# EFFECT OF PALM EMPTY FRUIT BUNCHES CHARACTERISTICS DECOMPOSED BY SYMBIONT BACTERIA OF LARVAE *ORYCTES RHINOCEROS* LINN TO GROWTH OF OIL PALM SEEDS (*ELAEIS GUINEENSIS JACQ.*) IN PRE-NURSERY

Kartigen
*Department of Agrotechnology, Faculty of Agriculture*
*University of Sumatera Utara, 20155 Medan, Indonesia*
*Email: kartikgen@gmail.com*

Marheni
*Department of Agrotechnology, Faculty of Agriculture*
*University of Sumatera Utara, 20155 Medan, Indonesia*
*Email: marheni@usu.ac.id*

Darma Bakti
*Department of Agrotechnology, Faculty of Agriculture*
*University of Sumatera Utara, 20155 Medan, Indonesia*
*Email: d.bakti0656@gmail.com*

## ABSTRACT

*Palm empty fruit bunches are palm oil mill waste that has the potential to be used as a source of compost raw material. However, the composting process is quite long due to the presence of lignin content so that required additional bioactivator. The purpose of this study was to identify the effect of palm empty fruit bunches characteristics decomposed by symbiont bacteria of larvae Oryctes rhinoceros Linn to growth of oil palm seedlings in pre nursery. The study was conducted in the greenhouse of Plant Seedling and Plant Protection Center , Medan, Indonesia and the propagation of horn beetle larvae symbiont bacteria at the Disease Laboratory of the Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia in January-May 2021. The study used a factorial randomized block design (RBD) with 2 treatment factor and 3 replications. The first factor is the type of activator bacteria consisting of 7 levels, namely, without activator bacteria, Bacillus stratosphericus 50 ml/kg, Bacillus stratosphericus 75 ml/kg, Bacillus stratosphericus 100 ml/kg, Bacillus siamensis 50 ml/kg, Bacillus siamensis 75 ml/kg kg and Bacillus siamensis 100 ml/kg. The second factor is the decomposition time consisting of 2 levels, namely 5 weeks and 7 weeks. The results showed that the treatment of bacteria activator type and decomposition time had a significant effect on the quality of the compost, namely pH, water content, C/N ratio and nutrient content. The interaction of B. siamensis 50 ml/kg palm empty fruit bunches with a decomposition time of 5 weeks resulted in the best growth of oil palm seedlings in pre nursery.*

Keywords: palm empty fruit bunches, symbiont bacteria, compost, pre nursery

## INTRODUCTION

Developments of oil palm plantation areas which is getting wider has resulted in an abundance of solid waste in the form of palm empty fruit bunches (PEFB). Oil palm empty fruit bunches can be used as mulch and a source of organic fertilizer. In addition to the source of organic fertilizer, oil palm empty bunches are a medium for the development of horn beetle larvae (Oryctes rhinoceros Linn) in the egg to pupa stage. Marheni (2012) states that the survival of oil palm horn beetle larvae in palm empty bunches is faster than on palm stems.

There are two sources of organic fertilizer available in oil palm plantations that operate processing plants, namely POME (palm oil mill effluent) and PEFB (palm empty fruit bunches). POME is liquid waste produced by factories which contains organic materials (including fats and oils), nutrients, suspended solids and microorganisms. For each production of 1 tonne of crude palm oil (CPO) produces 2.7 tonnes of POME. PEFB is factory waste that is produced as much as 1 ton per tonne of CPO production or about 20% of the processed fresh fruit bunches (Comte *et al*, 2013).

PEFB has the potential to be used as a source of raw material for compost, thereby reducing 50% of the volume and cost of transporting PEFB. PEFB compost that has been ripe contains N = 1.40%, total P = 0.96%, K = 0.41%, C-Organic = 19.81%, pH = 7.8 and C/N Ratio = 14.15 (Agung et al, 2019). PEFB compost is one of the solid wastes produced from processing oil palm mills. PEFB compost is organic material which contains the main nutrients N, P, K and Mg. Apart from being able to improve the physical properties of the soil, compost of palm empty fruit bunches is estimated to be able to increase fertilizer efficiency so that the fertilizer used for oil palm nurseries can be reduced (Suherman *et al*, 2007).

The composting process of oil palm empty fruit bunches naturally takes quite a long time, which is about 3 months. This is influenced by the constituent content of 45.9% cellulose, 46.5% hemi cellulose, and 22.8% lignin. The contents of the palm empty fruit bunches are difficult to decompose (Darmosarkoro and Rahutomo, 2007). For that we need special treatment in composting such as the addition of bioactivators (Agustini, 2006).

So far, the use of bacteria in the composting of oil palm empty fruit bunches has not been widely reported, where the role of aerobic ligninolytic bacteria is very important if it is related to the aerobic composting process. Therefore, we need a research related to the role of ligninolytic bacteria with different doses and times of decomposition of oil palm empty fruit bunches on the quality of the resulting compost. The effect of compost quality on plant growth can be determined by testing at the oil palm seedling stage in pre nursery.

## MATERIAL AND METHODE

### Study Site

The research was conducted at the Laboratory of the Center for Seedling and Plantation Plant Protection, Medan, North Sumatera, Indonesia and the propagation of horn beetle larvae symbionts bacteria at the Disease Laboratory of the Faculty of Agriculture, Universitas Sumatera Utara, Medan, Indonesia in January-May 2021.

The materials used in this study were palm empty fruit bunches, symbiont bacteria of horn beetle larvae consisting of *Bacillus stratospshericus* and *Bacillus siamensis*, oil palm seeds D x P Simalungun variety from the Oil Palm Research Center Medan, topsoil with inceptisol soil type obtained from PTPN plantations II Kuala Sawit Gardens, Langkat Regency, North Sumatra as a planting medium, and sand as a mixture of planting media.

The study used a factorial Randomized Block Design (RBD) with 2 treatment factors and 3 replications. The first factor is the type of activator bacteria consisting of 7 levels, namely: without activator bacteria ($B_0$), *Bacillus stratospshericus* 50 ml/kg ($B_1$), *Bacillus stratospshericus* 75 ml/kg ($B_2$), *Bacillus stratospshericus* 100 ml/kg ($B_3$), *Bacillus siamensis* 50 ml/kg ($B_4$), *Bacillus siamensis* 75 ml/kg ($B_5$) dan *Bacillus siamensis* 100 ml/kg ($B_6$). The second factor is the decomposition time consisting of 2 levels, namely 5 weeks ($T_1$) and 7 weeks ($T_2$). So that obtained 14 treatment combinations, namely $B_0T_1$, $B_1T_1$, $B_2T_1$, $B_3T_1$, $B_4T_1$, $B_5T_1$, $B_6T_1$, $B_0T_2$, $B_1T_2$, $B_2T_2$, $B_3T_2$, $B_4T_2$, $B_5T_2$, $B_6T_2$.

### Procedures

Making media

NA media was made with the composition of Peptone from meat 5 g, Meat extract 3 g, 12 g agar mixed with 1 liter of aquadest then put in autoclave at a temperature of 121º C with a pressure of 15 psi for 20 minutes then poured into a petridish as needed to growth bacterial. NB media was made with the composition of 1 g Lab Lemco Powder, 2 g Yeast extract, 5 g Peptone, and 5 g Sodium chloride mixed with 1 liter of aquadest then put in an autoclave at a temperature of 121ºC with a pressure of 15 psi for 20 minutes.

### Multiplication of bacterial

The bacterial symbiont's of the larvae O. rhinoceros was cultured in the laboratory. These bacterial were obtained from the collection of Bacillus stratosphericus bacteria which had previously been obtained from the digestive system of O. rhinoceros instar 3 larvae and then multiplied by inoculating the growing bacterial using an ose needle and scratched on NA media with the scratching method then the bacterial were stored in an incubator approximately 18-24 hours. Then the bacterial were harvested using 100 ml of NB medium.

### Calculation of bacterial density

Bacterial that have been harvested are then calculated for their density using spectrophotometry. First, the harvest is in a shaker for 15 minutes to homogenize the bacteria that have been harvested. From the results of this density calculation, the amount of NB media will be obtained which will be added to achieve the bacterial density of 108.

### Application of bacterial to palm empty fruit bunches

Bacterial that have been cultured with NA media are harvested and grown into liquid NB media, then applied to palm empty fruit bunches that have been chopped into smaller pieces and wait 5 and 7 weeks for the decomposition process. The palm empty fruit bunches that have been applied are covered with black plastic. The dosage used is 50 ml, 75 ml and 100 ml of bacterial culture for 1 kg of palm empty fruit bunches. Then once a week the palm empty fruit bunches are turned over and the temperature was measured.

### Oil Palm Planting

Oil palm planting was done by planting the sprouts into polybags as deep as 2 cm. The number of sprouts planted per polybag was 1 sprout in the planting medium of sand, top soil and composting treatment with a ratio of 200 g of topsoil : 200 g of sand: 200 g of palm empty fruit bunches in each decomposition treatment.

### Plant Maintenance

Plant maintenance consists of watering and weeding. Watering was carried out according to conditions in the field. Watering was done every afternoon, using a measuring cup (150 ml) with a volume of water as much as 150 ml/polybag for each treatment. Weeding was done to control weeds to avoid competition for nutrients in the soil. Weeding was carried out according to conditions in the field by manually pulling weeds.

### Observation Parameter

The parameters observed were seedling height, stem diameter and number of leaves.

### Analysis of Data

The observational data obtained were analyzed with analysis of variance at an error level of 5%. If there is no significant difference between treatments, it is continued with the Duncant Multiple Range Test at the 5% level.

**RESULT AND DISCUSSION**

Characteristics of palm empty fruit bunch decomposed by symbiont bacteria of larvae *Oryctes rhinoceros* Linn
Analysis of the characteristics of oil palm empty fruit bunches decomposed by symbiont bacteria of larvae *Oryctes rhinoceros* Linn by treating the type of bacteria and decomposition time including water content, pH, C/N ratio, and nutrient content of N, P, K. in the following table.

**Table 1: Analysis result of palm empty fruit bunch decomposed by symbiont bacteria of larvae *Oryctes rhinoceros* Linn**

| Treatment | Water content (%) | pH | C/N ratio | N (%) | P (%) | K (%) |
|---|---|---|---|---|---|---|
| $B_0T_1$ | 58.24 | 8.65 | 36.20 | 1.06 | 0.09 | 0.52 |
| $B_1T_1$ | 78.08 | 8,.76 | 12.99 | 2.23 | 0.23 | 1.57 |
| $B_2T_1$ | 77.23 | 9.06 | 10.73 | 2.54 | 0.32 | 1.31 |
| $B_3T_1$ | 78.82 | 9.21 | 11.03 | 2.59 | 0.13 | 1.35 |
| $B_4T_1$ | 71.80 | 9.18 | 8.54 | 3.34 | 0.35 | 1.31 |
| $B_5T_1$ | 76.13 | 9.10 | 8.94 | 3.20 | 0.18 | 1.09 |
| $B_6T_1$ | 67.37 | 9.17 | 7.65 | 3.39 | 0.12 | 1.54 |
| $B_0T_2$ | 62.23 | 8.54 | 18.66 | 1.82 | 0.12 | 0.67 |
| $B_1T_2$ | 79.66 | 8.86 | 11.05 | 2.67 | 0.19 | 0.92 |
| $B_2T_2$ | 77.97 | 9.02 | 14.11 | 2.10 | 0.23 | 0.92 |
| $B_3T_2$ | 79.69 | 8.88 | 12.47 | 2.08 | 0.10 | 0.96 |
| $B_4T_2$ | 79.44 | 8.92 | 10.23 | 2.86 | 0.14 | 0.71 |
| $B_5T_2$ | 77.80 | 8.69 | 15.26 | 2.04 | 0.17 | 1.52 |
| $B_6T_2$ | 76.46 | 7.01 | 8.88 | 3.34 | 0.17 | 0.76 |

Note: $B_0$ = without activator bacteria, $B_1$=*Bacillus stratosphericus* 50 ml/kg, $B_2$=*Bacillus stratosphericus* 75 ml/kg, $B_3$=*Bacillus stratosphericus* 100 ml/kg, $B_4$=*Bacillus siamensis* 50 ml/kg, $B_5$=*Bacillus siamensis* 75 ml/kg, $B_6$=*Bacillus siamensis* 100 ml/kg, $T_1$=5 weeks, $T_2$=7 weeks.

Based on Table 1, it is known that compost pH of palm empty fruit bunches with both types of bioactivators to the dose and time of decomposition ranged from 7.01 - 9.21. According to Isroi (2008), when the composting process is in the pH range of 5.5-8, it is a little neutral towards acid as long as the microorganisms decompose the organic matter. This condition will be neutral when the compost material is ripe. During the early stages of the decomposition process, it takes the form of organic acids. This acidic condition will decompose lignin and cellulose in the compost material. During the composting process, these organic acids will ripen, usually reaching a pH between 6-8.

The water content obtained in the compost with the two types of bioactivators ranged from 67.37 - 79.70%. The water content in this study was higher when compared to previous studies, namely 55-72% (Yeoh *et al*, 2012) and 43-51% (Suherman *et al*, 2014). Water content of 40 - 60% is the optimum range for microbial metabolism. If the water content is below 40%, microbial activity will decrease and will be even lower at around 15% (Rynk, 1992). If the humidity is greater than 60% of the nutrients will be washed, the air volume is reduced, as a result, microbial activity will decrease and anaerobic fermentation will occur which causes an unpleasant smell.

The ratio of C/N in the compost of oil palm empty fruit bunches with the two types of bioactivators to the dose and time of decomposition ranged from 7.65 - 15.26. This shows that humus stability and compost maturity have been achieved. According to (Murbandono, 2005), to determine the level of perfection of composting, the C/N ratio is determined. If the C/N ratio of compost produced is close to the C/N ratio of humus (10 - 12), then the organic compound has decomposed and can be used as organic fertilizer. Furthermore, Yeoh *et al* (2012) explained that in general during the composting process the nitrogen content in the compost material will increase while the carbon content decreases. This will result in a value corresponding to the decrease in the C/N ratio.

Based on Table 1, it can also be seen that the decomposition process of oil palm empty fruit bunches using the larval symbiont bacteria *Oryctes rhinoceros* Linn at the dose and time of decomposition resulted in compost with different nutrient availability. N nutrients ranged from 1.06%-3.39%, this value was higher than the standart compost quality base on SNI 19-7030-2004, where the N content is >0.40%. P nutrients ranged from 0.09%-0.32%, this value correlate with the standart compost quality base on SNI 19-7030-2004, where the P content is >0.10%. K nutrients ranged from 0.52%-1.57%, this value was higher than the standart compost quality base on SNI 19-7030-2004, where the N content is >0.20%.

**Growth of oil palm seedlings in pre nursery**
Observation of the growth of oil palm seedlings in pre-nursery using composting media for palm empty fruit bunches decomposed by symbiont bacteria of larvae *Oryctes rhinoceros* Linn with the treatment of bacteria types and decomposition time including seedling height, stem diameter and number of leaves. Observational data are presented in the following table.

**Table 2: Seedling height of oil palm using palm empty fruit bunch compost**

| Type of bacteria | PEFB decompose | | Mean |
|---|---|---|---|
| | 5 weeks ($T_1$) | 7 weeks ($T_2$) | |
| | ……………...……..cm……………….…..... | | |
| Without bacteria ($B_0$) | 11.80 d | 15.87 c | 13.83 c |
| *B. stratophericus* 50 ml/kg ($B_1$) | 23.43 b | 21.33 b | 22.38 ab |
| *B. stratophericus* 75 ml/kg ($B_2$) | 22.40 b | 22.33 b | 22.37 ab |
| *B. stratophericus* 100 ml/kg ($B_3$) | 20.90 b | 22.07 b | 21.48 ab |
| *B. siamensis* 50 ml/kg ($B_4$) | 26.93 a | 20.60 b | 23.77 a |
| *B. siamensis* 75 ml/kg ($B_5$) | 21.70 b | 19.67 b | 20.68 b |
| *B. siamensis* 100 ml/kg ($B_6$) | 21.77 b | 23.10 b | 22.43 ab |
| Mean | 21.28 | 20.71 | |

Note: The numbers followed by different letters show significant differences according to Duncan's Multiple Range Test at the level of $\alpha = 5\%$.

Based on Table 2, it can be seen that the highest oil palm seedling height was found in the planting medium resulting from the decomposition process of palm empty fruit bunches decomposed by *B. siamensis* 50 ml/kg was 23.77 cm. While the lowest seedling height was found in the treatment without bacteria (control) was 13.83 cm. The treatment interaction that resulted in the highest seedling height was the application of *B. siamensis* 50 ml/kg with a decomposition time of 5 weeks was 26.93 cm which significantly different from other treatments.

Decomposition time had no significant effect on seedling height, but the height of oil palm seedlings with 5 weeks of decomposition was higher than 7 weeks. Based on the results of laboratory analysis, it showed that the nutrient content of composting for 5 weeks was higher than 7 weeks, including N nutrients 18.35% and 16.91%, and K nutrients 8.69% and 5.54% respectively, where these nutrients are needed for vegetative growth such as plant height. Oil palm seeds require high levels of N nutrients to form new cells and tissues during vegetative growth, especially the height of oil palm seedlings. According to Notohadiprawiro *et al* (2006), nitrogen is needed by plants in the vegetative growth phase, especially stem growth which stimulates plant height growth. Besides, according to Lakitan (2005), potassium acts as an activator in carbohydrate synthesis. The carbohydrates produced will affect the activity of the apical meristem in the process of plant height growth. In accordance with Sulistyowati (2011), that the growth of plant height is caused by the activity of the apical meristem, which is the part of the shoot that is actively dividing, so that the plant will grow taller. Apical meristem activity is highly dependent on the availability of carbohydrates obtained from photosynthesis.

**Table 3: Stem diameter of oil palm using palm empty fruit bunch compost**

| Type of bacteria | PEFB decompose | | Mean |
|---|---|---|---|
| | 5 weeks ($T_1$) | 7 weeks ($T_2$) | |
| | ……………...……..cm……………….…..... | | |
| Without bacteria ($B_0$) | 0.37 | 0.47 | 0.42 c |
| *B. stratophericus* 50 ml/kg ($B_1$) | 0.67 | 0.83 | 0.75 a |
| *B. stratophericus* 75 ml/kg ($B_2$) | 0.67 | 0.77 | 0.72 ab |
| *B. stratophericus* 100 ml/kg ($B_3$) | 0.80 | 0.83 | 0.82 a |
| *B. siamensis* 50 ml/kg ($B_4$) | 0.87 | 0.77 | 0.82 a |
| *B. siamensis* 75 ml/kg ($B_5$) | 0.57 | 0.63 | 0.60 b |
| *B. siamensis* 100 ml/kg ($B_6$) | 0.67 | 0.80 | 0.73 ab |
| Mean | 0.66 | 0.73 | |

Note: The numbers followed by different letters show significant differences according to Duncan's Multiple Range Test at the level of $\alpha = 5\%$.

Based on Table 3, it can be seen that the largest stem diameter of oil palm seedlings was found in the planting medium resulting from the decomposition process of palm empty fruit bunches were applied to *B. stratophericus* 100 ml/kg and *B. siamensis* 50 ml/kg, namely 0.82 cm. Meanwhile, the smallest stem diameter was found in the treatment without bacteria (control) was 0.42 cm.

Decomposition of palm empty fruit bunches for 7 weeks showed a larger diameter of oil palm seedlings compared to 5 weeks. This is cause the palm empty fruit bunches that have been decomposed for 7 weeks have undergone a good decomposition process so that the nutrients needed by plants become available, including P and K nutrients that play a role in increasing stem diameter. The results of nutrient analysis also showed that the nutrient content of P and K in palm empty fruit bunches with a decomposition time of 7 weeks was quite high based on the SNI 19-7030-2004 standard. It is known that the enlargement of stem diameter is influenced by the availability of potassium nutrients. The potassium plays a role in accelerating the growth of meristematic tissue, especially in plant stems, strengthening the stem so that it does not fall easily, it is very important in the photosynthesis process where increasing photosynthesis in plants will increase the size of the diameter of the plant stem. According to Fajar *et al* (2016), that the stem is an area of accumulation of plant growth, especially in younger plants so that the presence of nutrients can encourage vegetative growth of plants including the formation of chlorophyll in the leaves so that it will spur the rate of photosynthesis useful for increasing the size of the diameter of the plant stem. The growth of the diameter of the stem diameter of oil palm seedlings is influenced by the presence of nutrient N, P and K, but K nutrient is an nutrient needed in larger quantities for the growth of the diameter of the weevil of oil palm seedlings. The available N acts as the main element for forming chlorophyll which is useful for photosynthesis while the available P element plays a role in producing energy which is also useful in the photosynthesis process. The potassium helps in the process of forming carbohydrates so that the carbohydrates formed will be translocated to the stem.

**Table 4: Number of leaves of oil palm using palm empty fruit bunch compost**

| Type of bacteria | PEFB decompose | | Mean |
|---|---|---|---|
| | 5 weeks ($T_1$) | 7 weeks ($T_2$) | |
| | ……………………..leaves……………..….... | | |
| Without bacteria ($B_0$) | 3.00 | 3.00 | 3.00 c |
| *B. stratophericus* 50 ml/kg ($B_1$) | 4.00 | 3.33 | 3.67 b |
| *B. stratophericus* 75 ml/kg ($B_2$) | 3.33 | 4.00 | 3.67 b |
| *B. stratophericus* 100 ml/kg ($B_3$) | 4.00 | 4.00 | 4.00 ab |
| *B. siamensis* 50 ml/kg ($B_4$) | 4.33 | 4.33 | 4.33 a |
| *B. siamensis* 75 ml/kg ($B_5$) | 4.00 | 3.67 | 3.83 ab |
| *B. siamensis* 100 ml/kg ($B_6$) | 3.67 | 4.33 | 4.00 ab |
| Mean | 3.76 | 3.81 | |

Note: The numbers followed by different letters show significant differences according to Duncan's Multiple Range Test at the level of $\alpha = 5\%$.

Based on Table 4, it can be seen that the highest number of leaves of oil palm seedlings was found in the planting media resulting from the decomposition process of palm empty fruit bunches were applied to *B. siamensis* 50 ml/kg, namely 4.33 leaves. While the lowest number of leaves was found in the treatment without bacteria (control) was 3.00 leaves.

The number of leaves of oil palm seedlings was not significantly different between the 5 and 7 weeks of decomposition, but the number of leaves was higher in the palm empty fruit bunches that were decomposed for 7 weeks, namely 3.81 leaves. Similar to the stem diameter parameter, this is also due to the high nutrient content in palm empty fruit bunches compost with a decomposition time of 7 weeks based on the SNI 19-7030-2004 standard, especially N and P nutrients, for formation of new cells and the main component of organic compounds in plants that affect plant vegetative growth. In accordance with Lakitan (2005), that the availability of N and P nutrient will affect leaves in terms of shape and number, where the N content contained in plants will be utilized by plants in cell enlargement. Nitrogen is needed in relatively large amounts in every plant growth, especially at the vegetative growth stage, such as an increase in the number of leaves (Novizan, 2005). While the P nutrient plays a role in the division and formation of plant organs. The division and enlargement of young cells will form leaf primordia (Hardjowigeno, 2007).

## CONCLUSION

The treatment of bacteria activator type and decomposition time had a significant effect on the quality of the compost, namely pH, water content, C/N ratio and nutrient content. The interaction of *B. siamensis* 50 ml/kg palm empty fruit bunches with decomposition time of 5 weeks resulted in the best growth of oil palm seedlings in pre nursery.

## REFERENCES

Agung, A.K., Adipresetyo, T., Hermansyah. (2019). Use of oil palm empty fruit bunch compost as a substitute for NPK fertilizer in oil palm pre nursery. *Journal of agricultural sciences,* 21(2):75-81. DOI: 10.31186/jipi.21.2.75-81.

Agustini, D. M. (2006). Earthworm Diversity in Coffee-Based Agroforestry in Tawangsari Village, Pujon District, Malang. [Student Paper]. University of Brawijaya. Malang.

Comte, I., Colin, F., Grunberger, O., Follain, S., Whalen, J.K., Caliman, J.P. (2013). Landscape-scale Assessment of soil Response to long-term organik and mineral fertilizer application in an indutrial oil palm plantation, Indonesia. *Agriculture, Ecosystem and Environment*, 58-68.

Darmosarkoro, W. & Rahutomo, S.. (2007). Oil Palm Empty Bunches As Soil Improvement Material. Journal of Palm Oil Land and Fertilization Issue 1. *Palm Oil Research Center,* C3: 167-180.

Fajar, A. (2016). The role of nitrogen fertilizers in growth and yield of stevia (*Stevia rebaudiana* bertoni M.). [Student Paper]. University of Brawijaya. Malang.

Hardjowigeno, S. (2007). *Soil Science*. Jakarta: Rajawali Press.

Isroi. (2008). *Compost*. Magazine. Indonesian Plantation Biotechnology Research Institute, Bogor.

Lakitan, B. (2005). *Physiology of Plant Growth and Development*. Jakarta: PT. Raja Grafindo Persada.

Marheni. (2012). Bioecological Characteristics of Orytes rhinoceros (L.) in Oil Palm Plantations. [Disertation]. Universitas Gadjah Mada. Yogyakarta.

Murbandono, L. (2005). *Composting*. Jakarta: Penebar Swadaya.

Notohadiprawiro, T., Soekodarmodjo, S., Sukana, E. (2006). Soil Fertility Management and Fertilization Efficiency Improvement. Soil Science Repro. University of Gadjah Mada. Yogyakarta.

Novizan, (2005). *Effective Fertilization Instructions*. Jakarta: Agromedia Pustaka.

Rynk, R. (1992). On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service Pub. No. 54. Cooperative Extension Service. Ithaca, New York. 186pp.

Suherman, C., Nuraini, A., Rosniawaty, S. (2007). Utilization of Arbuskilar Mycorrhizal Fungi (CMA) and Subsoil and Compost Mixed Media in Oil Palm Seedlings (*Elaeis quineensis*) Sungai Pancur Cultivars (SP2). [Student Paper]. University of Padjajaran. Bandung.

Suherman, I., Awaluddin, A., Itnawita. (2014). Analysis of compost quality from a mixture of oil palm empty fruit bunches and chicken manure using palm oil mill effluent and EM-4. *JOM FMIPA*, 1(2): 194-204.

Sulistyowati, H. (2011). Provision of Sago Dregs Bocation on Alluvial Medium for Jatropha Seedlings. *J. Tek. Perkebunan & PSDL,* (1): 8-12.

Yeoh, C.Y., Chin, N.L., Tan, C.S., Ooi, H.S. (2012). Industrial scale co-composting of palm oil mill waste with starter cultures. *Journal of Food, Agriculture and Environment*, 10 : 771-775.