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EFFECTS OF SEWAGE SLUDGE VERMICOMPOST AND MINERAL FERTILIZER APPLICATION ON THE ABOVEGROUND BIOMASS AND YIELD OF MAIZE (*Zea mays*)

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ABSTRACT

Biological agriculture concept has been recently introduced to solve problems related to the continuous and excessive application of mineral fertilizers for crop production. This concept emphasizes the importance of combined use of organic and mineral fertilizers. Thus, this research was conducted to investigate the potential of sewage sludge vermicompost to substitute mineral fertilizer in maize planting. Treatments involved were mixture of vermicompost (VC) and mineral fertilizer (MF) in the following ratios of VC and MF: 100% VC (T1), 75:25 (T2), 50:50 (T3), 25:75 (T4), and 100% MF (T5) along with T6 (without fertilizer) as the control. Standard laboratory procedures were used to analyze nutrient and heavy metal concentrations in the vermicompost. The fresh yield and total aboveground dry matter biomass of T5 (239.34 gm plant^{-1} and 75.00 gm plant^{-1}) were not significantly different with T3 (201.15 gm plant^{-1} and 73.61 gm plant^{-1}) and T4 (226.49 gm plant^{-1} and 70.00 gm plant^{-1}), respectively. These results showed that mixing 25% and 50% sewage sludge vermicompost with mineral fertilizer (T4 and T3) produced similar yield as the conventional rate of mineral fertilizer application (T5). Therefore, the amount of inorganic fertilizer for maize cultivation could be reduced.

Key words: Sewage sludge, vermicompost, mineral fertilizer, biological agriculture

INTRODUCTION

Conventional agriculture farming system relies on the application of mineral fertilizer to supply essential nutrients for crop production. This type of fertilizer usually contains concentrated amount of plant nutrients. For example, urea contains 46% nitrogen. However, continuous and excessive application of mineral fertilizer was found to cause soil degradation and environmental pollution. Barabasz *et al.* (2002) proved that continuous application of nitrogen based mineral fertilizer for 20 years has led to the formation and accumulation of carcinogenic nitrosamines in the soil which later cause the reduction of beneficial microorganisms in the soil. Decreasing amount of soil microorganisms will directly result in the reduction of essential soil biological activities such as nutrient cycling and degradation of organic matter which will cause soil fertility reduction. Savci (2012) showed that approximately 10% of nitrogen from nitrogenous mineral fertilizer was usually leached and caused eutrophication in surface water and nitrate contamination in the groundwater. In light of these facts, public awareness about the risk of contaminated food and drinking water on human health increased.

As an alternative to the conventional farming system, the concept of biological agriculture has been recently introduced. According to Kawabe (2011), biological agriculture is the biodynamic and sustainable farming system which produces healthy food to promote human health, with an emphasis on food quality while at the same time protecting the environment. These objectives can only be achieved with the correct ratios and balance use of organic and mineral fertilizer (Mucheru-Muna *et al.*, 2007). In general, sewage sludge is known to contain high amounts of essential nutrients for plant growth thus has a great potential to be utilized as an organic fertilizer. The increasing amount of sewage sludge production has led to the problem of improper disposal of this waste. According to Azizi *et al.* (2011), current sewage sludge disposal methods

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used in Malaysia such as the trenching systems, dedicated drying beds, landfilling or spreading on open land have caused serious negative effects on the environment and public health.

Vermicomposting can be used to convert sewage sludge into organic fertilizer while at the same time reducing its amount to be disposed in the landfill. Even though sewage sludge vermicompost has been successfully used as a fertilizer for crop production in many developed countries, similar approach is still not been practiced in Malaysia. Therefore, this research was conducted as an attempt to determine the nutrient and heavy metal concentrations in sewage sludge vermicompost and investigate its potential to substitute mineral fertilizer application in maize cultivation.

MATERIALS AND METHODS

Vermicomposting of sewage sludge

Sewage sludge was obtained from Indah Water Konsortium treatment plant in Rantau, Negeri Sembilan. It was subjected to pre-composting for 15 days prior to vermicomposting in concrete experimental ponds of 0.25 m x 0.25 m x 0.5 m. During pre-composting, the materials were turned daily to eliminate hazardous gases such as methane and nitrous oxide. Next, about 100 g of *Eudrilus eugeniae* was introduced into the pond with an optimal stocking density of 1.60 kg worms/m^2 and feeding rate of 0.75 kg feed/kg worm/day (Ndegwa *et al.*, 2000). The vermicomposting lasted for 30 days. During this period, the moisture content of the sewage sludge was maintained at 70 ± 10% by periodic sprinkling of an adequate quantity of water.

Laboratory analysis of vermicompost

Vermicompost produced was analyzed for its nutrient and heavy metal content. Total N was determined by the dry-combustion method (Jimenez and Ladho, 1993). Total P was determined using auto analyzer while K, Cu, Zn, Cd and Pb were measured using atomic absorption spectrophotometer (AAS) after wet digestion by the aqua regia method (McGrath and Cunliffe, 1985). Total organic carbon and organic matter content were determined using the loss on ignition method (Chefetz *et al.*, 1996).

Planting procedures and treatment applications

The experimental design for maize planting was randomized complete block design with three replications. The plot size within each block was 2.5 m (length) x 2.25 m (width). The distance between plots was 0.5 m and between blocks was 1.0 m with the planting distance of 0.75 m between rows and 0.25 m within plants. Each plot consisted of four rows with ten plants per row giving a total of 40 plants per plot. Maize (cultivar Thai Super Sweet) was used as the test crop. Treatments involved were mixture of vermicompost (VC) and mineral fertilizer (MF) in the following ratios of VC and MF: 100% VC (T1), 75:25 (T2), 50:50 (T3), 25:75 (T4), and 100% MF (T5) along with the T6 (without fertilizer) as control. All treatments were applied at two equal split applications on 10 and 28 day after sowing.

Harvesting and sample collection

Harvesting was conducted on the 73rd day after sowing. Only 16 plants were harvested (inner row only) in each plot to avoid bias due to competition between plots. Maize fresh yield was weighed and recorded during harvesting. The plant harvested was oven dried at 60ºC until constant weight was achieved. Then, the dry matter biomass was weighed and recorded.

Statistical analysis

All data collected were analyzed using ANOVA at $p<0.05$ for treatment effect followed by Duncan new multiple range test (DNMRT) for mean comparison.

RESULTS AND DISCUSSION

Selected nutrient and heavy metal concentrations in the sewage sludge vermicompost are shown in Table 1. Sewage sludge vermicompost was found to contain 2.77% N, 2.74% P and 0.48% K, respectively. According to Mengel *et al.* (2001), lower K concentration in the sewage sludge could be probably due to leaching of K^+ ions in the treated sewerage effluent. In terms of heavy metals, Cd and Pb were not detected by AAS due to the very low amount while Zn (640.65 mg kg^{-1}) and Cu (105.15 mg kg^{-1}) concentrations were lower than the standard limits established by the United States of America (2800 mg kg^{-1} for Zn and 1500 mg kg^{-1} for Cu) and European countries (210-4000 mg kg^{-1} for Zn and 70-600 mg kg^{-1} for Cu) for compost and biosolids (Brinton, 2000) as shown in Table 1. Based on these standard limits, sewage sludge vermicompost used in this study was considered safe for soil and plant applications in terms of heavy metal toxicity.

Treatment with 100% mineral fertilizer (T5) significantly recorded the highest fresh yield (239.34 gm plant^{-1}) (Fig. 1) and total aboveground dry matter biomass (75.00 gm plant^{-1}) (Fig. 2) as compared to the control (T6). However, it was not significantly different with T3 (201.15 gm plant^{-1} and 73.61 gm plant^{-1}) and T4 (226.49 gm plant^{-1}

Table 1. Nutrient and heavy metal concentrations in the vermicompost and the heavy metal standard limits for composted materials in USA and European countries

Properties	Sewage sludge Vermicompost	Heavy metal limits	
		EU	USA
N (%)	2.77 (±0.06)		
P (%)	2.74 (±0.09)		
K (%)	0.48 (±0.04)		
TOC (%)	26.85 (±1.14)		
OM (%)	46.29 (±1.96)		
Cd (mg kg^{-1})	nd	0.7-10	39
Pb (mg kg^{-1})	nd	70-1000	300
Zn (mg kg^{-1})	640.65 (±24.33)	210-4000	2800
Cu (mg kg^{-1})	105.15 (±4.52)	70-600	1500

Note: All data represent means of five replications. Values in the same row with different superscripts are significantly different at ($p \leq 0.05$). ( ) values in parenthesis represent standard error of the mean. *nd: not detected by AAS. Standard limit was adapted from Brinton (2000).

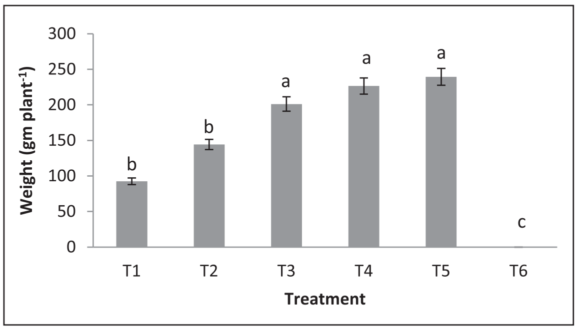

Fig. 1. Maize fresh yield at harvest. T1) 100% VC; T2) 75% VC: 25% MF; T3) 50% VC: 50% MF; T4) 25% VC: 75% MF; T5) 100% MF; T6) Control (without fertilizer). Different alphabets indicate significantly different at $p<0.05$ (n=16).

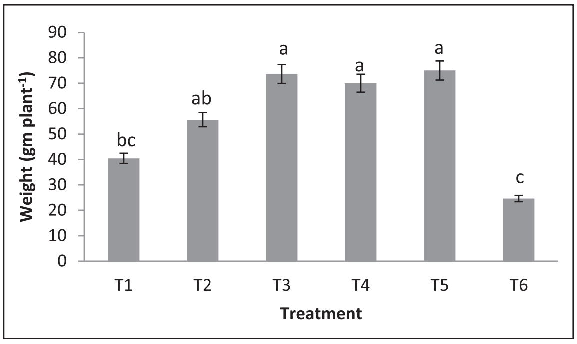

Fig. 2. Plant aboveground dry matter biomass. T1) 100% VC; T2) 75% VC: 25% MF; T3) 50% VC: 50% MF; T4) 25% VC: 75% MF; T5) 100% MF; T6) Control (without fertilizer). Different alphabets indicate significantly different at $p<0.05$ (n=16).

and 70.00 gm $plant^{-1}$), respectively. This shows that mixing 25% and 50% of sewage sludge vermicompost with mineral fertilizer produced similar yield and plant dry biomass as the recommended dose of mineral fertilizer application. The control (T6) recorded the lowest biomass (24.65 gm $plant^{-1}$) and did not produce any yield due to the lack of nutrients. Meanwhile, T1 and T2 recorded similar effects on plant dry biomass (40.42 gm $plant^{-1}$ for T1 and 55.63 gm $plant^{-1}$ for T2) and yield (92.55 gm $plant^{-1}$ for T1 and 144.17 gm $plant^{-1}$ for T2), respectively.

Previous study by Lazcano *et al.* (2011) on sweet corn showed that mixed application of 25% rabbit manure vermicompost with 75% mineral fertilizer produced no significant difference in corn yield (37.21 gm $plant^{-1}$) as compared to 100% mineral fertilizer (39.18 gm $plant^{-1}$). Another study by Das *et al.* (2007) also showed that mixed application of 50% vermicompost with 50% mineral fertilizer for mulberry produced similar plant height (175.73 cm) and biomass (56.7 Mt/ha/yr) compared to 100% mineral fertilizer treatment which recorded 174.04 cm plant height and 57.0 Mt/ha/yr biomass. These positive effects of vermicompost application could be due to the improvement of organic matter content in the soil. Results from laboratory analysis showed that sewage sludge vermicompost contained approximately 46.29% organic matter and 26.85% total organic carbon (Table 1).

Organic carbon is the most essential element for microorganism metabolism and activities. Application of organic fertilizer to agricultural soil will maintained carbon supply for microorganisms. In contrast, mineral fertilizer can only provide elemental plant nutrients such as N, P, K, Ca and Mg but not carbon. Chanda *et al.* (2011) showed that addition of vermicompost to the soil stimulated microbial activities and increase microbial population, thus releasing available plant nutrients through mineralization of organic materials. As an example, mineralization of organic nitrogen from proteins, chitins and amino acids by microorganisms produced ammonium ion (NH_4^+), a readily available form of nitrogen for plant uptake. In addition, the decomposition process of organic materials by microorganisms will produce the end product called humus. Humus, a dark brown to black in color material has a negative charge binding site to attract and hold cations such as K^+, Ca^{2+}, and Mg^{2+} which are essential for plant growth. Humus may also promote the enhancement of soil texture due to the improvement of water holding capacity and porosity which later facilitate root growth, respiration and nutrient absorption. In addition, according to

Atiyeh *et al.* (2000), vermicompost contains plant growth hormones such as auxin, gibberellin and cytokinin which may also promote plant growth. Therefore, treatment receiving a mixture of 25% and 50% sewage sludge vermicompost with mineral fertilizer produced similar yield and plant biomass as 100% mineral fertilizer application because of the direct effects of vermicompost application to the soil and plant growth and also the indirect effects from microorganism metabolism and activities.

In conclusion, this study has shown the potential of sewage sludge vermicompost as a substitute to mineral fertilizer in maize cultivation due to the similar effects on plant biomass and yield produced by T3, T4 and T5. The amount of mineral fertilizer could be reduced by 50% as normally applied in the conventional agricultural practices hence promoting biological agriculture practice for crop production in Malaysia. However, three to five cropping cycles may be required to confirm these findings including the assessment on the effect of sewage sludge application on heavy metal toxicity in the soil and plant tissues.

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REFERENCES

Atiyeh, R.M., Subler, S., Edwards, C.A., Bachman, G., Metzger, J.D. & Shuster, W. 2000. Effect of vermicompost and compost on plant growth in horticultural container media and soil. *Pedobiologia*, **44:** 579-590.

Azizi, A.B., Mahmood, N.Z., Teixeira da Silva, J.A., Abdullah, N. & Jamaludin, A.A. 2011. Vermicomposting of sewage sludge by *Lumbricus rubellus* using spent mushroom compost as feed material: effect on concentration of heavy metals. *Biotechnology and Bioprocess Engineering*, **16:** 1036-1043.

Barabasz, W., Albiñska, D., Jaśkowska, M. & Lipiec, J. 2002. Biological effects of mineral nitrogen fertilization on soil microorganisms. *Polish Journal of Environmental Studies*, **11(3):** 193-198.

Brinton, W.F. 2000. *Compost Quality Standards and Guidelines*. Woods End Research Laboratory Inc., New York. 15 pp.

Chanda, G.K., Bhunia, G. & Chakraborty, S.K. 2011. The effect of vermicompost and other fertilizers on cultivation of tomato plants. *Journal of Horticulture and Forestry*, **3(2):** 42-45.

Chefetz, B., Hatcher, P.G., Hadar, Y. & Chen, Y. 1996. Chemical and biological characterization of organic matter during composting of municipal solid waste. *Journal of Environmental Quality*, **25:** 776-785.

Das, P.K., Bhogesha, K., Rajanna, L. & Dandin, S.B. 2007. Vermicomposting of sericultural wastes and its impact on mulberry production. In: *Earthworms for Solid Waste Management*. S.M. Singh (Eds.). International Book Distributing Co., Lucknow. pp. 187-197.

Jimenez, R.R. & Ladho, J.K. 1993. Automated elemental analysis: A rapid and reliable but expensive measurement of total carbon and nitrogen in plant and soil samples. *Communications in Soil Science and Plant Analysis*, **24(15–16):** 1897-1924.

Kawabe, E. 2011. What is Biological Farming System. In: *Toward Sustainable Farming, by farmers for farmers*, Proceedings of the 1st National Conference on Biological farming Systems, Rotorua, October 27-28, 2011. G. Magesan (Eds.). Rotorua Lakes and Land Trust, New Zealand. pp. 43-47.

Lazcano, C., Revilla, P., Malvar, R.A. & Dominguez, J. 2011. Yield and fruit quality of four sweet corn hybrids (*Zea mays*) under conventional and integrated fertilization with vermicompost. *Journal of the Science of Food and Agriculture*, **91:** 1244-1253

McGrath, S.P. & Cunliffe, C.H. 1985. A simplified method for the extraction of metals Fe, Zn, Cu, Ni, Cd, Pb, Cr, Co and Mn from soil and sewage sludge. *Journal of the Science of Food and Agriculture*, **36:** 794-798.

Mengel, K., Kirkby, E.A., Kosegarten, H. & Appel, T. 2001. *Principles of Plant Nutrition 5th edition*. Kluwer Academic Publishers, Netherlands. 148 pp.

Mucheru-Muna, M., Mugendi, D., Kung'u, J., Mugwe, J. & Bationo, A. 2007. Effects of organic and mineral fertilizer inputs on maize yield and soil chemical properties in a maize cropping system in Meru South District, Kenya. *Agroforestry Systems*, **69:** 189-197.

Ndegwa, P.M., Thompson, S.A. & Das, K.C. 2000. Effects of stocking density and feeding rate on vermicomposting of biosolids. *Bioresource Technology*, **71:** 5-12.

Savci, S. 2012. An agricultural pollutant: chemical fertilizer. *International Journal of Environmental Science and Development*, **3(1):** 77-80.