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Influence of Earthworm *Lampito mauritii* (Kinberg) and Organic Additives for Efficient Vermicomposting of Fly Ash

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Abstract: In India, coal fly ash and pressmud are produced in large quantities and the storage or spreading of this waste on land causes contamination of the atmosphere, soil and water. The aim of this study was to convert coal fly ash (CFA) and pressmud (PM) mixed with cow dung (CD) into vermicompost using an anecic earthworm *Lampito mauritii* (Kinberg). Five treatments containing CD, CFA and PM in different ratios namely CFA: PM: CD in 1:1:8 ratio (T_1), CFA: PM: CD in 2:2:6 ratio (T_2), CFA: PM: CD in 3:3:4 ratio (T_3), CFA: PM: CD in 4:3:3 ratio (T_4) and CFA: PM: CD in 3:4:3 ratio (T_5) were run under laboratory conditions. The physico-chemical changes of substrate materials in different treatments were measured at the end of vermicomposting (90 days). The vermicomposted material showed decrease in Total Organic Carbon (TOC) (10.8 –27.3%), pH (9.2 – 11.6%) and Total Potassium (TK) (9.0 – 21.5%) and increase in Electrical Conductivity (EC) (12.6 – 14.1%), Total Kjeldhal Nitrogen (TKN) (33.3 – 85.2%) as well as Total Phosphorus (TP) (56.5 – 88.8%) contents. *L. mauritii* showed better growth performance in T_1 treatment also worms grew favourably in T_2 and T_3 treatment. Greater proportion of CFA and PM in T_4 and T_5 treatment significantly reduces ($p < 0.05$) the growth and reproduction rate of *L. mauritii* during experimentation. This study clearly indicates that CFA and PM could be potentially used as raw substrate in vermicomposting if mixed with CD in 1:1:8, 2:2:6 and 3:3:4 ratios, respectively.

Key words: Press Mud · Earthworm · Nutrient Changes · Growth

INTRODUCTION

The safe disposal and environmental friendly management of organic solid wastes have become a global priority. In India, about 80 million metric tons of coal fly ash is generated annually from thermal power stations with only a minor part used now for preparing bricks, ceramics and cements. Unclaimed coal fly ash occupies an additional 100 ha of land each year. Through washouts in each rainy season adjacent areas, including rice fields, inevitably become contaminated, thus potentiating grave problems [1]. Coal fly ash, contains silica, aluminium, oxides of iron, magnesium, calcium, chromium, arsenic, lead, zinc, nickel and other toxic metals [2, 3]. Some possible agronomic uses of coal fly ash as, a fertilizer [4, 5], a liming material [6] and as a physical amendment [7] have been indicated. Lower amendment levels of coal fly ash caused enhancements of both growth and yield while adverse effects at high levels were observed [8].

According to Department of Agriculture and co-operation, sugarcane production in India was estimated at 232.3MT during 2004-2005. During the production process considerable amounts of products such as pressmud, bagasse and trash are produced. Sugarcane mills mainly use activated sludge process for waste water treatment, which generates huge quantity of sludge commonly known as pressmud [9]. Parthasarathi [10] has reported approximately 12 million tons pressmud is produced in India annually. Pressmud generates intense heat (65°C), foul odour and takes long time for natural decomposition [11] and its high rate of application to soil leads to soil sickness and water pollution [12]. Pressmud has significant fertilizer value as it is a rich source of organic matter, organic carbon, sugar, protein, enzymes, micronutrients (Zn, Fe, Cu, Mn, etc.) and macronutrients (N, P and K) and higher microbial [13].

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Therefore, appropriate coal fly ash and pressmud management technology is desired which not only protects and conserves the environment but also to recover the nutrients present in it. In this regard, vermicompositing has been reported to be a viable, cost-effective and rapid technique for the efficient management of disposal of agricultural as well as industrial wastes [14-18]. The anecic earthworm, i.e. *Lampito mauritii* (Kinberg), which is commonly found in Indian soils, has appeared as an efficient tool for organic waste reduction [19]. The composting efficiency and biology of *L. mauritii*, is well documented in literature. Several workers have reported the vermicomposting potential of *L. mauritii* by using a variety of organic wastes [20, 21]. Hence the objectives of this study were to test the feasibility of earthworm *L. mauritii* to recycle coal fly ash mixed with pressmud and cow dung in different ratios. The assessment of growth and reproduction performance of *L. mauritii* in this vermicomposting system was also monitored.

MATERIALS AND METHODS

Coal Fly Ash, Pressmud and Cow Dung: Coal fly ash (CFA) was procured from the dumping site of thermal power station I, Neyveli Lignite Corporation (NLC), Tamil Nadu, India. Pressmud (PM) was obtained from effluent treatment plant of E.I.D.Parry Sugar Mill located at Nellikkuppam, Tamil Nadu, India. Fresh cow dung (CD) was collected from an intensively live stocked farm, Faculty of Agriculture, Annamalai University, Tamil Nadu, India. The main physico-chemical characteristics of all the three amended materials, i.e., CD, CFA and PM are given in Table 1.

Earthworms: Healthy clitellated species of earthworm, i.e., *Lampito mauritii* (Kinberg) were collected locally from agricultural field, Faculty of Agriculture, Annamalai University by hand sorting method. The species were identified at Department of Zoology, Annamalai University. The worms were cultured in mass culture tanks containing cow dung medium in the laboratory and were randomly picked for experimentation.

Treatment Design: The PM and CD was dried in air at room temperature. CFA was mixed with PM and CD in different ratios in order to produce different treatments (dry weight proportion). The composition of CFA, PM and CD in different treatments are described in Table 2. One kg of substrate material was added to each circular plastic container (Vol. 10L, diameter 38cm, depth 14cm) for experimental trial. All the treatments were kept for 14 days prior to experimentation for thermal stabilization, initiation of microbial degradation and softening of substrate material (pre-composting). Twenty clitellated earthworms, *L. mauritii* were inoculated into each treatment (after the end of pre-composting). During the vermicomposting period (90 days), the moisture content of the substrate in each treatment was kept at 70 – 75% by periodic sprinkling of adequate quantity of water. The experimental treatments were kept in triplicate. All the containers were placed in a humid and dark room at a temperature of 28.5±3°C. 100g of homogenized samples (free from earthworms, cocoons and hatchlings) of the substrate material were drawn at 0 (initial) and at 90 days (final product) from each treatment. Day 0 indicates the day of inoculation of earthworms. Initial substrate and vermicompost (final product) were air dried at room temperature and packed in airtight bottles for further physico-chemical analysis. The changes in individual biomass of *L.mauritii* in different treatments were determined by following method described by Suthar [22].

Table 1: Physico-chemical characteristics of CD, CFA and PM used in experiment

Parameters	CD	CFA	PM
pH	8.1±0.1	8.8±0.2	7.3±0.4
TOC (g kg^{-1})	429.7±2.7	297.9±5.1	445.7±3.4
TKN (g kg^{-1})	6.5±0.6	3.2±0.7	12.1±0.3
TP (g kg^{-1})	6.8±0.4	2.4±0.1	6.1±0.2
TK (g kg^{-1})	5.1±0.1	5.3±0.4	8.2±0.6
EC (mS cm^{-1})	1.21±0.20	0.75±0.08	1.19±0.09

All data represented average of triplicates

Table 2: Composition of different treatments used for experimentations

Treatment	Substrate composition --------------------------- CFA[a] PM[b] Cd[c]	Ratio
T_1	100g + 100g + 800g	1:1:8
T_2	200g + 200g + 600g	2:2:6
T_3	300g + 300g + 400g	3:3:4
T_4	400g + 300g + 300g	4:3:3
T_5	300g + 400g + 300g	3:4:3

[a] Coal Fly ash; [b] Pressmud; [c] Cow dung

Physico-Chemical Analysis: The pH and electrical conductivity (EC) were analysed in a 1:5 (v/v) water extract using a glass electrode. Total organic carbon (TOC) was measured using the method (partial oxidation) of Nelson and Sommers [23]. Total Kjeldhal nitrogen (TKN) was determined by digesting the samples with concentrated H_2SO_4 and $HClO_4$ (9:1, v/v) by Bremner and

Mulvaney [24] procedure. Total phosphorus (TP) was analysed using the method of Bansal and Kapoor [25]. Total potassium (TK) was determined by flame photometer after digesting the sample in diacid mixture (Conc. HNO_3 and Conc. $HClO_4$ (4:1, v/v) [25]. Data were subjected for analysis of variance (ANOVA) followed by Tukey's test to differentiate the significant difference between different treatments for chemical parameters, earthworm growth. The probability levels used for statistical significance were $p < 0.05$ for the tests.

RESULTS AND DISCUSSION

Physico-Chemical Changes During Vermicomposting: Physico-chemical characteristics of the initial feed mixtures and vermicompost after 90 days of vermicomposting are presented in Table 3. A decrease in pH was recorded in all treatments (T_1 – T_5) during vermicomposting. The maximum reduction for pH (as compared to initial values) was in T_1 and minimum in T_4. Other authors have found similar results in vermicomposting experiments and have suggested that the mineralization of nitrogen and phosphorus compounds, the release of CO_2 and organic acids by microbial metabolism and the production of humic and fulvic acids, as possible cause of the decrease in pH [26, 9]. The changes in pH during the experiment could be due to microbial decomposition during the process of vermicomposting. TOC of the final vermicompost was significantly ($P < 0.05$) reduced at the end of the experiment, as compared to the initial feed mixtures (Table 3). The maximum reduction in TOC was for T_1 treatment (lower than initial value) followed by T_2, T_3, T_5 and T_4. The results obtained in this study suggest that net organic matter stabilization in the substrate material was due to combined action of earthworms and microorganisms. A high TOC loss pattern in T_1, T_2 and T_3 treatment could be attributed to the rapid microbial respiration rate during vermicomposting [27]. The observed results are supported by those of other authors [14, 28] who have reported a significant decline in organic carbon in earthworm processed substrate material at the end of vermicomposting period. The EC was increased in the range of 12.6 – 14.1% for different treatments after 90 days of vermicomposting but the variation was insignificant among all the treatments (Table 3). Increase in EC was also reported by some authors during vermicomposting of sewage sludge using *Eudrilus eugeniae, Eisenia fetida* and *Perionyx excavatus* [27, 28]. The increase in EC may be due to loss of organic matter and release of different mineral salts in available forms (phosphate, ammonium, potassium, etc.) during vermicomposting [29].

TKN was significantly higher in the end product than initial substrate material (Table 3). The maximum TKN increase was in T_1 followed by T_2, T_3, T_5 and T_4. The difference in the TKN content of the vermicompost obtained from T_1, T_2 and T_3 treatments was not statistically significant ($P < 0.05$). Elvira *et al.*[30] have reported that TKN content increased significantly at the end of the vermicomposting period, probably because of mineralization of the organic matter. The results indicated that nitrogen enrichment pattern and mineralization activities mainly depend upon the total amount of N in the initial substrate material [31, 13]. Table 3 shows, at the end of the vermicomposting experiment maximum increase (compared to its initial value) in TP was registered in T_3, followed by T_1, T_2, T_4 and T_5 treatment. However, the differences in TP concentration in T_1, T_2 and T_3 was not significantly different, indicating the suitability of

Table 3: Physico-chemical characteristics of initial substrate and vermicompost obtained from different treatments

Treatment	pH	EC (mS cm^{-1})	TOC (g kg^{-1})	TKN (g kg^{-1})	TP (g kg^{-1})	TK (g kg^{-1})
Physico-chemical characteristics of initial substrate in different treatments after pre-composting of 14 days						
T_1	7.7±0.1	1.51±0.27	444.55±29.2	11.5±1.2	5.1±0.1	14.5±1.2
T_2	7.9±0.2	1.50±0.13	437.71±18.1	11.8±3.1	4.7±0.2	14.1±1.4
T_3	8.1±0.1	1.43±0.21	422.32±11.3	11.6±2.4	4.5±0.1	13.5±1.2
T_4	8.3±0.3	1.41±0.32	416.43±18.6	11.3±1.6	4.2±0.2	12.4±1.3
T_5	7.8±0.1	1.44±0.11	420.48±11.2	11.9±2.7	4.6±0.4	12.9±1.1
Physico-chemical characteristics of vermicompost obtained from different treatments after 90 days of vermicomposting (mean±SD., n = 3)						
T_1	6.9±0.2 ^{a}	1.70±0.21 ^{a}	349.21±17.2 ^{a}	21.3±2.3 ^{a}	9.6±0.3 ^{b}	13.3±1.2 ^{b}
T_2	7.2±0.1 ^{ab}	1.71±0.17 ^{a}	351.68±29.3 ^{a}	20.2±1.3 ^{a}	8.8±0.2 ^{b}	12.6±1.5 ^{b}
T_3	7.3±0.2 ^{b}	1.62±0.19 ^{a}	353.37±21.2 ^{a}	20.1±1.7 ^{a}	8.5±0.5 ^{b}	12.2±0.6 ^{ab}
T_4	7.6±0.2 ^{c}	1.61±0.24 ^{a}	381.51±15.1 ^{ab}	15.4±3.2 ^{b}	7.1±0.4 ^{a}	10.2±0.9 ^{a}
T_5	7.1±0.3 ^{ab}	1.63±0.13 ^{a}	379.33±12.3 ^{ab}	16.6±2.4 ^{b}	7.2±0.3 ^{a}	11.3±0.7 ^{ab}

Mean value followed by different letters (a – c) is statistically different (ANOVA, Tukey's test, $P < 0.05$)

Table 4: Growth of *L. mauritii* in different treatments (mean±SD., n = 3)

Treatment	Mean initial biomass worm^{-1} (mg)	Maximum biomass achieved worm^{-1} (mg)	Net biomass gained worm^{-1} (mg)	Maximum biomass achieved (week)	Growth rate worm^{-1} day^{-1} (mg)
T_1	376.3±2.61^a	985.2±18.21^b	608.9±16.30^c	6	14.5±0.38^c
T_2	379.0±4.76^a	961.3±17.24^b	582.3±20.21^b	6	13.9±0.49^b
T_3	381.6±3.42^a	960.6±31.23^b	579.0±26.12^b	6	13.8±0.62^b
T_4	380.5±5.73^a	881.5±13.27^a	501.0±10.18^a	7	10.2±0.28^a
T_5	379.6±4.81^a	893.2±11.52^a	513.6±11.21^a	7	10.5±0.22^a

Mean values followed by different letter in same column are statistically different (ANOVA; Tukey's test, $P < 0.05$)

substrate material (CFA, PM and CD in appropriate ratio) for providing better P nutrition. In the present study, the increase in TP during vermicomposting is probably through mineralization and mobilization of phosphorus by bacterial and faecal phosphatase activity of earthworms, direct action of worm gut enzymes and indirectly by stimulation of the microflora [32, 33]. According to Ghosh *et al*. [34] and Adi and Noor [31], vermicomposting can be an efficient technology for the transformation of unavailable forms of the phosphorus to easily available forms for plants. There was a decrease in TK in all treatments by the end of vermicomposting and the maximum decreases was in T_4, whereas T_1, T_3 and T_2 showed the lowest decreases for TK (Table 3). Similar results were reported by Orozco *et al*. [35] and Kaushik and Garg [36] for decrease in TK at the end of vermicomposting. Increase in TK was also reported by some authors during vermicomposting [37, 38]. Recently, Sangwan *et al*. [9] have reported a decrease in TK in pressmud during vermicomposting and they concluded that it may be due to leaching of soluble potassium by excess water.

Growth and Reproduction Rate by *L. Mauritii* in Different Treatments: In the present study, the increase in worm biomass (growth) and reproduction rate (cocoon production and hatchlings number) showed variation with different ratios of CFA and PM in the treatments (Table 4). The highest biomass of *L. mauritii* was observed in T_1 treatment (985.2±18.21 mg worm^{-1}) and the lowest in the T_4 treatment (881.5±13.27 mg worm^{-1}). The biomass production was significantly ($P < 0.05$) decreased with increasing ratio of CFA and PM with CD in treatments (T_4 and T_5). The net biomass by *L. mauritii* was significantly ($P < 0.05$) higher in T_1, T_2 and T_3 treatment than other treatments (T_4 and T_5) and maximum worm biomass was attained after 6 – 7 weeks of vermicomposting (Table 4). The growth rate of *L. mauritii* (mg worm^{-1} day^{-1}) was in the range of 14.5±0.38 (T_1) to 10.2±0.28 (T_4) during this vermicomposting period. According to Edwards *et al*. [39] the growth rate (biomass mg worm^{-1} day^{-1}) has been considered a good comparative index to compare the growth of earthworms in different organic waste materials. Recently Suthar [38] reported that the growth pattern in composting earthworm depends on microbial population and nutrient quality in feeds. Therefore the observed difference in growth rate of *L. mauritii* among different treatments was done to diverse substrate quality. It has been found that mixing of cow dung in coal fly ash and press mud before vermicomposting can accelerate earthworm composting efficiency. The results indicated that greater percentage of CFA and PM in the treatments (T_4 and T_5) significantly affected the growth of *L. mauritii*.

CONCLUSION

In the present study, the vermicomposting of CFA and PM mixed with CD resulted in the conversion of waste into value added product, i.e., vermicompost. Analysis of vermicompost obtained from different treatments clearly indicates the use of *L. mauritii* for vermicomposting of CFA and PM with CD in appropriate ratios (dry weight proportions). Higher percentage of CFA and PM in the substrate material retarded the growth of earthworms and also affected the physico-chemical nature of the substrate. The results confirmed the vermicomposting as an alternative technology for the management of CFA and PM if mixed with CD in appropriate ratios.

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