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Research Paper

The Use of Biofilm Biofertilizer to Increase Smart Farming System in Mustard Yield and Improve Soil Physical Properties of Vertisols

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Abstract
Soil serves as the growing medium and source of nutrients for plants. Vertisol soil, however, does bring with it some flaws particularly its physical characteristics. The application of organic fertilizer decomposed with *Biofilm biofertilizer*, thus, is expected to improve the physical characteristics of soil and yield of mustard. The aim of the research is to study the effect of the dose of organic fertilizer decomposed by *Biofilm biofertilizer* to the betterment of Vertisol soil physical characteristics and the mustard yield. The experiment was completed in a field with Randomized Complete Block Design consisting of a single treatment factor in the form of *Biofilm biofertilizer*. The data obtained from the series of observations was analyzed based on the F test with 95% confidence level followed by Duncan's Multiple Range Test (DMRT). The variables of the observations involve the mustard plant yield and the soil physical characteristics. The study shows that the application of the organic fertilizer decomposed by *Biofilm bio-fertilizer* provides significant effects towards the improvement of the vertisol soil's physical characteristics and the increase in mustard plant yield. The dose 21 tons/ha results in the highest increase in the mustard plant production and the best improvement of the vertisol soil physical characteristics. Organic fertilizer decomposed by *Biofilm bio-fertilizer* 21 tons/ha helps in developing permeability as much as 685.71%; aggregate stability index 201.6%; organic material 20.74%; and porosity 122.38%. Also, organic fertilizer decomposed by *Biofilm bio-fertilizer* 21 tons/ha can boost the mustard plant production as much as 4.25 tons/ha compared to the absence of organic fertilizer decomposed by *Biofilm bio-fertilizer*.

Keywords
vertisol soil, organic fertilizer, the mustard plant yield , physical characteristics

1. INTRODUCTION

Vegetables are an important commodity in supporting national food security and have high economic values. Vegetable production in Indonesia was declined annually from 2011 to 2015, and its consumption was recorded at 129.16 kg/capita/year in 2014 (Badan Pusat Statistik (BPS), 2015). One of the vegetables often consumed by people is mustard greens, *Brassica juncea* L. On the other hand, the mustard yield is insufficient to meet public demand due to the increasingly narrow planting area and low productivity. According to BPS (2014), the yield of mustard greens in the year 2013 amounted to 10.10 tons/ha, and in 2014, it decreased to 9.91 tons/ha. Increasing vegetable production, especially mustard greens, can be achieved through either intensification or extensification. Extensification, which involves extending the planting area, is still feasible, considering the availability of land that has not yet been optimally utilized for horticultural crop production. One type of land that can be optimized is Vertisol soil.

According to Yuwono (2002), the use of organic fertilizer has dual benefits: it improves the physical structure and fertility of the soil. One way to optimize the use of organic fertilizers is by decomposing them into *Biofilm* biofertilizer. *Biofilm* bio-fertilizer employs microbial methods to increase crop yields through the formation of a thin layer of microbial consortia that enhances nutrient availability and uptake and prevents pathogenic attacks (Sudadi, 2011).

Therefore, it is necessary to study the development efforts for mustard greens in high clay soils such as Vertisol or Grumosol, with the addition of organic fertilizers decomposed with *Biofilm* bio-fertilizers. Furthermore, the most appropriate dosage for the effective use of these fertilizers should also be reviewed so that mustard green production in Indonesia can be increased, leading to higher farmers' incomes.

2. EXPERIMENTAL SECTION

2.1 Material and Methods

Soil used in this experiment was Vertisol and soil analysis was conducted at Soil Chemistry and Fertility Laboratory, Soil Physics and Conservation Laboratory, and Soil Biology and Biotechnology Laboratory, Faculty of Agriculture, Sebelas Maret University, Surakarta including of soil C-organic content, aggregate stability, soil moisture content, soil porosity, and soil permeability. The experimental design used was Completely Randomized Block Design with a single treatment factor that is the dosage of organic fertilizer decomposed with biofilms bio-fertilizer (D) consisting of nine treatments i.e., D0 (0 ton/ha), D1 (3 ton/ha), D2 (6 ton/ha), D3 (9 ton/ha), D4 (12 ton/ha), D5 (15 ton/ha), D6 (18 ton/ha), D7 (21 ton/ha), and D8 (NPK fertilizer in the form of urea, SP-36, and KCl at 150, 75, and 40 kg/ha). Each treatment was replicated three times. Randomization was obtained by lottery. The observed data were analyzed based on the F test (ANOVA) with a 95% confidence level followed by Duncan's Multiple Range Test (DMRT) if there was any significant influence. Then the DMRT test continued. Preparation of biofilmed biofertilizer was done by multiplying the microbes on the medium of NA (Nutrient Agar) and PDA (Potato Dextrose Agar). The microbes consist of Phosphate Solubilizing Bacteria (PSB) Isolates (PBH 18), isolates of *Aspergillus niger* (YD 17), Kalium Solubilizing Bacteria (KSB) (PPH 7), Sulfur Oxidizing Bacteria (SOB) (HBH 12), *Beauveria sp.*, *Trichoderma sp.*, and Phosphate Solubilizing Fungi (PSF) *Aspergillus japonicus*. The material was boosted for 3 days and propagated in a liquid medium with a composition of 10 L of coconut water, 5 L of rice water, $\frac{1}{2}$ L molasses, 20 grams of SP-36, 10 grams of KCl, and 10 grams of urea. All ingredients were mixed after microbial inoculum was incubated and cultured for 1 week.

The organic fertilizer was made by mixing homogeneously the materials of (each of 100 kg organic fertilizer material): 75 kg of quail manure, 5 kg rice bran, 10 kg fine phosphate rock, 5 kg fine feldspar rock, 4.5 kg of $CaCO_3$, 0.5 kg fine sulfur, and 5 L of biofilm biofertilizer solution (1L liquid biofilm biofertilizer/20 liter of 3% molasses solution). The water content of the homogenous material was then adjusted to 40–60% by adding water. The material was then incubated for 3 weeks to decompose.

The land preparation was done by making plots. Each plot has an area of 1.5x1.2 meters. After that, the application of organic fertilizer decomposed with biofilms bio-fertilizer was conducted according to the treatment. NPK fertilizer treatment was given 14 days after planting. Mustard planting was done using seeds with a spacing of 15x15 cm and a plot size of 1.5x1.2 m. Six plant samples were taken from each plot, resulting in 162 plant samples in total. Land processing included embankment and cleaning of weeds and pests. Organic and NPK fertilizers were applied at the beginning of planting according to the treatment doses.

Table 1. Some characteristics of Vertisol soil used for experimental research

Variable Observations	Value	Unit	Rating
CEC	44.72	Cmol(+)kg	Very high
N Total	0.36	%	Medium
P Available	1.69	Ppm	Very low
K Available	0.05	Cmol(+)kg	Very low
Organic Materials	1.36	%	Low
Soil pH	6.7	-	Neutral
Porosity	24.44	%	Very poor
Aggregate	84.78	-	Very steady
Permeability	0.14	Cm/hour	Slow
Soil Texture			
Sand	3.47	%	Clay
Silt	10.39	%	-
Clay	86.13	%	Sandy

*Note: according to Soil Research Institute, 2009

Analysis of soil physical properties included soil permeability, soil aggregate stability, volume weight, specific gravity, moisture capacity, air-dry humidity, porosity, and initial texture. Maintenance included watering, weeding, and control of plant pests in mustard greens. Watering was done every day. Sampling was performed on each treatment plot, taking the middle samples (plants that are at least two bands from the edge of the plot) using the X method. From each plot, six plant samples were taken, totaling 162 plant samples.

3. RESULT AND DISCUSSION

Most of Vertisols were fertile soil with high cation exchange Capacity (CEC) and saturation base. The constraints of the soil were high clay content and shrink-swell properties. Proper application of organic matter will make that soil well-managed. Table 1 showed that soil CEC was very high so that its ability to store nutrients was relatively good. The cation exchange capacity is a chemical property that is closely related to soil fertility, the amount of clay determined the CEC level, higher the number of clay fractions of a soil type then the CEC will be increasing (Nurmasyitah et al., 2013). The level of organic matter included in the low class that was equal to 1.36%. Soils containing little organic matter had a low population density of microorganisms, since most of the transformation of organic matter was done by microorganisms (Sudirja, 2007).

3.1 Fertilizer Analysis

Organic fertilizer decomposed with biofilm bio-fertilizer had moisture content of 0.67%, N Total of 2.94%, P Total of 0.048%, K Total of 1.61%, Organic C of 16.1%, fertilizer pH of 7.6 and C/N ratio of 5.48. According to Tantya (2016)

Table 2. Fertilizer Analysis

Variables	Value
N Fertilizer (Urea)	2.94%
P Fertilizer (SP-36)	0.048%
K Fertilizer (KCl)	1.61%
C organic	16.1%
pH Fertilizer	7.6
C/N	5.48

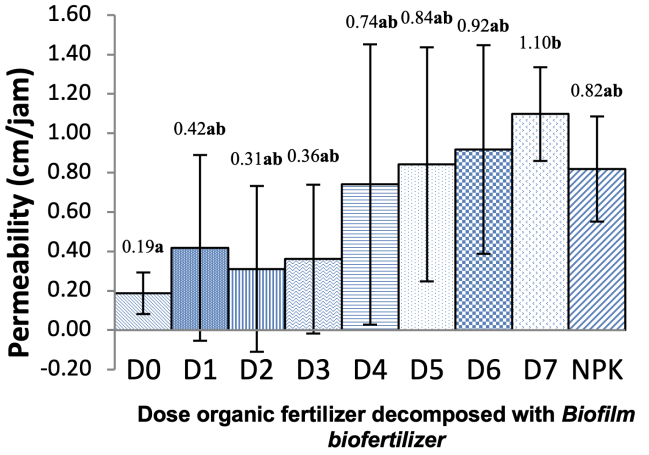

Figure 1. Treatment effect to the Vertisol soil permeability planted with mustard

C/N ratio was contained in the compost describes the level of compost maturity, the higher the C/N ratio means the compost has not decomposed perfectly or in other words immature and not ready for sale or used as fertilizer. The C/N ratio will affect the nutrient availability, if C/N ratio is high then the nutrient content is slightly available for the plant, otherwise if C/N ratio is low then the availability of high nutrients is available for the plant. C/N is one of the important factors affecting the decomposition process (Huang GF et al., 2004).

3.2 Influence of the Treatment on Soil Physical Properties

3.2.1 Soil Permeability

The F-test result at the confidence level of 5% hence giving of organic fertilizer decomposed with biofilm bio-fertilizers at mustard planted land had significant effect to the soil permeability. The result of variance analysis was significantly different then tested further by using DMRT with 95% confidence level, as shown in Figure 1.

High clay soils generally had strong aggregate bonds, few pores, and slow permeability. Understanding of soil permeability was the easiness of air, liquid or plant roots to penetrate or through a plot of soil or soil layer (Buckman and Brady, 1982). Good soil permeability in dry land

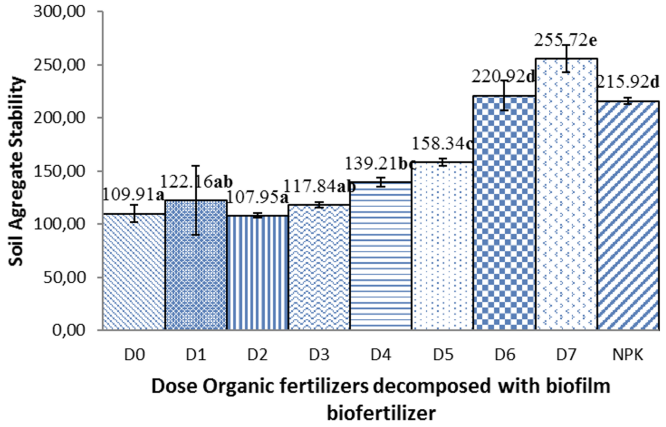

Figure 2. The effect of treatment to aggregate stability of Vertisol soil planted with mustard.

generally ranged from 1.5 to 5.0 cm hr^{-1}. Application of manure on high clay soil increased the number of pores of the soil, both of micro, meso, and macro pores. In addition, manure had high water absorbing properties. Manure can also improve the aggregate formation of soil well, resulting in reduced density (Saifuddin, 1985). Due to the reduced density then soil porosity will increase so that will increase the pores size of the soil and increased the soil ability in water passing. According to Arifin (2010) stated that intensive soil management and without the addition of organic matter resulted in damage to soil structure. Further result in the ability of soil permeability becomes decreased.

3.2.2 Soil Aggregate Stability

Given the importance of aggregate stability in the soil, it is necessary to improve it. One attempt to improve aggregate stability is the administration of organic matter. According to Mustoyo (2013) the application of manure can improve the physical properties of the soil. The increase of physical properties of the soil can be seen from the higher the dose given the more porous the soil and the water holding power is stronger. The more or higher the doses are given the more aggregates were formed and the more steady the situation.

The F-test result at confidence level of 5% hence giving of organic fertilizer decomposed with Biofilm bio-fertilizers have real effect to stability aggregate of vertisol soil planted with mustard. The treatment which has the highest aggregate stability index value is D7 with dose of 21 ton/ha has real effect to all treatment. This happens because organic matter can stimulate the formation of granulations on the soil. According to Judge et al. (1986), organic matter plays a role in stimulating aggregate granulation and can stabilize it.

Organic materials made the soil more friable, encouraging the activity of microorganisms in the soil so as to accelerate the formation of better soil aggregates. Organic matter is instrumental in the process of aggregate soil for-

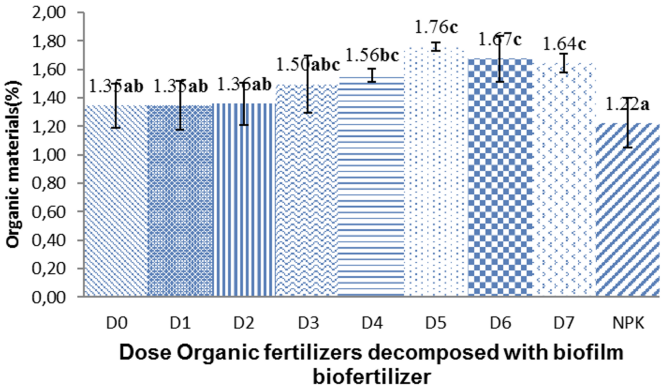

Figure 3. The effect of treatment on soil organic matter content of Vertisols planted with mustard

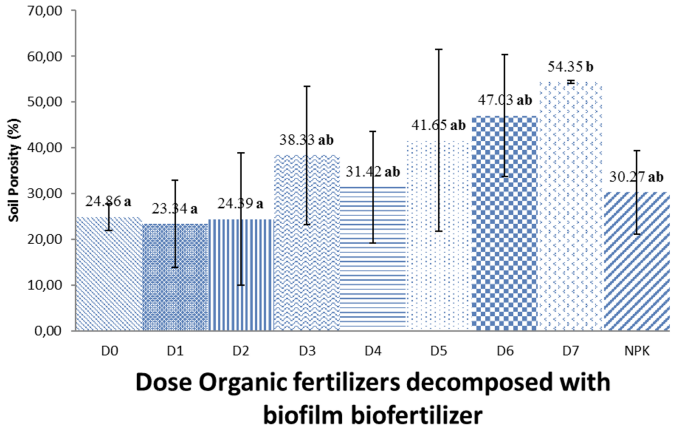

Figure 4. The effect of treatment to soil porosity of Vertisol soil planted with mustard

mation. Decomposition of organic matter produced organic compounds such as organic acids and humus that can glue the soil fractions into a whole aggregate unity. In accordance with the opinion of Saifuddin (1985) that the role of organic matter to the physical properties of the soil is to increase the stability of soil aggregates, improve soil structure and increase the rate of soil infiltration.

3.2.3 Soil organic content

The levels of organic matter in all organic fertilizer treatments had higher value compared to the NPK treatment. This is in accordance to the study results of Syukur and Indah (2006), that the application of compost and manure increased the content of soil organic matter. The more organic fertilizers added to the soil, the greater the organic matter content in the soil. The addition of manure will increase the content of soil organic matter. It is necessary as a substitute for organic matter lost or absorbed by plants or additions to soils of low organic matter content. This is in accordance to the Setyamidjaja (1986) and Soepardi (1983), that the addition of organic matter into the soil will increase the availability of nutrients and organic matter content in the soil.

3.2.4 Soil Porosity

Application of organic fertilizer decomposed biofilm bio-fertilizer was significantly affect to the soil porosity. This is in accordance to the Wolf and Snyder (2003) that porosity was influenced by soil organic matter. The study result was indicated that the composting of municipal waste as much as 10 tons ha^{-1} improved the physical properties of soil in the form of decreasing of soil content weight, increasing total pore space, capillary pore, and aggregate stability. While Essien (2011) showed that application of goat and chicken manure up to 70 ton/ha can increase infiltration rate and porosity of sandy clay soil.

Figure 4 was shown that the use of various doses of organic fertilizers decomposed with biofilm bio-fertilizers had a significant effect on soil porosity. According to Munawar (2011) increasing of organic material can indirectly increase the soil porosity through increasing soil fauna activity. In addition, according to S. (2007), soil porosity was influenced by organic matter content, structure, pore size and soil texture can also be said that high level of organic matter was resulted in increasing of soil porosity. Application of organic fertilizer decomposed with biofilm biofertilizers has a significant effect on soil porosity. With high organic material, it will be able to create a high pore space too. This was because the organic material increased the formation of crumbed soil structure and made the pores in the soil become more and loose (Refliaty, 2011). In addition, decomposed organic materials such as polysaccharides can act as agents that can bind the primary grains to secondary grains so as to create a larger pore space (Brady and Weil, 2002). According to S. (2007), soil with a high organic material content has high porosity as well. Judge et al. (1986) stated that soils with high organic matter can decrease the content weight and in turn increase the porosity of the soil.

3.3 Mustard Growth and Yield

3.3.1 Plants Height

One of the variables measured in this study was plant height. Plant height was calculated from the base of the stem to the end of the longest leaves. Plant height was often observed as an indicator of growth as well as a variable to measure the environmental influence or treatment applied because plant height is the most easily visible growth measure Ekowati and Nasir (2011).

Mustard height gave noticeable results with each experienced a significant increase. The highest plant height was in the treatment of D7 (21 ton/ha) which equaled 26.39 cm, while the lowest plant height is D0 (control) with 4.19 cm. The result of ANOVA test with 95% confidence level showed a significant influence. This shows that the fertilizer dose of 21 ton/ha was able to supply Nitrogen nutrient

Table 3. The effect of treatment to mustard growth and yield

Treatment	Plant Height (cm)	Number of Leaves (strands/plants)	Fresh weight (gr/plant)	Dry weight (gr/plant)
D0	4.19	5.56	6.11	0.79
D1	6.44	7.50	10.44	0.88
D2	9.06	9.83	28.22	1.64
D3	11.06	11.72	39.78	1.89
D4	13.03	12.56	55.50	2.10
D5	16.64	13.33	72.06	2.30
D6	20.64	14.83	85.11	2.68
D7	26.39	17.67	101.72	3.28
NPK	20.03	15.11	83.83	2.23

needs in the growth process and development of mustard plants, leading to better plant height. This is because the nitrogen element plays a role in the vegetative growth of plants such as the height of mustard plants.

Plant height was heavily influenced by nitrogen. Nitrogen is a major component and a variety of important substances in plants. Nitrogen was required in relatively large amounts of each plant growth, especially at the vegetative growth stage, such as shoot formation or stem and leaf development. If plants lack nitrogen then the plant will experience slow and dwarf growth Novizan (2005). The organic fertilizer used in this study is quail manure. This is according to Setyamidjaja (1986) suggested that animals fed a diet containing lots of protein and minerals will produce impurities and urine that is also high in nitrogen and other minerals. Nitrogen nutrient element is the main nutrient for plant growth because it is the compiler and all the proteins and nucleic acids and constituted the protoplasm as a whole. Thus, if more nitrogen elements are available than other elements, more proteins can be produced and leaves may grow wider, resulting in more photosynthesis (Syarief, 1985).

3.3.2 Number of Plant Leaves

Variance analysis was showed that the dosage treatment of biofilm bio-fertilizer had a significant effect on increasing the number of mustard leaves. Based on DMRT level of 5%, the lowest number of leaves is in the DO treatment as control which was average of 5.56 sheets of leaf, meanwhile the highest number of leaves at treatment D7 (21 ton/ha) of 17,67 leaf. This is thought to be due to the decomposition of quail manure produced elements such as phosphate and potassium and especially nitrogen elements that can improve vegetative growth of plants. The quail is a poultry fed from the factory and usually the rations contain lots of protein and minerals that will produce dirt and urine which is also high in nitrogen and other minerals.

Quail manure given an effect of increasing the number of leaves of mustard plants. The higher the dose of organic fertilizer and quail manure is given more and more the number of leaves of mustard plants due to quail manure have a high N content. The availability of sufficient nitrogen is necessary to support the growth and development of plants. Nitrogen elements absorbed by plants in sufficient quantities will spur the meristem tissue at the point of growing stems more active. This result in more and more formed stem segments and the more the number of leaves produced.

3.3.3 The Fresh and Dry Weight of Mustard

Quail manure was produced elements such as phosphate and potassium and especially nitrogen elements that can improve vegetative growth of plants. In addition to containing nitrogen nutrients, quail manure also contains elements of phosphate. According to Saifuddin (1985) phosphate elements play a role in cell division and also for the development of meristem tissue. Thus the phosphate element can stimulate the growth and roots of young plants.

Provision of quail manure helps the availability of phosphate in the soil. According to Sutedjo (1988) the provision of organic materials will reduce the phosphate fixation by soil so that phosphate elements in the soil are not in a state bound and become available to the plant. Provision of quail manure also increased the availability of potassium nutrients. According to Saifuddin (1985) potassium is one of the main elements needed by plants and greatly affects the level of crop production. Potassium is very important in every metabolic process in plants that is in the synthesis of amino acids and proteins and ammonium elements.

The analysis result of the biofilms bio-fertilizer effect on growth and yield of mustard plant showed that biofilm bio-fertilizer treatment had real effect to increase fresh and dry weight of mustard plant. Plant height and number of leaves affect wet and dry weight of plant stems. The greater the height of the plant and the more the number of leaves, the wet and dry weight of the mustard plant is increasing. It can be seen in Fig. 7 and Fig. 8 that the freshest and driest weight of the mustard plant is at the treatment of D7 (21 tons/ha) of 101.72 grams and 3.28 g, while the lowest is DO (control) of 6.11 g and 0.79 g.

This is shown that Biofilms bio-fertilizer of D7 treatment was able to supply nitrogen nutrient needs in the process of growth and development of mustard plants. Where the mustard plant response to the provision of biofilms bio-fertilizer, this is because the mustard plant is one type of vegetable crops are the main crop is the leaves so that the growth of mustard plants must be met the supply of their humus until the vegetative phase only. Nitrogen is the most important element in the growth of mustard plants because nitrogen is one of the essential nutrients. This is in line with the opinion of Lakitan (2008) that in the plant tissue,

nitrogen is an essential nutrient element and the constituent elements of amino acids, proteins and enzymes. In addition, nitrogen is also contained in chlorophyll, cytokinin and auxin hormones.

From the results of DMRT to fresh weight and fresh weight of plant showed that at 21 ton/ha yields the highest yield, this is due to the nutrient dosage is sufficient for the needs of plants and create desired soil conditions by mustard plants. This was supported by the opinion of Rahmat and Gerard (1995) which stated that the manure need for plant ranges from 10 to 20 tons/ha. At a dose of 25 tons/ha is a dose that is too much so that the organic material provided into the soil is also a lot and will increase the population of existing microorganisms, so that the activity of microorganisms in the soil will increase. This can have a negative effect on the growth and development of plants.

4. CONCLUSION

It can be concluded that the treatment of organic fertilizer decomposed with biofilm bio-fertilizers has a significant effect on permeability, aggregate stability, organic matter, porosity of vertisol soil. The best dosage treatment is D7 treatment with the dosage of organic fertilizer of 21 tons ha-1. Organic fertilizers decomposed with biofilm bio-fertilizers of 21 tons/ha increased permeability of 0.96 cm/h; aggregate stability index of 170.92; organic matter of 0.282%; and porosity of 29.91%. The treatment of organic fertilizers decomposed with biofilm bio-fertilizers has a significant effect on the height, number of leaves, fresh weight and dry weight of mustard plants. The best dosage treatment is D7 treatment with the dosage of organic fertilizer of 21 ton/ha.

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