Vermicomposting potential and plant nutrient contents in rice straw vermicast of *Perionyx excavatus* and *Eudrilus eugeniae*

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Vermicomposting is proven to be an effective way for nutrient cycling, converting large quantities of organic waste into value added product (vermicast). In order to harness the potential of earthworms in vermicomposting, selection of earthworm species that are able to consume large quantity of waste, and moreover, produce vermicast with high nutrient content is important. This experiment was carried out to compare the efficacy of *Perionyx excavatus* (PE) and *Eudrilus eugeniae* (EE) in vermicomposting rice straws. Ten earthworms were introduced into each verminbin containing grinded rice straw. The vermicast produced was collected periodically. The experiment was terminated when 70% of rice straw had decomposed. The plant nutrient contents and humic acids in vermicast were analysed. Vermicast of PE contained higher concentrations of total and available N, P, K and Mg while EE vermicast contained higher total and available Ca. Humic acid content was also found to be higher in EE vermicast. EE took 134 days while PE took 171 days to complete vermicomposting, thus, plant nutrient content generated per day in vermicast EE was higher compared to PE. Using EE in vermicomposting would contribute significantly towards practicing sustainable agricultural by recycling large amount of organic waste rice straw into value added high plant nutrient content vermicast.

**Key words:** Earthworm biomass, decomposition rate, humic acid, agronomy.

**INTRODUCTION**

Large quantities of organic wastes produced worldwide have necessitated researchers to develop appropriate waste recycling technologies in order to protect and preserve the environment. The burning of huge amounts of organic waste is a common practice in developing countries to return complex organic resources back into the soil. This scenario can be seen especially in rice cultivation where rice straws are chopped and open burnt in the rice field after harvesting. For example in Thailand which is a major global exporter of rice, 8 to 14 million tonnes of rice straw are burnt in the rice field each year (Suramaythangkoor and Gheewala, 2008). In India, 170 million tonnes of rice straw is open burnt each year (Pathak et al., 2006). Open-burning of rice straw is also a problem in many other countries (Pathak et al., 2006). Recycling these large amount of organic waste in an environmentally manner helps contribute significantly towards sustainable agricultural practices.

During vermicomposting, earthworms fragment the initial organic waste and increase its surface area for the consumption by microbes and ultimately altering the biological activity (Aira et al., 2002; Pramanik et al., 2008; Suthar, 2008; Vivas et al., 2009). Microbial activity has been reported to be greatly stimulated in vermicast (Aira et al., 2002; Fisher et al., 1997). Through the incorporation of enzymes such as phosphatase, glucosidase and protease the nutrient availability in
vermicompost is relatively high. Consequently, this promotes growth and yields of various horticulture and greenhouse crops (Arancon et al., 2006; Fernandez-Luquen et al., 2010).

Vermicomposting process shows great potential in the degradation of wastes converting some portion of waste into earthworm biomass and respiration product and expelling the remaining wastes as earthworm cast (Suthar, 2007a). The excreted vermicast is reported to contain high amounts of mineral nutrients, vitamins, plant growth hormones, proteins and enzymes (Prabha et al., 2007). Based on preceding reports, earthworms can consume 2 to 5 times its body weight and only uses 5 to 10% of nutrient from the feed stock for its growth (Prabha et al., 2007; Sharma et al., 2005). This implies that feeding rates of different earthworm species may vary in relation to their morphological differences.

The selection of earthworm species with a high rate of growth, reproduction and vermicast production is required to accelerate waste breakdown and stabilization (Aira et al., 2006). Besides that, identifying earthworm species that produces vermicast with high plant-available nutrient content is important to produce high quality vermicompost. Among the recommended epigeic earthworm species that have been widely used in vermicomposting of organic wastes in the tropics are Eudrilus eugeniae and Perionyx excavatus (Garg and Kaushik, 2005).

In order to harness the potential of earthworms in vermicomposting process, selection of earthworm species that is able to consume large quantity of waste is crucial. While most of the pioneering works have been more geared towards viability of producing nutrient rich vermicompost from various types of wastes, much work is still needed, in the selection of a highly effective earthworm as the vermicomposting agent. Studies need to be conducted using specific feed substrates and earthworm species to provide accurate design for efficient and economical vermicomposting system (Ndegwa et al., 2000).

By using a common feed substrate, the composting efficiency of earthworm species in producing vermicast with high decomposition rate and nutrient content can be performed. Therefore, the current research is carried out to evaluate the biological effectiveness (rate of reproduction, changes in total biomass and rate of decomposition) of earthworms E. eugeniae and P. excavatus as vermicomposting agent of agricultural waste rice straw (Paddy straw). The study also compares the plant nutrient contents and humic acids in the vermicasts produced by each earthworm species.

**MATERIALS AND METHODS**

The organic medium (250 g / dry weight) for vermicomposting which comprised of grinded rice straw and cow dung (4:1) was prepared. Cow dung was added as food supplement for the growth of earthworm. Ten matured earthworms, each comprising of P. excavatus (PE) (mean weight, 0.501 ± 0.04 g) and EE (E. eugeniae) (mean weight, 0.7544 ± 0.04 g) were introduced separately into vermicomposts. Rice straw was left to undergo natural decomposition without the addition of earthworms as the control. The vermicomposts (diameter: 25 cm, height: 20 cm) were set in six replicates with moisture content of 70% maintained in all treatments. The vermicasts were collected periodically, weighted and stored for further chemical analysis. The experiment was terminated when 30% of the initial feed materials were left. This was done by weighing the amount of rice straw left in the vermicast. This was done to ensure that the feed material was sufficient to support continuous growth of the earthworms. At the end of the experiment, plant nutrient content, total earthworm biomass, total number of earthworm and the number of days required to vermicompost 70% of rice straw were determined.

Total nitrogen was determined using Kjeldahl method (Van Ranst et al., 1999). Total phosphorus, potassium, calcium, magnesium and other plant micronutrient were digested and determined using ICPMS. Total organic carbon was determined on dried samples using elemental analyzer LECO CR-412. Extractable P, K, Ca and Mg were determined by Merlich 3 (Jones, 2001). Humic acid content in the vermicast was determined according to method suggested Rosliza et al. (2009). Vermicast pH was measured using pH meter (Mettler Toledo S20) with the suspension of 1:5 (w/v) vermicast: deionized water.

**Statistical analysis**

Data obtained were analyzed using Statistical Package for Social Sciences (SPSS) version 16.0. T-test analyses were carried out to compare the biological parameters (rate of reproduction, changes in total biomass and rate of decomposition) between the two earthworm species. The differences in nutrient contents between vermicasts and control were subjected to one way analysis of variance (ANOVA). Significant differences between means were determined using Duncan’s Multiple Range Test as the post hoc test analyses were carried out to determine the importance of nutrient from the feed stock for its growth (Prabha et al., 2007; Sharma et al., 2005). This i...
higher per day compared to PE (Table 2).

The lowest concentration of total nitrogen was found in EE vermicast; however, there was no significant difference (p>0.05) between vermicasts (Table 1). Analysis of total organic carbon in vermicasts showed that the greatest reduction in organic carbon has occurred in PE vermicast (254.55±0.00 mg/g) compared to EE vermicast (295.77±0.00 mg/g).

Total phosphorus concentration was higher in PE vermicast (1.48±0.40 mg/g) compared to EE vermicast (1.23±0.29 mg/g). Available P concentration showed significant difference (p<0.05) between the treatments. Vermicast produced by PE also contained higher concentration of total and available macronutrients (except available calcium) compared to its counterpart EE.

The largest differences in the vermicast nutrient concentration in of both earthworms were found in available P and total potassium whereby vermicast PE was 55.4 and 31.3% higher respectively compared to vermicast EE. Thus vermicast generated by earthworm PE has higher plant nutrient concentrations; however, when the lower vermicast production rate was taken into account the total plant nutrient content in vermicast generated per day was found to be higher in vermicast produced by EE (Table 3). Amongst the highest
Table 1. Plant macronutrient concentration, pH and humic acids of vermicasts (from EE and PE) and control harvested at 70% decomposition of rice straw (p<0.05).

<table>
<thead>
<tr>
<th>Chemical parameter</th>
<th>Vermicast EE</th>
<th>Vermicast PE</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.00±0.02a</td>
<td>7.10±0.01b</td>
<td>6.90±0.05b</td>
</tr>
<tr>
<td>Total nitrogen (mg/g)</td>
<td>14.78±0.12b</td>
<td>15.20±0.17b</td>
<td>20.18±0.20a</td>
</tr>
<tr>
<td>Total phosphorus (mg/g)</td>
<td>1.23±0.29c</td>
<td>1.48±0.40b</td>
<td>3.50±0.03a</td>
</tr>
<tr>
<td>Available phosphorus (mg/g)</td>
<td>0.33±0.00b</td>
<td>0.74±0.00a</td>
<td>0.19±0.01c</td>
</tr>
<tr>
<td>Total potassium (mg/g)</td>
<td>6.68±0.70a</td>
<td>9.90±0.01a</td>
<td>9.83±0.04b</td>
</tr>
<tr>
<td>Available potassium (mg/g)</td>
<td>4.07±0.00b</td>
<td>6.75±0.11a</td>
<td>0.92±0.06c</td>
</tr>
<tr>
<td>Total calcium (mg/g)</td>
<td>8.22±0.53b</td>
<td>10.37±1.38a</td>
<td>7.39±0.11c</td>
</tr>
<tr>
<td>Available calcium (mg/g)</td>
<td>5.46±0.08a</td>
<td>4.76±0.04b</td>
<td>4.40±0.02c</td>
</tr>
<tr>
<td>Total magnesium (mg/g)</td>
<td>1.48±0.29c</td>
<td>2.11±0.32b</td>
<td>3.14±0.07a</td>
</tr>
<tr>
<td>Available magnesium (mg/g)</td>
<td>1.20±0.09b</td>
<td>1.66±0.21a</td>
<td>0.28±0.01c</td>
</tr>
<tr>
<td>Humic acid (mg/g)</td>
<td>436.50±1.28a</td>
<td>377.20±1.85b</td>
<td>240.10±50.9c</td>
</tr>
<tr>
<td>Total organic carbon (mg/g)</td>
<td>295.77±0.00b</td>
<td>254.55±0.00c</td>
<td>358.15±1.27a</td>
</tr>
<tr>
<td>C:N ratio</td>
<td>20.19</td>
<td>19.09</td>
<td>17.74</td>
</tr>
</tbody>
</table>

Table 2. Amount of rice straw consumed and vermicast harvested for EE and PE when 70% of rice straw has been decomposed [EE at D134 (day 134) and EE at D171 (day 171)].

<table>
<thead>
<tr>
<th>Earthworms</th>
<th>Total rice straw left (g)</th>
<th>Total vermicast harvested (g)</th>
<th>Total vermicast harvested/day (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE (D134)</td>
<td>81.31 ± 7.51a</td>
<td>63.99 ± 7.78a</td>
<td>0.48 ± 0.06a</td>
</tr>
<tr>
<td>PE (D171)</td>
<td>74.97 ± 6.12a</td>
<td>45.15 ± 4.55b</td>
<td>0.26 ± 0.03b</td>
</tr>
</tbody>
</table>

Table 3. Total and available plant nutrient contents generated per day by earthworm EE and PE (weight of vermicast generated per day multiply nutrient concentration in vermicast).

<table>
<thead>
<tr>
<th>Chemical parameter</th>
<th>Total nutrients contents generated by earthworms per day (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vermicast EE</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>7.06</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>0.59</td>
</tr>
<tr>
<td>Available phosphorus</td>
<td>0.16</td>
</tr>
<tr>
<td>Total potassium</td>
<td>3.19</td>
</tr>
<tr>
<td>Available potassium</td>
<td>1.94</td>
</tr>
<tr>
<td>Total calcium</td>
<td>3.93</td>
</tr>
<tr>
<td>Available calcium</td>
<td>2.61</td>
</tr>
<tr>
<td>Total magnesium</td>
<td>0.71</td>
</tr>
<tr>
<td>Available magnesium</td>
<td>0.57</td>
</tr>
<tr>
<td>Humic acid</td>
<td>208.43</td>
</tr>
<tr>
<td>Total organic carbon</td>
<td>141.23</td>
</tr>
</tbody>
</table>

differences of plant nutrient contents generated per day by the different earthworm species were available Ca, TOC and total N (vermicast EE contained 52, 51.7 and 43.2% more respectively compared to vermicast PE).

The pH of EE vermicast was found to be significantly more acidic compared to vermicast PE and control. Besides that, EE vermicast showed greater amount of humic acids (436.50±1.28 mg) compared to vermicast PE (377.20±1.85 mg).

**DISCUSSION**

**Biological effectiveness: Earthworm reproduction, biomass and rate of decomposition**

In most of the studies conducted to investigate the effectiveness of earthworm as vermicomposting agent, the process was terminated at certain pre-determined time interval (for example, Gajalakshmi and Abbasi, 2004;
Garg et al., 2005; Loh et al., 2005). However, in the current research vermicomposting was terminated when 70% of rice straw has been decomposed. This was done to prevent loss of earthworm biomass and reproduction attributed by the exhaustion of food (Chaudhuri and Bhattacharjee, 2002; Garg et al., 2005). The present study suggested that EE decomposed rice straw at a higher rate compared to PE. Higher decomposition rate could be attributed to the larger size of EE which leads to the higher feeding rates of the earthworm. As the feeding rate of earthworms is reported at about 0.75 kg feed/kg worm/day (Loh et al., 2005), the voracious feeding habit allowed the EE to consume the rice straw more effectively compared to its counterpart. In addition the total biomass of EE is recorded to be about 50% higher compared to PE (Figure 2). This indicates that the higher biomass of EE may have also contributed to the higher composting rate of this earthworm species. Our results was supported by the findings of Suthar (2007) who showed that the biomass production rate of EE (9.8 ± 0.01 mg/worm/day) was higher compared to PE (3.75 ± 0.02 mg/worm/day) when both worms were fed with kitchen waste.

Plant macronutrient concentration, pH and humic acids in vermicasts

The vermicast obtained was odourless, stabilized and rich in nutrient that is available to plant. Chemical analysis showed that both vermicast produced by both earthworms has a C:N ratio less than 20 (initial C:N ratio for rice straw was 250). The ratio of carbon to nitrogen of 20 to 1 or less has been obtained for both vermicasts hence suggesting the maturity of the vermicasts. According to Loh et al. (2005) and Adi and Noor (2009) C:N ratio of less than 20 is an indicator of acceptable compost maturity. Losses in total organic carbon (TOC) amounting 34.0 and 23.3% occurred in vermicast PE and EE, respectively, suggested that earthworms mediated rapid organic matter mineralization during vermicomposting (Hait and Tare, 2011). The high population of microbes involved in organic waste decomposition during vermicomposting may lead to rapid C loss as microbial respiration might causes carbon dioxide to be release to the atmosphere (Garg and Gupta, 2010; Pramanik and Young, 2010; Suthar, 2007). Besides that, digestion of carbohydrates and other polysaccharides present in rice straw by the earthworms may also further reduce the carbon concentration. Some portion in the loss of carbon source in the rice straw could be converted into body mass of the earthworms through assimilation process (Suthar, 2010). Similar result was obtained by other researchers (Garg and Gupta, 2010; Loh et al., 2005; Subramanian et al., 2010; Suthar, 2010). Furthermore, the control showed higher degree of organic carbon suggesting the presence of more labile carbon hence lesser decomposition rate.

The total concentrations of N, P, K, Ca and Mg were found to be higher in vermicast from PE compared to vermicast EE. It is known that while epigeic earthworms EE and PE are voracious feeders of organic waste, the earthworms only utilizes a small portion of the ingested materials for their body synthesis and excreting a large part of these consumed waste materials in partially digested form (Sharma et al., 2005; Yadav et al., 2009). Due to the larger size of EE more nutrients are assimilated for their biomass production. Results showing less total calcium, magnesium and phosphorus concentration in the vermicast indicate that these could have been important nutrients acquired by EE. The high biomass attained by EE probably explains its higher reproduction rate. Previously it was reported by Chaudhuri and Bhattacharjee (2002) that individual earthworms will begin reproduction after attaining certain level of biomass. This probably contributed to the lower nutrients in the vermicast produced as large proportion of the resources is invested in cocoon production by the mature earthworm (Garg et al., 2005).

The two earthworm species showed different patterns of nutrient uptake for subsequent body synthesis. The largest difference was observed for calcium in which vermicast produced by EE contained 20.7% less total calcium concentration compared to vermicast PE. The difference in total Ca concentration in the vermicast could be due to the considerable differences between species in both the degree of development of the calciferous gland and their output secretion (Piearce, 1972). The difference in gland activity of the earthworms could be related to difference in the nature of organic material consumed, the quantity consumed, its rate of turnover and the earthworm’s ability to absorb calcium from diet (Piearce, 1972). Thus, this might contribute to the differences in calcium level in the vermicast produced.

Similarly to total plant macronutrient, lower concentration of plant available macronutrient (P, K and Mg) was observed in vermicast of EE. Yet, total nitrogen content in the vermicast did not differ significantly between the species. Ability of both earthworm species to produce vermicast with similar quantity of nitrogen concentration could be due to the release of fixed N in the vermicast by N-fixing bacteria in the earthworm’s guts (Marcus et al., 2003). Study done by Pramanik et al. (2007) found that there was a high correlation between the total nitrogen and the number of free living nitrogen fixing bacteria in vermicast. Thus, the quantity of nitrogen present in the vermicast may well be depending on the extent of nitrogen fixed by N-fixing bacteria in the gut or free N-fixing bacteria in the vermicast produced.

Analysis on the vermicast showed that there is a significant difference in pH for vermicast produced by the different earthworms. The lower pH found in the vermicast produced by EE could be explained by the lower concentration of calcium and magnesium. During
vermicomposting organic acids will be produced by microbial activity for the process of bioconversion of the complex organic compound (rice straw) into simpler forms (Singh et al., 2005). As both calcium and magnesium can provide buffering capability towards acidification the lower amounts of these cations causes an insufficiency for these metallic cations to absorb the additional H⁺ ion that is being released (Jakobsen, 1996). Besides that, another reason that may cause the lower pH in the vermicast of EE is the higher concentration of humic acids. Humic acids exhibit acidic characteristics through the presence of carboxylic and substantial amount of phenolic group (Tan, 2003). Many scientists considered humic acids to be characterized by the presence of elemental composition of nitrogen content which might be contributed by amino acids or protein compounds (Tan, 2003). In the ligno-protein theory, proteins and amino acids are considered important precursors to the genesis of humic matter (Tan, 2003). Earthworms are known to release nitrogen in decomposing material by excreting mucus, nitrogenous excretory substances, growth stimulating hormones and enzymes (Sangwan et al., 2008; Suthar, 2009; Tripathi and Bhardwaj, 2004). With the higher biomass and decomposition rate of EE, this species is perhaps more effective in carrying out nutrient recycling by producing higher amount of proteinaceous substance which is important as the precursor of humic acid formation in the vermicast produced.

Agronomic value of vermicast generated by EE and PE

The earthworm’s biological performances and their relationship with organic waste nutrient recycling need to be evaluated. This is important to choose the most suitable vermicomposting agent for composting organic wastes. The comparison in vermicomposting efficacy of different earthworms has been carried out by a number of researchers (for example, Khwairakpam and Bhargava, 2009; Lourduraj and Joseph, 2010; Manna et al., 2003; Tripathi and Bhardwaj, 2004). Most of these studies had been based on nutrient contents (concentration) in vermicompost produced by the different species earthworms fed by organic waste. However the relationship between the biological performances and nutrient concentrations in vermicast should be taken into consideration when choosing earthworm for vermicomposting. Though vermicast PE has higher total and available plant nutrient contents, the rate of vermicast generation by this species was relatively low compared to EE.

Conclusion

When both the vermicast production rate and the nutrient concentration in vermicast were taken into account, the amount of plant nutrient content generated per day was found to be higher in vermicast of EE. Therefore, the study suggests that EE is more prominent to serve as the vermicomposting agent for organic waste rice straw.

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REFERENCES

Jones JB (2001). Laboratory guide for conducting soil tests and plant analysis. CRC Press, USA.


