The effect of biofilm biofertilizer formula and organic fertilizer dosage to phosphorus uptake and yield of shallot on Vertisols

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Abstract. The research aims to find the effect of biofilm biofertilizer formula and dose of organic fertilizer on phosphorus uptake and yield of shallot on Vertisols. The research was arranged in a completely randomized block design with two factors: dosage of organic fertilizer (0, 10, 20-ton ha⁻¹) and the formula of biofilm biofertilizer (without BiO₂, BiO₂ 1, BiO₂ 2, BiO₂ 3). Variables observed are available-P, P-uptake, bulb number, and bulb weight. Data were analyzed using F test followed by DMRT at α = 0.05. The result shows that 20-ton ha⁻¹ organic fertilizer decomposed with biofilm biofertilizer yield highest P-uptake and plant dry weight which increases 322 and 216 % to control treatment (0.50 and 1.26 g plant⁻¹). The use of 10-ton ha⁻¹ of organic fertilizer yield highest bulb number and weight i.e 5.58 bulbs plant⁻¹ and 116 g plant⁻¹ increase 27 and 172% compared to the control. The BiO₂ formula only affected to the plant height, and the use of formula 1 able to increase the plant height about 13.5% compared to control treatment.

1. Introduction
Shallot is widely cultivated because of its high economic value and its benefits. The demand of shallots keeps increasing every year, but the productivity still cannot meet the national demand. Shallot production result in average decreased by 871 tones (28.10%) in 2014 [1]. The decrease of the productivity caused by several factors, one of them is the decrease of the soil nutrient, such as the availability of Phosphorus (P). Generally, the soil major problem is low phosphorus availability, such as in Vertisols. Vertisols have very low P content and dominated by cation exchange Ca²⁺ and Mg²⁺ which react with phosphate ions to form insoluble compounds [2,3]. The use of inorganic fertilizers has been shown increase the crop productivity, but over a long period of time, the excessive uses can damage soil conditions [4]. The use of organic fertilizer is an alternative solution as a substitute for inorganic fertilizers. In addition to more environmentally friendly, organic fertilizer also contains nutrients needed by plants, and can increase the activity of beneficial soil microorganisms [5]. Biofilm biofertilizer is a functional microbial utilization method that can improve the crop yields because the microbial inoculants can form biofilms, synergize each other and provide nutrients needed by plants [6,7]. The use of organic fertilizer decomposed with biofilm biofertilizer (BiO₂) innovation still rarely to use. The previous research on the greenhouse scale [8], the application of biofilm biofertilizer (BiO₂) with a...
The C/N ratio describes the maturity level of the compost, the higher C/N ratio means the compost has not been completely decomposed with biofilmed biofertilizer to increase phosphorus uptake and yield of shallot in Vertisols.

2. Materials and method

Research was conducted in Gunung Wijil Village, Jaten, Karanganyar in April-June 2016. Soil and tissue analysis was conducted at Soil Chemistry and Soil Fertility Laboratory Faculty of Agriculture, Sebelas Maret University, Surakarta. The tools used in the study were hoes and analytic scales. The materials used in this research were chicken and quill manure as organic material, feldspar, ash powder, sulfur powder, dolomite, rock phosphate, 3% molasses solution, coconut water and rice-wash water, shallot seed bulbs, SP-36 fertilizer, KCl, urea, ZA, Potato dextrose agarose (PDA) and Nutrient Agarose (NA) medium.

Experiments arranged in completely randomized block design with two factors; The first factor was the formula of biofilmed biofertilizer (F0, F1, F2, F3). Formula 0 consist of: organic material (25 kg chicken manure, 25 kg quill manure), without BiO2 inoculum, Formula 1 consist of: organic material (20 kg chicken manure, 20 kg quail manure, 5 kg rock phosphate, 0.75 kg Feldspar, 0.25 kg sulfur powder, 2 kg dolomite, 2 kg ash powder), BiO2 inoculum 1 (consortium of phosphorus-solubilizing bacteria (TBH 18, TBH), Phosphate-solubilizing fungi (Aspergillus niger), Potassium-solubilizing bacteria (PPH 7), BBS (HBH12), Beauveria, Trichoderma sp, Phosphate-solubilizing fungi (green), Aspergillus japonicas (brown), and Nitrogen-fixing bacteria), carrier medium (10 L coconut water, 5 L rice water, ½ L molasses, 20 grams SP36, 10 grams KCl, 10 grams Urea fertilizer), Formula 2 consist of the same formula as formula 1, but without Nitrogen-fixing bacteria (NFB) inoculums. Formula 3 also consist of the same formula as formula 1, but formula 3 use organic matter-decomposer inoculums. The second factor was dosage of organic fertilizer decomposed with biofilmed biofertilizer (0 tones ha⁻¹, 10 tones ha⁻¹, 20 tones ha⁻¹). They were 12 treatments, plus NPK (200 kg ha⁻¹ urea at initial planting and 100 kg ha⁻¹ on second fertilization, 200 kg ha⁻¹ ZA at initial planting and 100 kg ha⁻¹ on second fertilization, 400 kg ha⁻¹ SP36, 100 kg ha⁻¹ KCl on second fertilization) as comparative treatment or positive control and each treatment was repeated three times, resulting total 39 combination treatment.

The study included microbial isolation, microbial inoculation to carrier (10 L of coconut water, 5 L of rice-wash water, ½ L molasses, 20 grams SP36, 10 grams KCl and 10 grams urea), and fertilizer formulation. Organic material such as chicken manure, quail manure, rock phosphate, dolomite, ash powder, feldspar, and sulfur powder watered with biofilmed biofertilizer inoculum (biofilmed biofertilizer used as decomposer to make organic fertilizer). Water and molasses added in the ratio of 6:1 to the field capacity, then the fertilizer materials are mixed well and incubated for 2 weeks. Variables observed included available P, P uptake, plant height, dry biomass, the number of bulbs, and the weight of bulb. Data analyzed with F test at 5% level of significant and followed with DMRT 5% if any significant influences. Correlation tests were used to find out the relation between primary dependent variable and secondary dependent one.

3. Results and discussion

Vertisols has a high cation exchange capacity (CEC), but this soil has not been considered to have good fertility, since nutrient analysis results shows low available P, low available K, and low soil organic matter on criteria (Table 1). Vertisols is one of the problematic soils in its management and requires management with certain techniques, in order to remain productively utilized in agriculture [9,10]. As shown in Table 2, the organic fertilizer formulas were applied in the Vertisols. The C/N ratio describes the maturity level of the compost, the higher C/N ratio means the compost has not been completely...
decomposed [11]. The standard value of C/N ratio according to SNI 19-7030-2004 is <20. The value of water content according to SNI 19-7030-2004 is <50%. Too much water content can increase the dense materials, and as a result, it can inhibit food sources required by microbes and prevent the input of the oxygen [12].

Table 1. Selected of soil characteristic used in experiments.

| Variables      | Value   | Unit     | Class. Value | Classification |
|----------------|---------|----------|--------------|----------------|
| Cation Exchange Capacity | 58.66   | cmol(+)/kg | >40          | Very High*     |
| N Total        | 0.315   | %        | 0.21-0.5     | Average*       |
| Available P    | 1.116   | ppm      | <5           | Very low*      |
| Available K    | 0.188   | cmol(+)/kg | 0.1-0.3    | Low*           |
| Soil OM        | 1.81    | %        | 1-2          | Low*           |
| Soil pH        | 7.17    | -        | 6.6-7.5      | Neutral*       |
| Soil texture   | -       | -        | -            | Sandy Clay*    |

*) According to Balai Penelitian Tanah Bogor [13]

Table 2. Characteristic of organic fertilizer used in experiments.

| Variables      | F0       | F1       | F2       | F3       |
|----------------|----------|----------|----------|----------|
| N              | 2.21%    | 2.30 %   | 1.32 %   | 1.88 %   |
| P              | 0.6%     | 1.3 %    | 1.4 %    | 1.3 %    |
| K              | 1.63 %   | 1.69 %   | 1.70 %   | 1.25 %   |
| C- organic     | 21.42 %  | 19.51 %  | 19.85 %  | 18.49 %  |
| pH             | 8.39     | 7.39     | 7.55     | 8.11     |
| C/N ratio      | 9.69     | 8.48     | 15.03    | 9.83     |

3.1. The effect of treatments on available and uptake of phosphorus
The P form that can be available to plants in the soil is in the form of orthophosphate ions (HPO$_4^{2-}$ and H$_2$PO$_4^{-}$). Orthophosphate’s ions are produced from the weathering process of mineral apatite, mineralized organic matter, and dissolved P fertilizer. The result of F test at 5% level of significant indicated that the dose of organic fertilizer given significantly effect to the Available P at maximum vegetative growth (p<0.01). The significant influences then tested using DMRT at 5% level of significant. as shown in Figure 1.

Figure 1. The effect of organic fertilizer decomposed with BiO$_2$ dosage and NPK fertilizer to soil available-P of Vertisols
The increase of dose of organic fertilizer also increasing the available P in soil (Figure 1). The increase of dosage causes the higher content of soil organic matter. Thus, helping to release phosphate
The decomposition of organic matter produces organic acids which form complex compounds with Al, Fe, and Ca thus helping to release phosphate (P) [14]. Humic acid is known to play a role in increasing nutrient availability through its ability to bind, absorb and exchange nutrients and water [15,16]. The organic acid, because of organic materials decomposition, are also capable for assisting the dissolution of rock phosphate given [17]. In addition, the increase of available P from organic matter is also due to the organic matter capable of spurring the release of P from fertilizer and indicating the release of P from mineralization [18].

P-uptake by plant depends on the availability of P in the soil solution because many nutrients are absorbed through the roots. The increase of soil nutrients causes the increase of different concentrations in the soil, and as a result, the rate of diffusion to the roots is getting higher. The result of F test at 5% level of significant indicated that the dose of organic fertilizer given significantly effect to P uptake at maximum vegetative growth (p<0.01). The significant influences then tested using DMRT at 5% level of significant as shown in Figure 2.

![Figure 2](image_url)

**Figure 2.** The effect dosage of organic fertilizer decomposed with BiO₂ and NPK fertilizer to uptake-P of shallot

The increase of dose of organic fertilizer also increases P uptake significantly. Organic matter leads the improve of physical soil conditions and the availability of P as the result. The contact of the roots becomes closer, as well as the absorbed of nutrients becomes higher. The organic matter also contributes to the dissolution or the release of P, so that it becomes available and absorbed by the plant. The correlation test showed that P uptake was positively correlated with available P (r=0.585). Organic acids from the decomposition of organic matter can increase the amount of phosphate through the mechanism of chelation [19]. Furthermore, the increase of the nutrients affects the amount of nutrients absorbed by plants. The uptake of P is influenced by the input and the availability of P into the soil. Thus, the increase of the availability of nutrients, the amount of nutrients that can be absorbed by the plants also increases [20–22].

3.2. The effect of treatments on shallot growth and yield

The result of F test at 5% level of significant indicated that the formula of biofilmed biofertilizer given significantly effect to the plant height at maximum vegetative growth (p<0.05). The significant influences then tested using DMRT at 5% level of significant as shown in Figure 3.
Figure 3. The effect of BiO₂ formula to shallot height on Vertisols.

Figure 3 shows that the highest plant height is obtained on formula 1 followed by formula 3 and 2. Formula 1 and formula 2 both contain phosphate-solubilizing bacteria (PSB), but the difference is in formula 1 contain nitrogen-fixing bacteria (NFB). It is suspected that the NFB contained in formula 1 are able to synergize each other in increasing the solubility of nutrients. Available P and the nitrogen produced by a mixture of phosphate-solubilizing bacteria and nitrogen-fixing bacteria can increase the formation of new cells in the meristematic tissue of the plant. resulting the increase of the plant height [23,24]. The correlation test showed that plant height was positively correlated with dry biomass (r= 0.846), the number of bulb (r= 0.381) and the weight of bulb (r= 0.853). The increase of photosynthesis will produce the large amounts of carbohydrates which will be used for plant-division, enlargement, and differentiation of cells. resulting the increase of the plant height [23,25].

Dry biomass is a common indicator to determine whether good or not the growth of plants, because it can describe the efficiency of plant physiological processes. The result of F test at 5% level of significant indicated that the dose of organic fertilizer given significantly effect to biomass at maximum vegetative growth (p<0.01). The significant influences then tested using DMRT at 5% level of significant. as shown in Figure 4.

Figure 4. The effect dosage of organic fertilizer decomposed with BiO₂ and NPK fertilizer to shallot shoot dry weight on Vertisols.
The increase of dose of organic fertilizer also increases the dry biomass significantly. Organic matter give effect to the increase of dry biomass through photosynthesis process. Based on the correlation test, dry biomass was positively correlated with available P ($r=0.557$) and P uptake ($r=0.793$). Organic materials are capable for increasing the respires activities that affect the process of photosynthesis through the increase of nutrient availability resulting the increase of production and dry matter content [26]. The correlation test also showed that dry biomass positively correlated with plant height ($r=0.846$). The number of bulb ($r=0.409$) and the weight of bulb ($r=0.771$). The increase of dry biomass indicates the efficient of the photosynthesis activity. The greater the biomass the more efficient the process of photosynthesis and as the result. The productivity and the development of cells is getting higher and faster as well as the growth of the plant [27].

The result of F test at 5% level of significant indicated that the dose of organic fertilizer given significantly effect to the number of bulbs at maximum vegetative growth ($p<0.01$). The significant influences then tested using DMRT at 5% level of significant. as shown in Figure 5.

![Figure 5](image_url)

**Figure 5.** The effect dosage of organic fertilizer decomposed with BiO$_2$ and NPK fertilizer to shallot bulb number on Vertisols.

When macro nutrients in the soil is increase as well as the amount that can be absorbed by plants. accompanied by the formation of organic compounds in the plant tissues [21]. Organic matter is the factor affecting the number of bulb because the adding of organic matter will form the binding granular without clay. and cause the soil becomes more porous [28]. In addition, the adding of organic materials is also able to increase the availability and nutrients uptake that increase the photosynthesis process and the results carbohydrates will be transported to all parts of plant organs to increase the number of bulbs [29,30]. The result of photosynthesis will be transported from the leaves to the meristem part that produces ATP at the growing point and increase the cell division of leaf bud [31]. The correlation test showed that the number of bulbs was positively correlated with plant height ($r=0.381$), dry biomass ($r=0.409$), and the weight of bulb ($r=0.447$). This explains that the increase of photosynthesis is closely related to plant growth variables. resulting the increase of the number of bulbs.

The result of F test at 5% level of significant indicated that the dose of organic fertilizer given significantly effect to the weight of bulb at maximum vegetative growth ($p<0.01$). The significant influences then tested using DMRT at 5% level of significant as shown in Figure 6.
Figure 6. The effect dosage of organic fertilizer decomposed with BiO$_2$ and NPK fertilizer to shallot bulb weight on Vertisols.

The higher the dose given, the higher the yield of bulb. The correlation test showed that the weight of bulb was positively correlated with available P ($r = 0.486$), P uptake ($r = 0.659$), plant height ($r = 0.853$), dry biomass ($r = 0.771$) and the number of bulb ($r = 0.447$). High organic matter can increase the supply of nutrients such as NPK, and by slow release process (slow release fertilizer) can be utilized by roots efficiently, resulting in the increase of the weight of bulbs due to the fulfillment of the elements required for bulb formation [32]. Phosphate plays a role in the increase of cell division, root development, flower, seed formation, fertilization, RNA and DNA formation, and bulb formation [33].

4. Conclusion

The increase dosage of organic fertilizer decomposed with BiO$_2$ applied tend to increase P uptake and shallot growth and yield while BiO$_2$ formula only influence on available-P. The application of 10-ton ha$^{-1}$ organic fertilizer decomposed with BiO$_2$ gives the highest number and weight of bulb; 5.58 bulbs/plant and 116 grams/plant or increase 27and 172% compared to control but is lower than NPK fertilizer treatment. The use of formula 1 increase the plant height 13.5% compared to control. Further research to increase the effectiveness of the biofilmed biofertilizer’s formula need to do to maximize its performance in increasing the production and the growth of plants in various agro-ecological condition.

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