Application of compost produced by bioconversion of coffee husk by black soldier fly larvae (*Hermetia illucens*) as solid fertilizer to lettuce (*Lactuca sativa* var. crispa) : Impact to harvested biomass and utilization of nitrogen, phosphor, and potassium

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Article Info

Article history:

Received Jul 12th, 2017
Revised Aug 20th, 2017
Accepted Oct 26th, 2017

Keyword:

Bioconversion
Coffee Husk
Compost
Growth
Lettuce

ABSTRACT

Coffee husk is main by product of coffee production and considered has low economic value. Application of this product as feedstuff of insect larvae (i.e. black soldier fly larvae (Hermetia illucens)) could potencially produce insect biomass and organic solid fertilizer which has significant improved economic value. This study aimed to observe the effect of application of manure, conventional compost of coffee husk, and compost produced by bioconversion activity of black soldier fly larvae to biomass, nitrogen, phosphor, and potassium utilization of lettuce (Lactuca sativa). The result showed lettuce cultivated with manure produced significantly highest biomass (62.513 gram) and nitrogen utilization (2.912 gram/kilogram). On the other hand, lettuce cultivated with compost produced by bioconversion had highest phosphor (0.00937 gram/kilogram) and potassium (3.18118 gram/kilogram) utilization. Based on the results, it could be concluded that compost produced by bioconversion process of coffee husk by black soldier fly larvae allowed plant to fulfill their requirement of phosphor and potassium which is considered lack in common Indonesia soil.

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1. INTRODUCTION

Indonesia is one of the major coffee production with increasing trend of production. However, during processing of coffee beans, about 40-55% of bean disposes as coffe husk which has not been properly utilized. This hard and difficult to decompose organic waste usually ignored and thrown away [1]. Coffee husk that is allowed to mount could become source of disease source, unpleasant odour, and pollute environment [2]. Coffee husk, in general, contains 2.07% nitrogen; 0.55% P_2O_5 and 2.87% K_2O, which is potencially can be used as raw material of solid organic fertilizer [3] and support the increasing organic farming practices in Indonesia.

The demand for organic products in the world has increased 15-20% per year with a market share of US$ 100 million [4]. Organic food is food produced at least or free of synthetic chemical residues from pesticides, fertilizers, hormones, and medicines. Organic food also does not contain seeds derived from GMO / genetic engineering thus the production process is done naturally from cultivation until processing. The advantage of organic products is a taste better, content more vitamins, minerals and enzymes are good for body health and reduce the risk of chronic diseases such as hypertension, cancer, heart disease, diabetes, and others [5]. Organic farmland in the world reaches 24 million hectares spread in the largest organic farmland in some areas of China, India, Italy (1.2 million ha), Argentina (3.2 million ha), and Australia (10.5 million ha) [6]. The opportunities for organic farming in Indonesia are enormous due toits high population who can potentially become organic products consumer.

Lettuce is considered as the vegetable with largest demand in the world. The lettuce leaves contain phosphate, antioxidant from betakarotin, and indol which can protect the body from cancer attack. In addition, the natural fiber content of lettuce can improve the health of the digestive organs [7]. West Java is major lettuce producer in Indonesia with major plantation located in Cipanas (Cianjur) and Lembang (Bandung). However, local producer unable to fulfill market demand for this vegetable which lead to import about 953 kg or equivalent to US $ 1,956.2 per year (in 1984-1988) [8]. Based on that facts stated previously, it is necessary to develop a cultivation system that could fulfilled market demand for both conventional and organic markets. One of limiting factors in lettuce production is fertilizer. Application of synthetic chemical fertilizer would add additional cost to farmers while in the same time remove the possibility of entering organic market. Thus, utilization of unused organic waste, like coffee husk, could be an answer to solve environmental problem while in the same time supporting the development of organic farming through application of solid organic fertilizer [9], [10]. In this study, coffe husk was converted into solid organic fertilizer by biconversion process utilized Black Soldier Fly Larva (BSFL) as agent. This organism is known for their ability to consume wide range of organic wastes such as agricultural wastes [11], [12], animal and human remains [13]-[14], fish offal [15], food waste [16]-[18], as well human and livestock feces [19]-[22]. During this process, undigested feed materials and feces produced by larvae is can be use as solid organic fertilizer for plant [21]. In order to know the effectiveness of fertilizer, it is necessary to undertand the utilization major nutrients, Nitrogen, Phosphor, and Potassium, which is the purpose of this study by plant This study focuses on the use of coffee husk as a compost both composted by black soldier fly and naturally composted husk (without BSF) to meet the nutritional and growth biomass of organic lettuce plants.

2. RESEARCH METHOD

2.1 Research Area and Period

The research was conducted in Institut Teknologi Bandung Campus Jatinangor Sumedang District. Preparation The research was conducted from October 2016 to April 2017. The planting started on April 22 2017 and harvesting started on May 24, 2017. The measurement of plant biomass was done at harvest time in Laboratory Technique 1A, ITB Jatinangor while the analysis of nutrient uptake level was done in Chemistry Analytical Laboratory Reksa Buana, Bandung. During the research, the average ground temperature of the study sites was 27.40C with an average humidity of 66.315% and soil pH of 5.68.

2.2 Compost production

Compost was originated from bioconversion of coffee husk by black soldier fly larvae (BSFL compost). Coffee husk used in this study produced as waste in coffee bean milling at Ciparay. During bioconversion, BSFL was fed with combination of milled coffee husk with water (60:40) until metamorphosed into prepupae. Residue (consisted of undigested feeding material and faecal produced by larvae) was collected and used as compost for this study.Some chemicals content of compost that related to cultivation (Nitrogen, Phosphor, Potassium, and C-organic) were analyzed in Balai Penelitian Tanaman Sayuran, Lembang, West Java (Table 1).

Table 1. Chemical content of Coffee Husk and BSFL Compost

Parameter	Coffee Husk	BSFL Compost
C-Organik (%)	51.31	31.10
N-Total (%)	1.64	1.27
C/N Rasio	31	24
P_2O_5 (%)	0.19	0.46
K_2O (%)	2.84	2.79

2.3 Compost application

The study was conducted by Randomized Block Design (RAK) consisting of 5 treatments and 5 replications. Each replication consists of 6 plants so that the total plant observed is 150 plants.

In this study completely random design was applied. Plant was sowing in germination material for 14 days then removed to polybag (20 x 30 cm) filled with specific growth medium designed for this study. There were 5 types of growth medium

A : soil and cow's dung (1 : 1)[23]
B : soil and BSFL compost (1 : 1)
C : soil and BSFL compost (2 : 1)
D : soil and coffee husk (1 : 1)
E : soil and coffee husk (2 : 1)

Plant watered with 200 ml water twice a day and organic pesticide was applied as pest control. All plants were harvested 30 days after planted.

2.4 Data Collection

Observed variables were fresh biomass, dry biomass, and N, P, K utilization analysis of harvested products. Fresh biomass of plants measured included total biomass of root and leaves. Dry biomass was measured 24 hours of fresh biomass storage at an oven of 105ºC.

Analysis of N, P, and K utilization levels was analyzed in chemistry analytical laboratory of Reksa Buana, Bandung.

2.5 Statistical Analysis

The data collected in this study were analyzed using ANOVA with 95% confidence level ($\alpha = 0.05$). If the obtained values are significantly different then it tested further by statistical Tukey test. Data which has no normal distribution value is conducted non parametric test in the form of Kruskall Wallis test. If the value of significantly different then doing the other statistical tests. In this research, author used Mann-Whitney test.

3. RESULTS AND ANALYSIS

3.1. Fresh and Dry Biomass

Group A produced significantly heaviest fresh biomass than other groups while lettuce planted in growing medium with coffe husk produced significantly lightest fresh biomass (Table 2). On the other hand, Lettuce of Group A also has heaviest dry mass while group D and E has the lightest (Table 2).It could be assume that microbial activities in group A, B, and C provided more available nutrient for plant in faster rate. High C/N ratio of coffee husk prevent decomposition of organic material into available nutrient for plant due to insufficient nitrogen required for cellulolytic process by microflora thus slowing down rate of nutrient availability for plants Atkins et al. [24].Low levels of C / N can minimize the uptake of nitrogen for the growth of soil microbes so that the uptake of plant nitrogen will be higher. The nitrogen element encourages the growth of stems and leaves, so the higher the nitrogen the higher the yield of the photosynthate of plants [25].

Table 2. Result of Fresh And Dry Biomass Letuce

Treatment	Fresh Biomass	Dry Biomass
A	62.251± 16.8913a	4.03867± 0.9494a
B	21.004 ± 7.8663b	1.68867±0.8242b
C	11.781± 3.8658c	1.10667±0.3061b
D	2.500± 0.5162d	0.27067±0.0541c
E	1.975± 0.4940d	0.25333±0.0499c

Different letter indicated signficantly different value ($P \leq 0{,}05$)

Average fresh weight of lettuce biomass obtained has an average of 19.902 grams with the largest fresh biomass of 62.251 grams and the smallest fresh biomass of 1.975 grams (Table 2). Expected average fresh biomass of polybag curling lettuce is 34.17 grams [26] which is much higher then result of this study. This can be caused by the variance of biomass which is too large in each treatment or differences in environmental condition.

Average dry weight lettuce biomass obtained has an average of 1.472 grams with the largest dry biomass of 4.039 grams and the smallest dry biomass of 0.253 grams (Table 2) which also lighter compared to Jasminarni [26]who reported dry biomass of polybag curling lettuce is 2,675 grams. This can be caused by fresh biomass in treatment A produces the greatest dry weight as well. The rate of photosynthesis is different, the number of photosynthates produced will be also different and the impact of dry weight of the plant reflects the rate of plant growth [27].

3.2. Nitrogen Utilization

The highest nitrogen utilization was treatment A with an absorption value of 1 kilogram of lettuce samples was 2.912 grams while the lowest nitrogen utilization was treatment C with the absorption value of each 1 kilogram of lettuce sample was 1.62161 gram (Table 3).

Table 3. Nitrogen Utilizatoin of Lettuce

Treatment	Nitrogen Utilization (gram/ kg lettuce sample)
A	2.912
B	2.06008
C	1.62161
D	2.04978
E	2.34985

This result supported the data on biomass which showed that group A has the highest biomass value. Nitrogen is a constituent component of essential compounds in the form of amino acids, nucleic, protein, chlorophyll, and the main components of dry biomass from plant protoplasm [28].The nitrogen element promotes the growth of stems and leaves so that the higher the nitrogen the higher the yield of the photosynth of the plant [25]. Based on the research results, the average nitrogen utilizationeach 1 kilogram sample of lettuce composting of Black Soldier Fly converted coffee husk is lower (1.840845 gram) than the compost without BSF converted (2,199815 gram). This can be caused by the nitrogen content in the compost absorbed by *Black Soldier Fly* for metabolic process in order to develop their biomass [29].

3.3. Phosphor Utilization

The highest phosphorus utilization is in treatment B with the absorption value of each 1 kilogram sample is 0.00937 grams and the lowest phosphorus absorption rate is in treatment A with the absorption value per 1 kilogram is 0.00294 gram / kg. The phosphorus uptake of 1 kilogram of lettuce samples of coffee husk bioconversion by BSF compost treatment was higher (0.007635 gram) than coffee husk without bioconversion by BSF compost (0.005295 gram) (Table 4).

Table 4. PhosphorUtilization to Lettuce

Treatment	Phosphor Utilization (gram/ kg lettuce sample)
A	0.00294
B	0.00937
C	0.0059
D	0.00543
E	0.00516

This result is suitable with the statement of Dzung et al.[30] which states that the coffee husk without agent composting has very low phosphorus content with high C/N ratio value so that composting effort and the addition of compost agent are needed. According to Miza [31], there is a mutual influence between nitrogen utilization and the availability of phosphorus. Phosphorus fertilization is highly dependent on nitrogen in the soil. If the available nitrogen is limited then the phosphorus utilization islimited too. Good growth conditions with sufficient nitrogen allowing plants to absorb phosphorus more effectively. Nitrogen also promotes growth and development root so that it increase the absorption capacity and speed of phosphorus uptake. Nitrogen is also a major constituent of phosphate enzymes that play an active role in the process of P-mineralization in soil [32]. If the phosphate is available less, then the nitrogen utilization will decrease. However, the results showed that treatment A with the highest nitrogen absorption did not have the highest phosphorus uptake (the highest phosphorus absorption was coffee husk bioconversion by BSF(1: 1) compost with absorption value of 1 kilogram of lettuce samples 0.00937 gram). This can be caused by lost of phosphor content in lettuce during storage prior analysis.

Phosphorus is necessary because it plays a role in the process of photosynthesis. Phosphor is absorbed in the form of H_2PO_4 ions and a small portion of HPO_4^{2-} ions [33]. In the generative phase, phosphor plays a role in the process of growing fruits, seeds, and flowers [34]. Based on this study, it could be assume the BSFL compost may provide better product in fruit plant due to high utilization of phosphor by plant.

3.4. Potassium Utilization

The highest potassium absorption rate was in treatment C with an absorption value of 1 kilogram of lettuce samples was 3.18118 grams while the lowest phosphorus absorption rate was in treatment A with the absorption value per 1 kilogram of lettuce sample was 2.6618 gram. The absorption value of each kilogram of lettuce samples in the treatment of coffee husk bioconversion by BSF (3.15965 gram) was higher than that without bioconversion by BSF (2.735175 gram) (Table 5).

Table 5. Potassium Utilization to Lettuce

Treatment	Potassium Uttilization (gram/ kg lettuce sample)
A	3.04945
B	3.13821
C	3.18118
D	2.80855
E	2.6618

This result is accordance with Dzung et al [30] which states that the potassium, calcium and phosphorus content will increase after the composting process. The activity of microorganisms in the composting agent plays a major role in the oxidation of potassium and phosphorus dissolved, thus increasing the uptake of plant nutrients.Potassium is very important for plants because it plays a role in the assimilation of carbon dioxide. Potassium is absorbed in the form of K. Plants that have many leaves require an abundant K_2O element for photosynthesis. Potassium also plays a role in the generative phase because it acts as a tissue booster of flowers, leaves, and fruits not to easily fall out.Based on this study, it could be assume the BSFL compost may provide better product in fruit plant due to high utilization of phosphor by plant.

4. CONCLUSION

Compost produced by bioconversion of coffee husk by Black Soldier Fly Larvae (BSFL compost)able to be used as solid organic fertilizer for lettuce cultivation. Lettuce has higher phosphor and phosphat utilization in BSFL compost. Thus, it provide alternative to improve the phosphor and potassium condition of many agricultural soils in Indonesia especially during rise of organic farming in Indonesia.

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ACKNOWLEDGEMENTS

This study was partially funded by Penelitian Strategi Nasional Institusi granted to first author.The author would like to than Prof Dr. Ir. Agus Pakpahan who has given practitioners knowledge about BSF and also provided BSF eggs. The author are also grateful to Maju Mekar Rancakalon Coffee Farmer Group, Mr. Sulaeman, and Mr. Bustome who have provided coffee husk grants to be used as compost raw materials.

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