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Production of compost and worm casting organic fertiliser from *Lumbricus rubellus* and its application on red spinach plant (*Altenanthera amoena* V.)

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KEYWORDS

Vermicompost
Compost
Worm
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Spinach

ABSTRACT

Fertiliser is one of the important components in agricultural practices, mainly applied to increase plant's productivity and soil's quality. However, the use of chemical fertiliser is still favourable among most of the farmers due to its great contribution on improving crop yields. Currently, organic fertiliser is widely used to substitute chemical fertiliser as it can reduce the risk of build-ups of toxic chemical, making it as sustainable and environmental friendly option in agriculture farming system. There are various types of organic fertilisers, including vermicompost and compost. Worm casting is a type of organic fertiliser produced from a mixture of earthworm drop (or waste) and other organic materials. While compost is an organic fertiliser derived from the decomposition of plant or animal waste and/or a mixture of both wastes. Organic fertiliser can improve the chemical, physical and biological properties of the soil and can be used in various agricultural businesses such as vegetables, ornamental plants, fruits, and etc. This research aimed to compare the quality of vermicompost and commercial compost, as well as to evaluate their application on the growth of red spinach plant growth. The results indicated that vermicompost has superior quality compared with commercial compost. Further application of vermicompost has significantly enhanced the growth of red spinach, as indicated by the highest number of plant leaves and height.

Introduction

In any agricultural practice, fertiliser is one of the necessary inputs to facilitate an increase in agricultural production and an improvement in the soil nutrients (Mariyono et al., 2010). Many farmers, including in Indonesia, prefer to use chemical fertiliser due to its great contribution on improving crop yields, its fast release of nutrient needed by the soils, as well as its convenience and easy to use (Resosudarmo and Yamazaki, 2011; Semedi and Barker, 2014; Mariyono, 2015). According to data from the Indonesian Fertiliser Producers Association (2019), two main fertilisers produced include urea and NPK with the total production of 6.9 million tonnes and 3.001 million tonnes (2015) increased to 7.44 million tonnes and 3.16 million tonnes (2018), respectively. While the production of organic fertiliser was only 7.5 thousand tonnes (2015) and increased to 8.4 thousand tonnes (2018). These data show that organic fertiliser is still not an important element in Indonesian agricultural practices, and the use of chemical fertiliser is still favourable among most of the farmers.

However, many studies have reported that the application of chemical fertiliser on agricultural land causes environmental degradation effect to the soil fertility due to the accumulation of toxic chemicals (Komatsuzaki and Syuaib, 2010; Moeskops et al., 2010; Savci, 2012). Therefore, some suggestions have been made to enhancing the quality of environment alongside with improving

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the soil fertility, such as replacing chemical fertiliser with organic fertiliser, and agricultural technological change (Marlina et al., 2014; Maryono, 2015; Agegnehu et al., 2016; Syuaib, 2016). The application of organic fertiliser has been enforced by the Indonesian government aiming to improve the soil's quality and to achieve sustainable agricultural farming system, through the adoption of green revolution in agriculture (Jahroh, 2010; Mariyono et al., 2010; Ariesusanty, 2011; Mariyono, 2015). Enhancing the organic matters and nutrients content in the soil may contribute to improve soil's elastics properties and macro-porosity, thus enhancing the soil's structural stability (Djajakirana, 2002; Bouajila and Sanaa, 2011; Markgraf et al., 2012; Mamedov et al., 2014, 2016; Diacono and Meonemurro, 2015), providing a good soil texture plant root systems..

There are various types of organic fertilisers, such as vermicompost and compost. Worm casting is a type of organic fertiliser produced from a mixture of earthworm drop (or waste) and other organic materials (Mulat, 2003; Arifah, 2014; Elfayette et al., 2017). Compost is an organic fertiliser derived from decomposition of plant or animal waste and/or a mixture of both wastes (Supadma and Arthagama, 2008; Cahaya et al., 2008; Indriani, 2011). Many studies have reported that organic fertiliser can be an alternative replacement of chemical fertiliser and it has been applied to many agricultural crops farming system or business include vegetables, ornamental plants, fruits, and etc. (Simanjuntak, 2004; Mariana, 2006; Oka, 2007; Suhartini, 2007; Zabarti et al., 2013). However, each type of organic fertiliser has different influence on the growth of plants. Therefore, it is necessary to evaluate the effect of giving different organic fertilisers on the same plant. This study used red spinach plants and two types of organic fertilisers namely compost and vermicompost.

The objective of this research was to compare the quality of vermicompost and commercial compost, and to evaluate their application on the growth of red spinach plant growth.

Research Methods

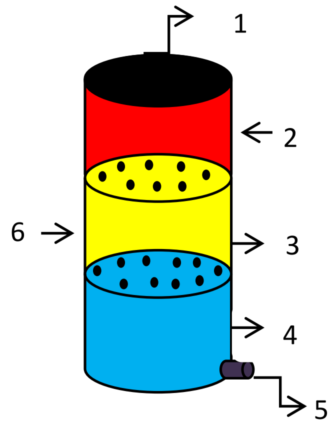
This research was conducted at Campus C, Universitas Internasional Semen Indonesia, located on street of Siti Fatimah Binti Maimun, Gresik, from July to August 2017.

Materials

Earthworm used in this study was *Lumbricus rubellus*. Forage materials for making vermicompost or compost include leaves, molasses, cow manure and effective microorganism (EM4).

Worm composting bin installation

The installation of worm composting bin is shown in Figure 1.



Descriptions:

1. Black Paranet
2. New feed and media container
3. Worm casting container
4. Worm urine container
5. Faucet outlet
6. Media. Feed, and Worm

Figure 1. Design of worm composting bin

The worm composting bin was made of 3 plastic containers covered with a black paranet. In this study, two rectangular containers were used with size of 43 cm x 30 cm x 30 cm (L xH x W) and a tubular container was used with dimension of 30 cm x 45 cm (D x H). These containers were arranged on top of each other in the following order: 2 square containers were as base and middle part, while tubular container was on the top part, as shown in Figure 1. The base of top and the middle container were punched. Each assembled container has a different purpose. The prepared forage materials (as feed) and media were placed in the top container of the worm composting bin. The middle rectangular container was functioned as vermicomposting container for collecting the worm casting. The lower rectangular container (or base container) was to collect the worm urine. Withdrawing the worm urine was carried out using the faucet outlet placed on the base container.

Preparation of Worm's Growing Media

Two portions of cow manure were prepared, each weighed for 5 kg. EM4 solution and molasses solution were prepared separately with a dilution ratio of 1:100. A portion of cow manure was mixed with EM4 solution, and another portion with molasses solution. Both prepared growing media were stirred until thoroughly blended and moist. The mixed cow manure was considered to have adequate moisture content (MC) for fermentation if there is no water dripping when it was squeezed or no breakage when it was formed into a ball. Then, after the MC of the prepared media met the requirement, it was separately placed in a closed container for 4-day fermentation process. The heat was checked on a daily basis, if pile of the fermented media was too hot, turning or aeration was carried out to dissipate the heat. After 4 days, the fermented media was ready to be used as growing media for the earthworms.

Preparation of Worm's Feed

Green leaves were pressured for a short time to soften the texture. Then, the leaves were fed into the growing media containing earthworms. The amount of the feed given was equivalent to the weight of the earthworm in the media.

Vermicomposting Process

Two prepared growing media (i.e. cow manure+EM4 and cow manure+molasses) were placed in a separate container. After that, two portions of earthworms were prepared, each weighed for 500 g. The earthworms were then placed in each growing media's container. A 500 g of the worm feed was also added into each container. Water was sprinkled after the release of the earthworms, aiming to maintain the humidity and moisture of the media. Then, a black paranet was used to cover the top of the container to protect the earthworms from the sunlight. The watering was carried on a daily basis if the media looks dry, while the feeding was done in a 3-day period.

Composting Process

Composting was carried out by preparing solid inoculant substrates made of bagasse, bran, and husk at a ratio of 1: 2: 1. EM4 was used as a decomposer agent to fasten the degradation of organic materials in the inoculant substrates. Dry leaves and green leaves were weighted with a ratio of 2: 1. The solid inoculant substrates were added into the leaves mixture, with a ratio of 1:3. After that, the mixture was stirred until thoroughly mixed. A 70 g of yeast was dissolved in 20 L of water. The yeast solution was added to the mixture substrates little by little until the mixture can be shaped like a ball with no dripping water when it was squeezed. Then, the mixture substrates were laid on an open rectangular container closed with a gunny sack or a coconut fibre mat. The composting process was monitored on a daily basis. A turning (or aeration) was carried out if the compost is too hot. Watering was done if the MC of the compost decreased. In this study, the compost used was after 7 days composting process.

Red Spinach Planting

The red spinach seeds were sown for 2 weeks. Meanwhile, several types of plant growth media were prepared in a polybag according to the treatment. In this study, 5 treatments were applied using various organic fertilisers, include soil (as control), soil and vermicompost (EM4), soil and vermicompost (molasses), soil and compost, soil and commercial compost (from stores). The ratio of soil and organic fertiliser was 1: 1. A randomized block design with 9 replications was used in this study. After 2 weeks, the sown red spinach was transferred into a polybag according to each treatment. The polybags were randomly arranged into 9 groups. After 7 days, observations were made on the growth of red spinach, particularly on the parameters of the number of leaves and plant height.

Figure 2. Trials with multiple treatments

Figure 3. Biocomposting

Results and Discussion

Installation Design of Worm Composting Bin

The current installation design of the worm composting bin was considered sufficient to improve the previous design. There are 2 main problems with the previous design, include many maggots that were found in the growing media and vermicompost was cannot automatically move to below container. Therefore, the improvement in the current design was made based on the two problems.

The first problem was possibly due to the MC of the growing media, the high amount of feed added, as well as the nature of the feed that is prone to the growth of maggots. According to Purwaningtyas et al. (2014), there are several types of feed that can invite maggots, particularly foods with high protein content and/or with foul-smelling and stinky odor. Therefore, in this study, the cultured *Lumbricus rubellus* worms were only fed with the forages. This step was adequate to solve the first problem as indicated that during the turning period of vermicompost, only one maggot was found, particularly in treatment with addition of molasses.

The second problem was solved by using the nature of the worms itself. Worms have the nature of moving away from light and approaching their food. Such behavior was used as the basis for adding the containers containing new media and feed, as well as for harvesting the vermicompost. The base of the container that new media and feed was punched, thus the worms can move up to occupy new media and leave the old media (i.e. vermicompost). The hypothesis was that the worms move to the new containers because the old growing media was not fed, thus no sufficient food source was available. Indeed, the results of this study were also proven found that the application of this method was able to promote the movement of the worms from the old growing media to the new growing media. However, the worms moved very slowly possibly due to a small amount of litter was available as worm's feed in the new growing media used. Yet, further in-depth study is still needed to investigate the potential causes of a slow movement of the worms in this vermicomposting process.

As described before, two vermicomposting treatments were applied in this study, including the growing media with addition of EM4 and molasses solution. The EM4 treatment was placed in a beam-shaped container with dimension size of 43 cm x 30 cm x 30 cm, while the molasses treatment was in a cylindrical container with size of 30 cm (diameter) and 45 cm (height). Both treatments were given the same amount of worms (i.e. 5 g). The study showed that the amount of the worms grew on the media with EM4 was two-fold higher than that of on the media with molasses. This can be potentially caused by the larger surface area of the beam-shaped container used in the EM4 treatment compared with the cylindrical container in the molasses treatment. Such a condition was found to influence the growth of the worms. As stated by Palungkun (2010), a container with dimension of 43 cm x 30 cm x 16 cm is needed for 250 g of worms used in the vermicomposting unit.

The Characteristics of Vermicomposts

Table 1 compares different types of compost based on the parameters of pH, MC, organic content and minerals content. In general, after 3-week vermicomposting process, both vermicomposts from the EM4 and molasses treatments have pH value of 8.04 and 7.8, respectively. This indicates that vermicomposts from both treatments have alkaline properties, as supported by Azmi et al. (2016) that pH value of > 7.5 has alkaline properties. The result of the study was different from the research conducted by Elfayetti et al. (2017), who reported that the pH of 3-week old vermicomposts were 6.5 (for water spinach waste feed) and 7.41 (for spinach food waste feed). The difference in the pH value of vermicompost can be due to different feed was given. The difference in the quality and the amount of feed given to worms can affect the properties and nutrient content of the vermicompost produced (Suim, 1988 in Elfayetti et al., 2017).

Table 1. The characteristics of different type of compost

Parameters	Vermicompost (EM4)	Vermicompost (Molasses)	Compost	Commercial compost
pH	8.04	7.8	8.36	8.19
MC (%)	51.22	60.28	43.97	70.64
Organics content (%)	62.33	66.07	47.96	81.75
Minerals content (%)	37.67	33.93	52.04	18.25

The MC of the 3-week old vermicomposts from the EM4 and molasses treatments was 51.22% and 60.28%, respectively. These values were higher than the MC value of 13.64% reported by Marvelia et al. (2006). This can potentially due to the vermicomposts produced in this study were not adequately dried, thus some amount of water was still present in the vermicompost. According to Sutanto (2002), MC in the vermicomposts should not exceed 15-25%, and good quality of vermicompost was indicated by a low MC concentration. Thus, it can be addressed that the quality of the resulted vermicomposts was still needed to be improved due to its high MC content.

In addition to pH and MC, the quality of vermicompost is also determined by the content of organic matter and minerals. The results of this study showed that the vermicompost contained 62.33% organic matter for the EM4 treatment and 66.07% for the molasses treatment, with the mineral content of 37.67% and 33.93%, respectively. The difference in the organic matter content may be influenced by the rate of decomposition occurred during vermicomposting. Marvelia et al. (2016) stated that a high organic content in vermicompost indicated that a complete decomposition of organic materials has not occurred, which attributed to excessive organic matter was not available to be absorbed by plants. A fast or slow decomposition rate of organic matter by worms is influenced by the feeding regime. Research conducted by Arifah (2014) showed that the variation in the worm's feed may change the nutrient, organic matter, and minerals content of the resulted vermicompost produced. However, the ideal organic matter content in vermicompost was in the range of 30-60% (Sutanto, 2002 in Marvelia et al., 2006). This study indicated a high organic content was still available in the vermicompost, thus further improvement in the vermicomposting process is necessary.

The Characteristics of Composts

The pH value of the resulted compost was 8.36, while the commercial compost was 8.19, respectively. Supadma and Arthagama (2008) reported that compost which had been incubated for 7 weeks had a pH value ranging from 7.07 to 8.42. This study found that the amount of feed given to the worms may contribute to the changes in pH value. When the worms were given a high amount of organic waste feed, the pH was increased, and vice versa. However, in general, the pH value of the resulted compost was well within the ideal range, as described above.

This study also found that the pH difference could also be due to the length of composting time. The pattern of changes in the pH of the compost was an acidic pH at the beginning process due to a formation of simple organic acids, followed by an increase in pH value (alongside with an increase in the length of incubation period) due to protein breakdown and ammonia release (Dalzell et al., 1991 in Supadma and Arthagama, 2008).

MC content of the commercial compost and compost was 43.97% and 70.64%, respectively. A study by Cahaya et al. (2008) reported that the MC content of the compost was 16.90%. The difference was possibly caused by the type of substrates/feedstocks and the length of composting time. In this study, the substrates used in composting were mixtures of dried leaves, wet leaves and *blotong* (a mixed of bagasse, bran, and husk), followed by fermentation for 7 days. The commercial compost, however, was made from mixtures of cow dung and *lamtoro* leaves. In a study by Cahaya et al. (2008), the substrates used for composting were mixtures of vegetable waste and bagasse, which fermented for 30 days. Furthermore, the MC content of the compost decreases with increasing the composting time. Subali and Ellianawati (2010) stated that the MC content in the compost was used to maintain the temperature of the compost. In addition, according to Sutanto (2002), the compost is considered to have a good quality if it has a low MC content.

The results also showed that the organic matter content of the compost and commercial compost was 47.96% and 81.75%, while the minerals content was 52.04% and 18.25%, respectively. The findings confirmed that a higher concentration of organic matter in the compost was corresponding with lower minerals and nutrients content available for the plants. Also, higher minerals content means that the quality of compost is enhanced. The mineralization process releases various compounds and elements that act as nutrients for plants (AAK, 1983). The difference in organic and minerals content may due to the length of decomposition time.

Statistical Analysis Results

The results of the ANOVA showed there was at least one treatment that affects the number of red spinach leaves, as indicated by the value of F (28.972)> Fcrit. (2.90). Similarly, the ANOVA test results also demonstrated that adding organic fertiliser has impacts on the height of red spinach with the value of F(3.319)> Fcrit. (2.90). The effects of different type of organic fertiliser on the number of leaves and the height of red spinach plant are shown in Figure 4 and 5.

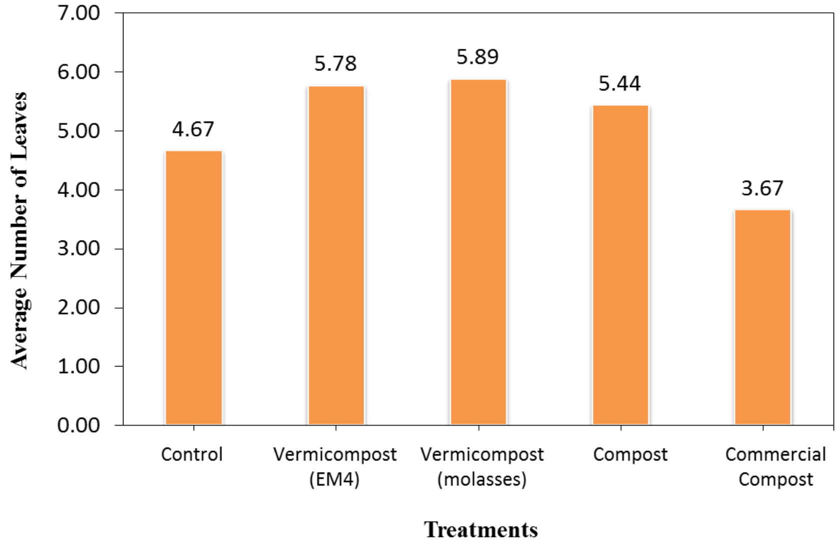


Figure 4. Effect of various types of organic fertilisers on the number of leaves of red spinach plant

Figure 4 shows that using vermicompost and compost as organic fertiliser were able to improve the growth of red spinach plants, as indicated by a higher number of leaves compared to control and commercial compost treatment. This study also indicated that commercial compost has the worst performance as indicated by the lowest number of red spinach leaves. This is in line with the physical characteristics of organic fertiliser used in this study, indicating that the quality of vermicompost and compost was better than that of commercial compost. The study found that commercial compost has the highest levels of organic matter compared to other organic fertilisers. This shows that the nutrients that can be absorbed by plants are available in low amounts. This is in agreement with Marvelia et al. (2006) who reported that a high content of organic matter remained in compost showed that there were still some solid fractions that had not been decomposed, thus made some nutrients were not available to be absorbed by plants.

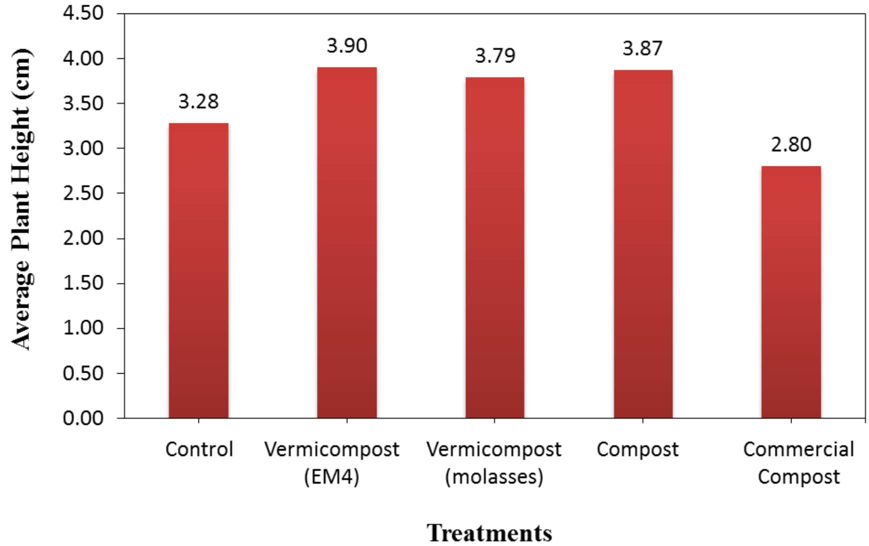


Figure 5. Effect of various types of organic fertilisers on the height of red spinach plant

Figure 5 also shows that vermicompost from the EM4 treatment produces the tallest red spinach, followed by the compost, vermicompost from the molasses treatment and soil (control). The commercial compost, however, has the lowest performance compared to other treatments. There was a slight difference between vermicomposts and compost. But, the red spinach planted in the vermicompost had a larger stem diameter compared with that planted in the compost. This is because casting worms contain growth hormones in the form of auxin, gibberellins, and cytokinins, as well as contains *Azotobacter* sp which is a non-symbiotic N fastening agent capable of adding N elements in the soil (Oka, 2007).

This process was related to the availability of nutrients that are easily absorbed and can immediately be used by plants, particularly during the leaf formation (Suhartini, 2007). According to Fahriani (2007), an increase in the number of leaves was directly proportional to an increase in plant height. The potential cause of an increase in the number of plant leaves was the supply of nutrients into the plant. In addition, the growth phase of the plant was also influenced by the number of branches and the plant height (Salisbury and Ross, 1995). According to Jumin (1992), the vegetative growth of plants is inseparable from the availability of nutrients in the soil. The plant leaves play an important role in photosynthesis to produce organic compounds important for the growth of the plant. Also, an increase in the number of plant leaves is depended on the adequate supply of nutrients into the plants (Riandi et al., 2009).

In this study, the increase in the plant height was caused by the ability of vermicompost to increase the aggregate stability and the total porosity of the soil, as previously reported by Fahriani (2007). In line with the statement of Thamrin (2000) in Mariana (2006) that the organic matter content in the composts contributes the release of nutrients to the soil, where a higher nutrient content in the soil can increase the crop yield. Gardner et al. (1991) stated that nutrients are used to stimulate the photosynthesis. The photosynthesis end products are transported throughout the plant to stimulate vegetative and generative development of the plant. The microbial content in vermicompost also plays a critical role in improving the soil's structure and texture, in which this can increase the nutrient uptake by the roots. Growth regulating substances contained in vermicompost such as auxin can trigger the plant to grow taller (Zabarti et al., 2013). Similarly, Campbell et al. (2003) also found that auxin can affect the elongation of plant cells which triggers the height growth.

Figure 6. From left to right: vermicompost (molasses), vermicompost (EM4), compost, commercial and control (soil)

Conclusions

The findings in this study confirmed that the current worm composting design can overcome the problems of maggots and limited worms' movement found in the previous design. In general, based on the pH, MC, organic content and mineral content parameters, the vermicompost (EM4) has better quality, followed by the vermicompost (molasses), the compost and the commercial compost, respectively. Applying vermicomposts and compost as the growing media for red spinach plant was found to increase the number of plant leaves and the plant height. However, a further in-depth study is necessary to obtain a more comprehensive and reliable data, including the addition of total nitrogen and potassium on the compost.

Conflict of interest

The authors declare that there is no conflict of interest in this publication.

References

AAK (Aksi Agraris Kanisius). (1983)*Dasar-Dasar Bercocok Tanam*. Yogyakarta: Kanisius. [In Indonesian]

Agegnehu, G., Bass, A.M., Nelson, P.N. and Bird, M.I. (2016) 'Benefits of biochar, compost and biochar–compost for soil quality, maize yield and greenhouse gas emissions in a tropical agricultural soil', *Science of the Total Environment*, 543, pp. 295-306

Ariesusanty, L. (2011) Indonesia: country report. In *The World of Organic Agriculture, Statistics and*

Emerging Trends 2011. Willer, H. and Kilcher, L. (Eds.). FiBL-IFOAM Report. Frick: IFOAM, Bonn & FiBL.

Arifah, S.M. (2014) ‘Analisis komposisi pakan cacing *Lumbricu*s sp. terhadap kualitas kascing dan aplikasinya pada tanaman sawi’, *Jurnal Gamma*, 9(2), pp. 63-72 [In Indonesian]

Azmi, Z., Saniman and Ishak. (2016) ‘Sistem penghitung pH air pada tambak ikan berbasis mikrokontroller’. *Jurnal Ilmiah Sains dan Komputer*, 15(2), pp. 101-108 [In Indonesian]

Bouajila, K. and Sanaa, M. (2011) ‘Effects of organic amendments on soil physico-chemical and biological properties’, *Journal of Materials and Environmental Science*, 2(1), pp. 485-490

Cahaya T.S., Andhika dan Nugroho, D.A. (2008) Pembuatan kompos dengan menggunakan limbah padat organik (sampah sayuran dan ampas tebu). Undergraduate Thesis. Universitas Diponegoro. Semarang. [In Indonesian]

Campbell, C.S., Reece, J.B., Mitchell, L.G. and Taylor, M.R. (2003) *Biology Concepts and Connection*. 4th Ed. San Francisco: Von Hoffman.

Diacono, M. and Montemurro, F. (2015) ‘Effectiveness of organic wastes as fertilisers and amendments in salt-affected soils’, *Agriculture*, 5(2), pp.221-230

Djajakirana, G. (2002) ‘Pemanfaatan bahan organik untuk meningkatkan produktivitas tanaman’, *Jurnal Tanah dan Iklim*, 20, pp. 35-46 [In Indonesian]

Elfayetti, M.S., Pinem, K. dan Primawati, L. (2017) ‘Analisis kadar hara pupuk organik kascing dari limbah kangkung dan bayam’, *Jurnal Geografi*, 9(1), pp. 1-10 [In Indonesian]

Fahriani, Y. (2007) Pengaruh pemberian vermikompos sampah daun terhadap beberapa sifat fisik tanah dan pertumbuhan tanaman jagung (*Zea mays* L.) pada alfisol Jatikerto.Undergraduate Thesis. Universitas Brawijaya. Malang. [In Indonesian]

Gardner, F.P., Pearce, R.B. and Mitchell, R.L. (1991) *Physiology of Crop Plant*. Translated by Susilo, H. in *Fisiologi Tanaman Budidaya*. Jakarta: UI-Press. [In Indonesian]

Indonesian Fertiliser Producers Association. (2019) Supply and demand 2007-2018. Retrieved from http://www.appi.or.id/?statistic on 15 May 2019.

Indriani, Y.H. (2011) *Membuat Kompos secara Kilat*, Jakarta: Penebar Swadaya. [In Indonesian]

Jahroh, S. (2010) Organic farming development in Indonesia: lessons learned from organic farming in West Java and North Sumatra. In *ISDA 2010* Jun 2010, Montpellier, France. 11 p. hal-00521832.

Jumin, H.B. (1992) *Ekologi Tanaman*. Jakarta: CV. Rajawali. [In Indonesian]

Komatsuzaki, M. and Syuaib, M.F.(2010)‘Comparison of the farming system and carbon sequestration between conventional and organic rice production in West Java, Indonesia’, *Sustainability*, 2(3), pp.833-843.

Mamedov, A.I., Bar-Yosef, B., Levkovich, I., Rosenberg, R., Silber, A., Fine, P. and Levy, G.J. (2014) ‘Amending soil with sludge, manure, humic acid, orthophosphate and phytic acid: effects on aggregate stability’, *Soil Research*, 52(4), pp.317-326

Mamedov, A.I., Bar-Yosef, B., Levkovich, I., Rosenberg, R., Silber, A., Fine, P. and Levy, G.J. (2016) ‘Amending soil with sludge, manure, humic acid, orthophosphate and phytic acid: effects on infiltration, runoff and sediment loss’, *Land Degradation & Development*, 27(6), pp.1629-1639

Mariana, H. (2006) Pengaruh kompos ampas tapioka dan pemberian air terhadap ketersediaan air dan pertumbuhan tanaman sawi (*Brassica juncea* L.) pada entisol Wajak Malang Selatan. Undergraduate Thesis. Universitas Brawijaya. Malang. [In Indonesian]

Mariyono, J., Kompas, T. and Grafton, R.Q. (2010) ‘Shifting from Green Revolution to environmentally sound policies: technological change in Indonesian rice agriculture’, *Journal of the Asia Pacific economy*, 15(2), pp.128-147

Mariyono, J. (2015) ‘Green revolution-and wetland-linked technological change of rice agriculture in Indonesia’, *Management of Environmental Quality: An International Journal*, 26(5), pp.683-700

Marlina, N., Gofar, N., Subakti, A.H.P.K. and Rohim, A.M. (2014) ‘Improvement of rice growth and productivity through balance application of inorganic fertiliser and biofertiliser in inceptisol soil of lowland swamp area’, *AGRIVITA, Journal of Agricultural Science*, 36(1), pp.48-56

Markgraf, W., Watts, C.W., Whalley, W.R., Hrkac, T. and Horn, R. (2012) ‘Influence of organic matter on rheological properties of soil’, *Applied Clay Science*, 64, pp.25-33

Marvelia, A., Darmanti, S. and Parman, S. (2006) ‘Produksi tanaman jagung manis (*Zea mays* L. Saccharata) yang diperlakukan dengan kompos kascing dengan dosis yang berbeda’, *Buletin Anatomi dan Fisiologi*, 14(2), pp. 7-18[In Indonesian]

Moeskops, B., Buchan, D., Sleutel, S., Herawaty, L., Husen, E., Saraswati, R., Setyorini, D. and De Neve, S. (2010) ‘Soil microbial communities and activities under intensive organic and conventional vegetable farming in West Java, Indonesia’, *Applied Soil Ecology*, 45(2), pp.112-120

Mulat, T. (2003) *Membuat dan Memanfaatkan Kascing Pupuk Organik Berkualitas*, Jakarta: PT Agromedia Pustaka. [In Indonesian]

Oka, A.A. (2007) ‘Pengaruh pemberian pupuk kascing terhadap pertumbuhan tanaman kangkung darat’, *Jurnal Sains MIPA*, 13(1), pp. 26-28 [In Indonesian]

Palungkun, R. (2010) *Usaha Ternak Cacing Tanah Lumbricus rubellus*, Jakarta: Penebar Swadaya. [In Indonesian]

Purwaningtyas, E.F., Kasmiyatun,M. dan Mulyaningsih, M.F.S. (2014) ‘Karakterisasi minya pupa sutera sebagai alternatif bahan baku pembuatan surfaktan biodegradable', *Prosiding Seminar Nasional Aplikasi Sains dan Teknologi (SNAST)*, Yogyakarta, pp. 225-230 [In Indonesian]

Resosudarmo, B.P. and Yamazaki, S.(2011)'Training and visit (T&V) extension vs. farmer field school: the Indonesian experience', *Crawford School Research Paper*, (2011/01).

Riandi, O., Armaini and Edison, A. (2009) aplikasi pupuk N, P, K dan mineral zeolit pada medium tumbuh tanaman rosella (*Hibisccus sabdariffa,* L). Undergraduate Thesis. Universitas Riau. Riau. [In Indonesian]

Salisbury, F.B. and Ross, C.W. (1995) *Plant Physiology*, California: Wadsworth Publishing Company, Inc.

Savci, S.(2012)'Investigation of effect of chemical fertilisers on environment', *Apcbee Procedia,* 1, pp. 287-292

Semedi, P. and Bakker, L. (2014) 'Between land grabbing and farmers' benefits: land transfers in West Kalimantan, Indonesia', *The Asia Pacific Journal of Anthropology*, 15(4), pp.376-390

Simanjuntak, D. (2004) 'Manfaat pupuk organik kascing dan cendawan mikoriza arbuskula (CMA) pada tanah dan tanaman', *Jurnal Penelitian Bidang Ilmu Pertanian*, 2(1), pp. 5-9 [In Indonesian]

Subali, B. and Ellianawati. (2010) 'Pengaruh waktu pengomposan terhadap rasio unsur C/N dan jumlah kadar air dalam kompos', *Prosiding Pertemuan Ilmiah XXIV HFI Jateng dan DIY*, Semarang, pp. 49-53 [In Indonesian]

Suhartini. (2007) respon pertumbuhan tanaman selada *(Lactuca sativa L.)* pada media yang menggunakan vermikompos limbah budidaya jamur merang.Undergraduate Thesis. Universitas Negeri Yogyakarta. Yogyakarta. [In Indonesian]

Supadma, A.A.N. and Arthagama, D.M. (2008) 'Uji formulasi kualitas pupuk kompos yang bersumber dari sampah organik dengan penambahan limbah ternak ayam, sapi, babi dan tanaman pahitan', *Jurnal Bumi Lestari*, 8(2), pp. 113-121 [In Indonesian]

Sutanto, R. (2002) *Penerapan Pertanian Organik.* Yogyakarta: Kanisius. [In Indonesian]

Syuaib, M.F. (2016) 'Sustainable agriculture in Indonesia: facts and challenges to keep growing in harmony with environment', *Agricultural Engineering International: CIGR Journal*, 18(2), pp. 170-184

Zabarti, E., Wahyu, L. and Mayta, N. I. (2013) Pengaruh dosis dan interval waktu pemberian pupuk organik cair nasa terhadap pertumbuhan dan produksi tanaman tomat(*Solanum lycopersicum* Lam.). Undergraduate Thesis. Universitas Riau. Riau. [In Indonesian]