decreased from alkaline to slightly acidic in all the treatments of *P. ceylanensis*. A decreasing trend (alkaline to slightly acidic/neutral) in pH was found with higher amount of RH and PD with SPM in the treatment. The increase in pH during composting of this study was attributed to the production of ammonia associated with protein degradation in the raw materials and to the decomposition of organic acids (Warman and Tremmeer, 2005). Moreover, presence of carboxylic and phenolic groups in humic acids caused lowering of pH while ammonium ions increased the pH of the system and combined effect of these two oppositely charged ions actually regulates the pH of compost leading to a shift of pH towards neutrality at the end of composting and vermicomposting (Ndegwa and Thompson, 2000).

A significant increase in EC of vermicompost was observed in all the PD, RH and SPM treatments as compared to the initial substrate and control treatments. The maximum increase in EC was observed in treatments VTPT3, VTPT5, VTPT7 and VTPT6. Whereas, the increases in EC was not statistically significant among worm worked and worm un worked natural compost treatments at the end of worm experiment, respectively (Table 3). In the present study, maximum increase in EC during composting and vermicomposting treatments might have been due to effective composting by earthworms and release of different mineral ions, such as phosphate, ammonium, and potassium during composting and vermicomposting, respectively (Yadav and Garg, 2011). In this study total organic carbon (TOC) content was lesser in all the vermicomposts produced by *P.ceylanensis* than control treatments and initial TOC content. Maximum decrease in TOC was recorded in VCPT2, VCPT3, VCPT6 and VCPT7 treatments at the end of experimentation, respectively than other treatments. However, minimum reduction of TOC was recorded in VCPT4 and VCPT5 among worm composting (Table 4). The results observed in this study are consistent with previous work of Molla *et al.,* (2001) and Manivannan *et al* (2004) and they reported that significant reduction in total organic carbon content after vermicomposting. Moreover in this study there was a significant difference among the treatments for TOC possibly due to different rate of enzyme activity related to carbon mineralization.

TN content in initial mixtures and vermicompost is given in Table 5. An increase in the TN content after worm composting was observed in all the treatments of *P. ceylanensis*. Maximum increase was observed in the experimental treatments of VCPT2, VCPT3, VCPT6 and VCPT7 for *P.ceylanensis* after experimentation, respectively and were not significantly significant different from ($P < 0.05$) each other, although significantly different with other worm composting treatments and without worm treatments. Increase in nitrogen content in the final product in the form of mucus, nitrogenous excretory substances, growth stimulating hormones and enzymes from earthworms have also been reported (Manivannan *et al.*, 2004). The C:N ratio of vermicompost was decreased significantly as compared to the initial waste material and worm unworked treatments (VCPT1 – VCPT7) after worm composting than control treatments. In the present observation reduction in C:N ratio during worm composting was in the range from 55.21 to 95.29% for *P. ceylanensis* (Table 6). The C:N ratio was statistically different in all the vermicomposting treatments except for VCPT2 and VCPT3 treatments ($P < 0.05$).

All the vermicomposting treatments assessed in this study responded with increases in TP content which was significantly increased as compared to the initial substrate material and control treatments at the end of experiment (Table 7). The maximum increase of TP was recorded on 50 day of worm composting in VCPT2, VCPT3, VCPT6 and VCPT7 treatments for *P.ceylanensis*. Similarly, the total potassium (TK) content was increased in all treatments of worm composting than control treatments (Table 8). Total K content of the vermicompost reached a maximum level on 50 days of worm composting and slightly decreased at the end of experiment (75 day). Whereas, the differences in TK content in the vermicompost obtained from VCPT1, VCPT2, VCPT3, VCPT4, VCPT5, VCPT6 and VCPT7 treatments of *P. ceylanensis* was statistically significant ($P <0.05$). The significant increase in TP during experimentation is may be due to mineralization and mobilization of phosphorus by microbes and phosphate activity of microorganisms (Mahesh kumar and Manivannan, 2015). The previous studies suggested that microorganism processed waste material contains higher concentration of exchangeable K due to enhanced microbial activity during the vermicomposting process, which consequently enhances the rate of mineralization (Suthar, 2007).

CONCLUSION

This study suggests that selective earthworms effectively degraded these waste in the treatments, however, the highest degradation was recorded in VCPT2, VCPT3, VCPT6 and VCPT7 treatments by *P.ceylanensis*. Moreover, Among the various amendment combinations, 1:1:1: ratio, gave the best result in terms of macronutrients and C:N ratio.

Table 1: Description of different treatments with poultry droppings, rice husk and sugar industry press mud used for experimentations

Treatments	Treatment description	proportion
Vermicomposting with *P. ceylanensis*		
VCPT1	Poultry droppings (PD)+ Rice husk (RH)	1:1
VCPT2	Poultry droppings (PD) + Press mud (SPM)	1:1
VCPT3	Poultry droppings (PD)+ Rice husk (RH)+ Press mud (SPM)	1:1:1
VCPT4	Poultry droppings (PD)+ Rice husk (RH)	3:1
VCPT5	Poultry droppings (PD)+ Press mud (SPM)	3:1
VCPT6	Poultry droppings (PD)+ Rice husk (RH)	1:3
VCPT7	Poultry droppings (PD)+ Press mud (SPM)	1:3
without the inoculation of worms (controls)		
CT8	Poultry droppings (PD)+ Rice husk (RH)	1:1
CT9	Poultry droppings (PD) + Press mud (SPM)	1:1
CT10	Poultry droppings (PD)+ Rice husk (RH)+	1:1:1

	Press mud (SPM)	
CT11	Poultry droppings (PD)+ Rice husk (RH)	3:1
CT12	Poultry droppings (PD)+ Press mud (SPM)	3:1
CT13	Poultry droppings (PD)+ Rice husk (RH)	1:3
CT14	Poultry droppings (PD)+ Press mud (SPM)	1:3

Table 2: pH variation in initial substrate and vermicompost obtained from different treatments.

Experimental Treatments	pH			
	Days			
	0	**25**	**50**	**75**
VCPT1	6.5±0.04^{a}	6.2±0.05^{a}	6.8±0.02^{a}	6.5±0.02^{a}
VCPT2	7.9±0.03b^{c}	7.6±0.03^{c}	7.2±0.05^{b}	7.0±0.05^{b}
VCPT3	8.2±0.06^{c}	8.0±0.02^{bc}	7.2±0.03^{b}	6.9±0.06^{a}
VCPT4	7.5±0.04^{b}	7.4±0.02^{b}	7.8±0.02^{bc}	7.7±0.07^{b}
VCPT5	7.8±0.07^{bc}	7.7±0.05^{bc}	7.9±0.07^{bc}	7.8±0.06^{c}
VCPT6	8.1±0.05^{c}	8.0±0.04^{c}	7.3±0.04^{b}	7.2±0.04^{b}
VCPT7	8.1±0.06^{c}	7.9±0.03b^{c}	7.3±0.06^{b}	7.2±0.06^{b}
CT8	6.5±0.04^{a}	6.1 ±0.05^{a}	6.6±0.04^{a}	6.2±0.04^{a}
CT9	7.9±0.03b^{c}	6.0±0.09^{a}	6.8±0.04^{a}	6.7±0.05^{a}
CT10	8.2±0.06^{c}	8.0±0.03^{c}	7.2±0.02^{b}	6.9±0.04^{a}
CT11	7.5±0.04^{b}	7.7±0.05^{bc}	7.9±0.07b^{c}	7.8±0.06^{bc}
CT12	7.8±0.07^{bc}	7.5±0.02^{b}	6.1±0.07^{a}	6.1±0.02^{a}
CT13	8.1±0.05^{c}	7.8±0.07bc	7.6 ±0.05^{b}	7.3±0.04^{b}
CT14	8.1±0.06c	8.0±0.04c	7.9±0.03^{bc}	7.3±0.05^{b}

VCPT1 to VCPT7: Vermicomposting by *P. ceylanensis*; CT8 to CT14: Without the inoculation of worms (controls); Mean values followed by different letters in same column are statistically different (ANOVA; Tukey's test, $p<0.05$).

Table 3: EC variation in initial substrate and vermicompost obtained from different treatments.

Experimental Treatments	EC (dSm^{-1})			
	Days			
	0	**25**	**50**	**75**
VCPT1	1.7±0.04a	1.9±0.07a	2.1±0.05c	2.0±0.03bc
VCPT2	2.1±0.03b	3.3±0.04c	3.9±0.05cd	3.5±0.04c
VCPT3	2.3±0.04b	3.4±0.05c	3.9±0.04cd	3.6±0.05c
VCPT4	2.0±0.05b	3.1±0.08c	3.3±0.05c	3.1±0.07c
VCPT5	2.1±0.03b	3.2±0.05c	3.5±0.06c	3.4±0.03c
VCPT6	2.3±0.04b	3.5±0.08c	3.7±0.07c	3.5±0.05c
VCPT7	2.0±0.05b	3.2±0.03c	3.8±0.06cd	3.5±0.06c
CT8	1.7±0.04a	1.9±0.04a	2.7±0.07b	2.7±0.05
CT9	2.1±0.03b	2.7±0.05b	2.8±0.05b	2.5±0.04c
CT10	2.3±0.04b	2.5±0.05b	2.9±0.03b	2.6±0.09b
CT11	2.0±0.05b	2.7±0.04b	2.7±0.04b	2.5±0.07b
CT12	2.1±0.03b	2.9±0.03b	2.7±0.05b	2.6±0.06b
CT13	2.3±0.04b	2.5±0.02b	2.9±0.06b	2.6±0.06b

CT14	2.0±0.05b	2.7±0.06b	2.8±0.04b	2.6±0.05b

VCPT1 to VCPT7: Vermicomposting by *P. ceylanensis*; CT8 to CT14: Without the inoculation of worms (controls); Mean values followed by different letters in same column are statistically different (ANOVA; Tukey's test, $p<0.05$).

Table 4: Changes in TOC of initial substrate and vermicompost obtained from different treatments.

Experimental Treatments	TOC (gkg^{-1})			
	Days			
	0	25	50	75
VCPT1	423.6±18d	344.4±11b	302.8±19b	261.7±14a
VCPT2	430.7±27d	326.4±15b	290.6±15ab	245.8±25a
VCPT3	423.4±18d	324.9±17b	291.5±21ab	247.6±13a
VCPT4	431.6±15d	352.5±12b	311.8±20b	265.5±16a
VCPT5	407.7±21cd	309.7±19ab	281.6±25ab	261.8±17a
VCPT6	430.9±27d	346.7±16b	308.4±27b	258.3±25a
VCPT7	451.6±15de	332.4±23b	293.5±19ab	252.4±12a
CT8	423.6±18d	472.7±15ef	386.4±15c	362.5±17bc
CT9	430.7±27d	415.7±23cd	390.9±54c	327.7±53b
CT10	423.4±18d	407.5±21cd	329.7±24b	294.5±15ab
CT11	431.6±15d	472.7±15ef	405.5±11cd	375.3±16c
CT12	407.9±21cd	465.4±18ef	392.3±15c	347.2±22bc
CT13	430.5±27d	463.21±18ef	382.4±11c	344.5±26bc
CT14	451.7±15de	461.4±18ef	372.7±11bc	338.4±27bc

VCPT1 to VCPT7: Vermicomposting by *P. ceylanensis*; CT8 to CT14: Without the inoculation of worms (controls); Mean values followed by different letters in same column are statistically different (ANOVA; Tukey's test, $p<0.05$).

Table 5: TN content in initial substrate and vermicompost obtained from different treatments.

Experimental Treatments	TN (gkg^{-1})			
	Days			
	0	25	50	75
VCPT1	6.1±0.37a	11.6±0.21d	18.7±0.31f	18.4±0.44f
VCPT2	6.5±0.21a	16.4±0.25e	22.7±0.45g	20.8±0.15g
VCPT3	6.9±0.19a	16.8±0.31e	23.6±0.41gh	21.4±0.26g
VCPT4	6.9±0.21a	15.7±0.19e	20.6±0.27g	18.0±0.27f
VCPT5	6.4±0.21a	11.5±0.45d	18.2±0.40f	18.0±0.35f
VCPT6	6.8±0.19a	11.8±0.19d	18.9±0.19f	18.1±0.15f
VCPT7	6.1±0.37a	15.4±0.25e	22.7±0.21g	20.4±0.25g
CT8	6.1±0.37a	7.5±0.13a	10.5±0.11cd	9.5±0.15bc
CT9	6.5±0.21a	8.9±0.21b	11.2±0.15d	9.8±0.38bc
CT10	6.9±0.19a	7.5±0.42a	12.5±0.09d	9.11±0.57bc
CT11	6.9±0.21a	7.9±0.13a	8.5±0.23b	8.7±0.21b
CT12	6.4±0.21a	8.2±0.13b	8.5±0.23b	8.9±0.21b
CT13	6.8±0.19a	8.5±0.13b	11.5±0.11d	9.2±0.19bc
CT14	6.1±0.37a	8.9±0.42b	10.9±0.07cd	9.5±0.18bc

VCPT1 to VCPT7: Vermicomposting by *P. ceylanensis*; CT8 to CT14: Without the inoculation of worms (controls); Mean values followed by different letters in same column are statistically different (ANOVA; Tukey's test, $p<0.05$).

Table 6: C:N ratio in initial substrate and vermicompost obtained from different treatments.

Experimental Treatments	C:N ratio	
	Initial substrate	Final material
VCPT1	69.44±0.27ab	14.2±0.8a
VCPT2	66.15±0.35ab	11.8±0.9a
VCPT3	61.30±0.14a	11.6±0.5a
VCPT4	62.44±0.45a	14.3±0.5a
VCPT5	63.72±0.58a	14.6±0.7a
VCPT6	63.21±0.64a	13.3±0.6a
VCPT7	74.70±0.74b	12.4±0.2a
CT8	69.44±0.27ab	38.2±1.5b
CT9	66.15±0.35ab	33.4±1.7b
CT10	61.35±0.14a	32.3±2.4b
CT11	62.44±0.45a	43.1±1.8bc
CT12	63.77±0.58a	39.0±1.4b
CT13	63.28±0.64a	37.4±1.9b
CT14	74.90±0.74b	36.6±2.5b

VCPT1 to VCPT7: Vermicomposting by *P. ceylanensis*; CT8 to CT14: Without the inoculation of worms (controls); Mean values followed by different letters in same column are statistically different (ANOVA; Tukey's test, $p<0.05$).

Table 7: TP in initial substrate and vermicompost obtained from different treatments.

Experimental Treatments	TP(gkg^{-1})			
	Days			
	0	25	50	75
VCPT1	6.2±0.31a	12.3±0.18c	15.6±0.29e	15.4±0.31e
VCPT2	6.2±0.31a	13.7±0.25cd	17.2±0.28ef	16.3±0.41e
VCPT3	6.6±0.19a	13.9±0.38cd	17.9±0.19ef	16.2±0.27e
VCPT4	6.9±0.21a	12.8±0.41c	15.2±0.25e	14.3±0.25de
VCPT5	5.8±0.11a	13.0±0.18cd	15.7±0.18e	14.5±0.24de
VCPT6	6.6±0.19a	12.5±0.13c	16.1±0.15e	15.5±0.19e
VCPT7	5.9±0.23a	13.4±0.17cd	16.9±0.32e	15.1±0.19e
CT8	6.2±0.31a	7.9±0.15ab	9.8±0.21b	9.2±0.10b
CT9	6.2±0.31a	9.5±0.15b	13.2±0.32cd	12.2±0.19c
CT10	6.6±0.19a	12.5±0.18c	14.5±0.27de	14.1±0.17de
CT11	6.9±0.21a	6.9±0.22a	8.7±0.09b	8.2±0.06b
CT12	5.8±0.11a	7.4±0.18ab	9.4±0.19b	9.1±0.15b
CT13	6.6±0.19a	9.7±0.22b	12.5±0.17c	11.4±011c
CT14	5.9±0.23a	10.3±0.52b	13.8±0.41cd	12.7±0.27c

VCPT1 to VCPT7: Vermicomposting by *P. ceylanensis*; CT8 to CT14: Without the inoculation of worms (controls); Mean values followed by different letters in same column are statistically different (ANOVA; Tukey's test, p<0.05).

Table 8: TK in initial substrate and vermicompost obtained from different treatments.

Experimental Treatments	TK (g kg^{-1})			
	Days			
	0	25	50	75
VCPT1	3.8±0.15a	7.8±0.36bc	9.9±0.23c	9.5±0.17c
VCPT2	3.9±0.17a	8.5±0.12bc	10.5±0.17c	10.1±0.45c
VCPT3	3.9±0.26a	8.9±0.29c	10.8±0.16cd	10.4±0.18c
VCPT4	3.4±0.24a	6.3±0.11b	9.0±0.13c	8.2±0.08bc
VCPT5	3.5±0.23a	6.7±0.27b	9.2±0.14c	8.9±0.31c
VCPT6	3.9±0.15a	8.0±0.25bc	10.1±0.24c	9.6±0.22c
VCPT7	3.9±0.29a	8.2±0.09bc	10.3±0.31c	9.6±0.17c
CT8	3.8±0.15a	5.4±0.14ab	6.8±0.03b	6.2±0.26b
CT9	3.9±0.17a	7.2±0.25bc	8.0±0.16bc	7.6±0.25bc
CT10	3.9±0.26a	7.8±0.31bc	8.7±0.15bc	8.2±0.42bc
CT11	3.4±0.24a	5.0±0.19ab	6.3±0.36b	6.0±0.08b
CT12	3.5±0.23a	5.2±0.14ab	6.5±0.03b	6.0±0.26b
CT13	3.9±0.15a	6.5±0.19b	6.9±0.19b	6.5±0.20b
CT14	3.9±0.29a	6.5±0.12b	6.9±0.35b	6.5±0.43b

VCPT1 to VCPT7: Vermicomposting by *P. ceylanensis*; CT8 to CT14: Without the inoculation of worms (controls); Mean values followed by different letters in same column are statistically different (ANOVA; Tukey's test, p<0.05).

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