The Use of Biofilm Biofertilizer to Improve Soil Fertility and Yield of Upland Kale (*Ipomoea reptans*) in Vertisol

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ABSTRACT

The application of biofilm biofertilizer is potential to improve soil fertility and increase plant yield. The research aimed to assess the use of organic fertilizer decomposed with biofilm biofertilizer to improve soil fertility and yield of upland kale in Vertisol. The field experiment was conducted in Vertisol at Jaten, Karanganyar, Central Java, arranged in a Randomized Complete Block Design with a single factor, which was organic fertilizer dose consisting of 0, 3, 6, 9, 12, 15, 18, and 21 ton.ha^{-1} organic with NPK fertilizer as comparison treatment. Upland kale seeds were planted in 15 x 15 cm plant spacing. The variables observed were total nitrogen, available P, exchangeable K, soil organic matter, pH, cation exchange capacity, leaf number, plant height, fresh and dry weight. The data obtained were analyzed using F test followed by Duncan Multiple Range Test (DMRT) 95%. The result showed that the organic fertilizer dose had a significant effect on all of the observed variables. Optimal doses of organic fertilizer to improve soil fertility and upland kale yield was 15 - 18 ton.ha^{-1}. The highest yield of upland kale was observed in the treatment of 21 ton.ha^{-1} organic fertilizer (76.5 ton.ha^{-1}), which was increased by 176% compared to control (34.7 ton.ha^{-1}) and by 108.8% (45.78 ton.ha^{-1}) compared to NPK treatments. The application of 3 ton.ha^{-1} organic fertilizer gave better yield of upland kale than NPK fertilizer.

Keywords: Biofilm biofertilizer, Chemical fertility, Ipomoea reptans, Organic fertilizer, Vertisol

ABSTRAK

Penelitian bertujuan untuk menilai penggunaan pupuk organik hasil dekomposisi menggunakan *biofilm biofertilizer* dalam meningkatkan kesuburan tanah dan hasil kangkung darat pada tanah Vertisol. Percobaan lapangan dilakukan di Jaten, Karanganyar, Jawa Tengah, April – Mei 2016 menggunakan rancangan acak kelompok lengkap (RAKL) faktor tunggal yaitu dosis pupuk organik (0, 3, 6, 9, 12, 15, 18, 21 ton ha-1), dan pupuk NPK sebagai pembanding. Benih kangkung ditanam dengan jarak tanam 15 x 15 cm. Peubah yag diamati meliputi N total, P-tersedia, K-tertukar, kadar bahan organik, pH, kapasitas tukar kation, jumlah daun, tinggi, berat segar dan berat kering tanaman. Data dianalisis menggunakan uji F dilanjutkan uji jarak berganda Duncan aras kepercayaan 95 %. Hasil penelitian menunjukkan bahwa dosis pupuk organik berpengaruh nyata terhadap semua peubah yang diamati. Dosis pupuk organik yang optimal untuk meningkatkan kesuburan tanah dan hasil kangkung darat berkisar 15 – 18 ton.ha^{-1}. Hasil kangkung darat segar paling tinggi diperoleh dari dosis pemupukan organik 21 ton.ha^{-1} (76,5 ton.ha^{-1}), meningkat 176 % dibanding control (34,7 ton.ha^{-1}) dan 108,8 % (45,78 ton.ha^{-1}) dibanding pemupukan NPK. Penggunaan pupuk organik 3 ton.ha^{-1} memberikan hasil kangkung yang lebih tinggi dibanding penggunaan pupuk NPK.

Kata Kunci: *Biofilm biofertilizer*, Kesuburan kimiawi, *Ipomoea reptans*, Pupuk organic, Vertisol

INTRODUCTION

Vertisol is one of the soil types with many obstacles in tillage. Vertisol belongs to Montmorillonit mineral clay (2:1) that is dominated by smectite mineral clay (Nursyamsi and Setyorini 2009), darkish grey in color, and it has clay texture (Prasetyo 2007). This type of soil expands when it is wet and shrinks when it is dry. It also has high Cation Exchange Capacity (CEC) and low organic matter content (usually less than 1%). Actually, Vertisol has rich nutrients, but these nutrients are trapped by the clay, thereby lowering the nutrient availability for the plant.

Upland kale planted in Vertisol often has many obstacles related to the difficult tillage and the limited macro nutrients (nitrogen, phosphorus and potassium) availability. One effort to reduce those two major obstacles is by applying organic fertilizer to improve soil fertility, either chemical, physical, or biological fertility (Nelvia, 2012).

Innovation in organic fertilizer manufacture has increased from year to year. One of the innovations is the use of biofilm biofertilizer as a decomposer of organic fertilizer. Biofilm biofertilizer contains many beneficial microorganisms, such as nitrogen-

fixing bacteria, phosphate solvent fungi, potassium solvent bacteria, and plant disease control fungi. The microbes are formulated in a special carrier so that they can be used as a starter or decomposer (Santoso dan Sajidan, 2013). This research aimed to determine the effectiveness of biofilm biofertilizer as a decomposer and the exact dose of organic fertilizer to improve Vertisol chemical fertility and achieve the optimum yield of upland kale.

MATERIALS AND METHODS

The research was located at Gunung Wijil Village, Jaten, Karanganyar with the coordinates of 7° 32 '57'' South Latitude and 110° 52' 11 '' East Longitude at 90 m above sea level with 54 mm/day annual rainfall (BPS 2015). It was a rainfed lowland with Vertisol soil. The biofilm biofertilizer inoculum was prepared in Laboratory of Soil Biology and Biotechnology. Soil fertility analysis was conducted in Laboratory of Soil Physics and Conservation and Laboratory of Soil Chemistry and Fertility, Faculty of Agriculture, Sebelas Maret University, Surakarta.

The experiment was arranged in a Randomized Complete Block Design with single factor, which was the dose of organic fertilizers decomposed with biofilm biofertilizer, consisting of 0 tonha^{-1}, 3 tonha^{-1}, 6 tonha^{-1}, 9 tonha1, 12 tonha^{-1}, 15 tonha^{-1}, 18 tonha^{-1} and 21 tonha^{-1}, with NPK fertilizer (150 kgha^{-1}Urea, 75 kgha^{-1} SP-36 and 40 kgha^{-1} KCl) usually applied by farmer as comparison treatment. Each treatment was replicated three times.

The Biofilm Biofertilizer used contains P-solubilizer bacteria (PSB) isolate (TBH 18 isolate), P-solubilizer Fungi (Aspergillus niger YD17, Aspergillus japonicus MU1 and JPF1), Potassium-solubilizer bacteria isolate (PPH7), Sulfur-oxidizer bacteria isolate (SOB) (HBH12), Beauveria sp., and Trichoderma sp. One agar slant culture of each isolate was inoculated on a liquid medium consisting of 10 L coconut water, 5 L rice water, 0.5 L molasses, 20 grams SP-36, 10 grams KCl, and 10 grams urea. They were mixed homogenously then incubated for a week. The organic fertilizer was made by mixing 160 kg quail manure, 30 kg phosphate rock, 6 kg feldspar, 5 kg calcite, 4 kg plant ash and 20 liters biofilm biofertilizer as inoculum bio-starter composting. The mixture was added with 5% molasses solution (50 ml / L water) to reach field capacity then incubated for 3 weeks. Organic fertilizer was applied by mixing it evenly with topsoil. The upland kale seeds were planted with 15 x 15 cm plant spacing. The variables observed were soil total nitrogen (Kjeldahl), available P (Olsen), exchangeable K (ammonium acetate), organic matter content (Walkley-Black), pH-H_2O (glass electrode 1 : 2.5), cation exchange capacity (KCl 1 N), plant height, shoot fresh and dry weight (Sulaeman et al., 2005). Data were analyzed using F test 95% followed by Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The soil analysis showed that the soil has low fertility to be used as cultivation land (Table 1). Vertisol is a dark gray to blackish in color with clay texture (Prasetyo, 2007). Vertisol has 2: 1 clay minerals dominated by smectite. Montmorillonite will expand when wet with a very sticky and firm consistency and shrivel up to form a crack, and it is very hard to tillage when dry. (Buol et al., 2003; Sunarminto and Santoso, 2008). The application of organic fertilizer will improve the soil fertility and make it easy for tillage, thereby increasing the plant growth rate and yield. The use of organic fertilizer will increase soil organic matter content as well (Jauhari, 2010).

Based on the result analysis, this organic fertilizer fulfills the requirements of The Indonesia Ministry of Agriculture Decree No. 261/KPTS/

Table 1. Chemical properties of the soil used for the research

Variables	Value	Rating value	Unit	Criteria
Total N	0.36	0.21-0.5	%	Medium*
Available P	1.69	<5	ppm	Very Low*
Exchangeable K	0.05	<0.1	cmol(+)/kg	Very Low*
CEC	44.72	>40	cmol(+)/kg	Very High*
pH-H_2O	6.6	6.6-7.5	-	Neutral*
Organic matter content	1.36	1-2	%	Low*
Texture				Clay*
(sand)	32.55		%	
(silt)	9.98		%	
(clay)	65.27		%	

Description: *Criteria according to Soil Research Institute 2009

SR.310/4/2019 about Organic Fertilizer, Biofertilizer and Soil Conditioner, in which the pH is 4 – 9, organic C content is ≥ 15%, C/N ratio is ≤ 25 and N + P_2O_5 + K_2O is ≥ 2%.The organic fertilizer is also following the minimum criteria set by Balittan (2009), in which organic C content is at least 12%, pH range is 4-8, and levels of N, P and K is below 6%. The low C/N ratio indicates that this organic fertilizer has decomposed well. The nutrient will be available to upland kale, thereby improving its yield (Jesu, 2015).

Effects of the treatments on the soil fertility

Although not significant (Figure 1), the doses of organic fertilizer decomposed with biofilm biofertilizer tended to increase soil total N until the dose of 15 tonha^{-1}, and the total N decreased as the dose was increased to more than 15 tonha^{-1}, which might be caused by leaching as the soil more porous. However, the total-N of the soil treated with organic fertilizer treatment was higher than that treated with NPK treatment, which might be due to the slow release property of N from organic fertilizer, making it exist longer in the soil.

Phosphorus is the second largest element that is needed by plant after nitrogen. Phosphorus plays a key role in the formation of DNA/RNA and also ADP and ATP (Adenosine di- and triphosphate), which are source of energy for the growth and development of plants. P deficiency causes the plant to collapse easily because the roots are not strongly formed, otherwise flowering and fertilization will be inhibited (Masrchner, 1997; Sutejo et al., 2007). The effect of organic fertilizer on the available P was very significant (P= 0.002), but the value is still very low (Figure 2). This result maybe because the initial available P of the soil was very low (Table 1). The low content of organic carbon of the soil can cause low soil nutrient content including phosphorus. Heavy texture of the soil can also be one of the factors of lower available P. The highest available P was found in 18 tonha^{-1} of organic fertilizer application (2.75 ppm), while the lowest was in control treatment (2.00 ppm). The available P increased concomitantly with the increasing doses of organic fertilizer applied, reaching a maximum dose of 18 tonha^{-1}. The higher dose than 18 tonha^{-1} tended to lower the available P due to the decrease of soil

Table 2. Nutrient content of organic fertilizer used

Variables	Value
pH	7.6
Nitrogen (%)	2.94
Phosphor (%)	0.48
Potassium (%)	1.61
Organic-C (%)	16.1
C/N ratio	5.48

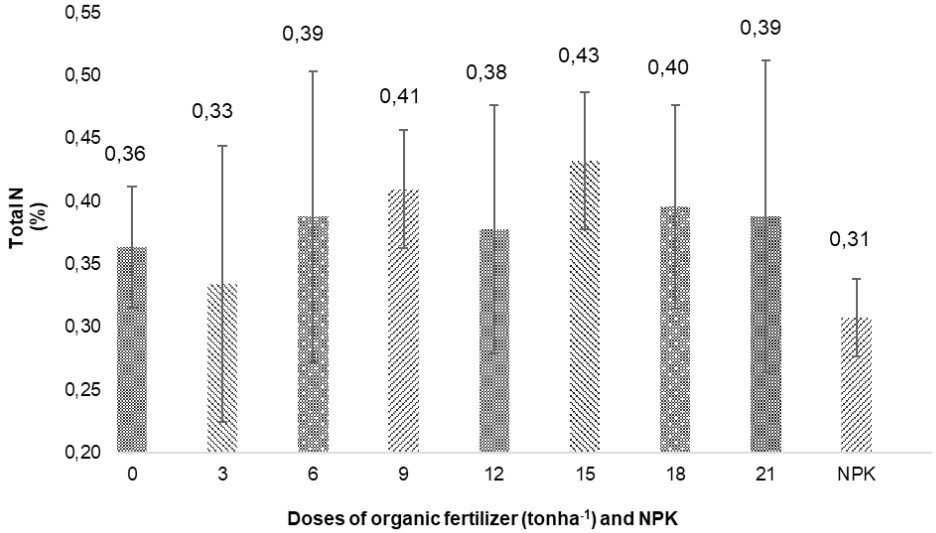

Figure 1. Effect the doses of organic fertilizer decomposed with biofilm biofertilizer on total N of Vertisol soil planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

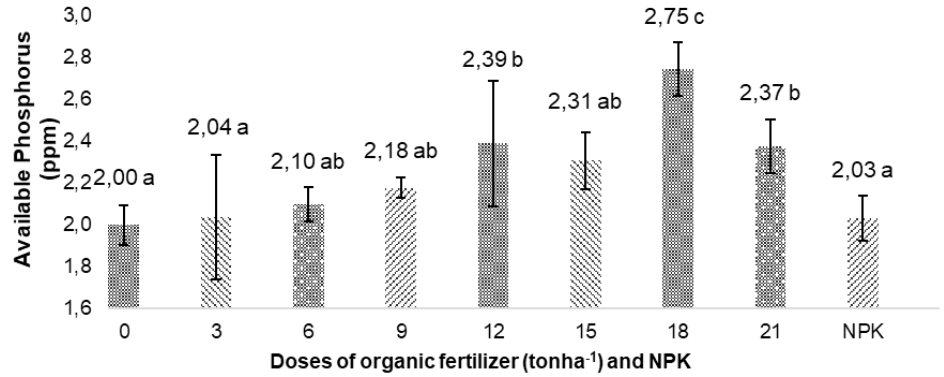

Figure 2. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the available Phosphorus of Vertisol soil planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

pH (Figure 4). Available P is strongly correlated positively (r = 0.673 **) with soil pH.

The available P of the soil treated with 75 kgha^{-1} NPK fertilizer was equal to that treated with 3 tonha^{-1} organic fertilizer decomposed with biofilm biofertilizer. Biofilm biofertilizer contains consortium of bacteria and fungi enable to solubilize P and K, oxidize sulfur, fix atmospheeric N2, and decompose organic matter. Chemical fertilizers such as SP-36 is faster available but they also tend to be immediately unavailable for plant. Organic fertilizers usually release their nutrient slowly but they are available longer for plant.

Similar to the available P, the increasing dose of organic fertilizer decomposed with biofilm biofertilizer tended to increase the exchangeable K (Figure 3). Orcutt and Nilsen (2000) suggested that potassium may support leaf formation and increase stomatal resistance, resulting in the larger amount of CO2 that diffuses into plant chlorophyll, and photosynthesis rate will increase. The doses of organic fertilizer have significant effect (P= 0.031) on the exchangeable K that tend to increase with the increasing doses used with the highest value observed in 18 tonha^{-1} organic fertilizer (0.08 cmol(+)kg^{-1}). Meanwhile, the lowest value was in

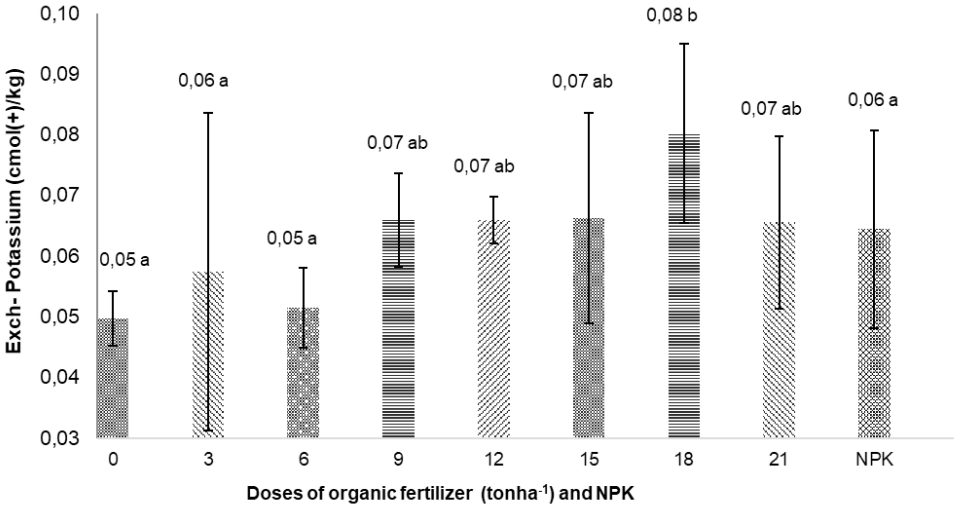

Figure 3. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the exchangeable K of Vertisol soil planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

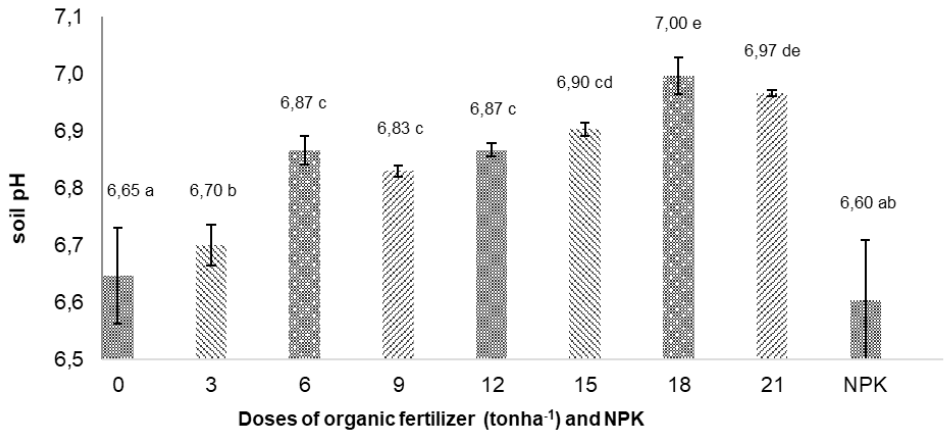

Figure 4. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on soil pH of Vertisol planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

control treatment (0.05 cmol(+)kg-1). Unlike the available P, the application of 40 kgha^{-1} KCl was equal to the application of 9 – 15 tonha^{-1} organic fertilizer (Figure 3). This result maybe because the exchangeable-K from KCl is available for long time, while organic fertilizer contains relatively small amount of K. The low availability of K can occur because potassium is a very mobile element, and its availability can be lower due to the type of shrunken soil, especially if the soil is dry. According to Borchardt (1989), K availability is often become a problem as K is fixed by a 2:1 clay mineral, such as from the smectite class inon Vertisol.

Similarly, the increasing dose of organic fertilizer used tended to increase soil pH with the maximum value observed in the application of 18 tonha^{-1} (Figure 4). The decreasing pH with the application of organic fertilizer at a dose of more than 18 toha^{-1} maybe due to the higher organic acid produced along with the decomposition process.

This result is in accordance with the statement of Rahmah (2014), mentioning that pH may affect other reactions in the soil, such as decomposition rate of soil organic matter, clay mineral formation, and plant growth. The highest value of soil pH (7.00) was obtained in the application of 18 tons/

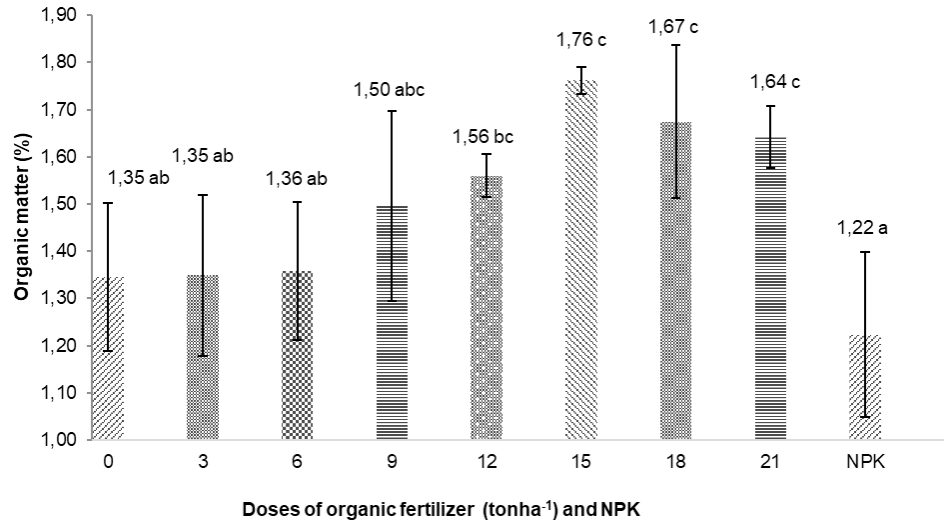

Figure 5. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the organic matter content of Vertisol soil planted with upland kale. The values followed by the same letters are not significantly different based on the DMRT 95%.

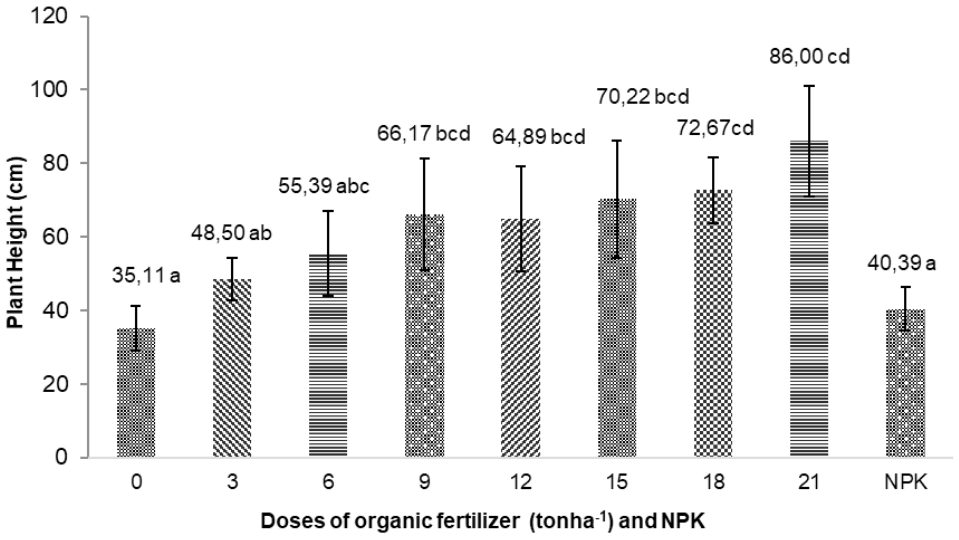

Figure 6. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the plant height of upland kale in Vertisol soil. The values followed by the same letters are not significantly different based on the DMRT 95%.

ha, while the lowest value (6.60) was obtained in NPK treatment. The increase in soil pH is due if the added organic material has been well decomposed. The mineralized organic material releases minerals in the form of basic cations (Suntoro, 2003).

Effect of organic fertilizer decomposed with biofilm biofertilizer on the soil organic matter content was very significant (P= 0.004) although according to Balittan (2009), all of the criteria were low, which might be due to the low initial soil organic matter content (1.36%; Table 1) (Nurdin et al., 2008). Organic fertilizers improve soil chemical fertility and nutrient release (Barbarick, 2006). Different from available-P and exchangeable-K, the highest soil organic matter content (1.76%) was obtained in the application of 15 tonsha^{-1} organic fertilizer, and the lowest organic matter content (1.22%) was in NPK treatment with (Figure 5). Soil organic

matter content has strong positive correlation (r= 0.673**) with soil pH. This result suggests that the increase in organic matter applied is closely corelated to the increase in pH. Suntoro (2003) states that the addition of decomposed organic matter will increase soil pH because mineralized organic matter will release minerals in the form of basic cations. Soil organic matter content was the lowest in the treatment of NPK because there was no organic matter added.

Effects of treatments on the growth of upland kale

Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer was very significant (P = 0.002) on the growth of upland kale as indicated by the increase in the plant height, number of leaves, as well as plant fresh and dry weight (Fig. 6 - 8). Lingga and Marsono (2001) stated that organic fertilizer, through its available nutrients (nitrogen, phosphorus, potassium, etc.) content, can stimulate the vegetative growth of plants, especially plant height. Upland kale is a vegetable crop whose height or length is one of the main criteria for good product. The highest plant height (86 cm) was achieved in the application of 21 tonha^{-1} organic fertilizer decomposed with biofilm biofertilizer, while the lowest (35.11 cm) was in the control treatment. The application

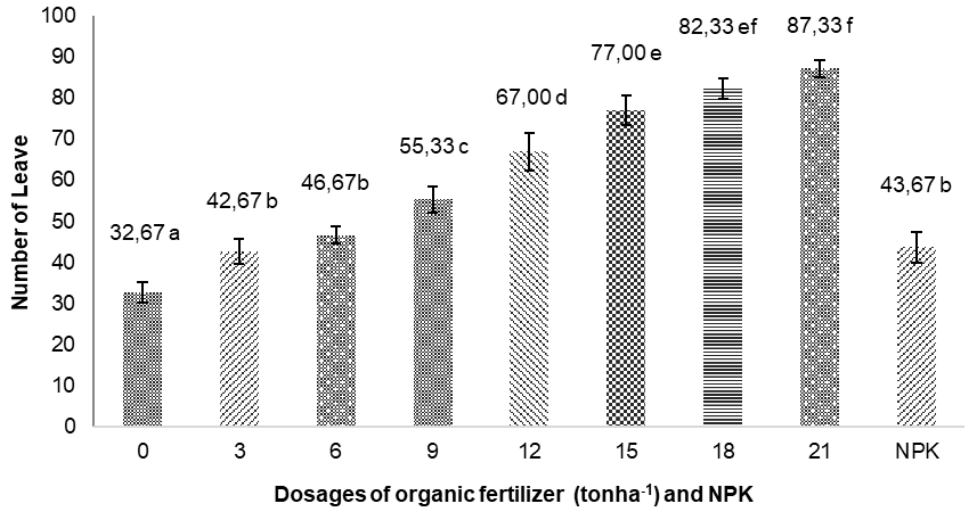

Figure 7. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the number of leaves of upland kale in Vertisol soil. The values followed by the same letters are not significantly different based on the DMRT 95%.

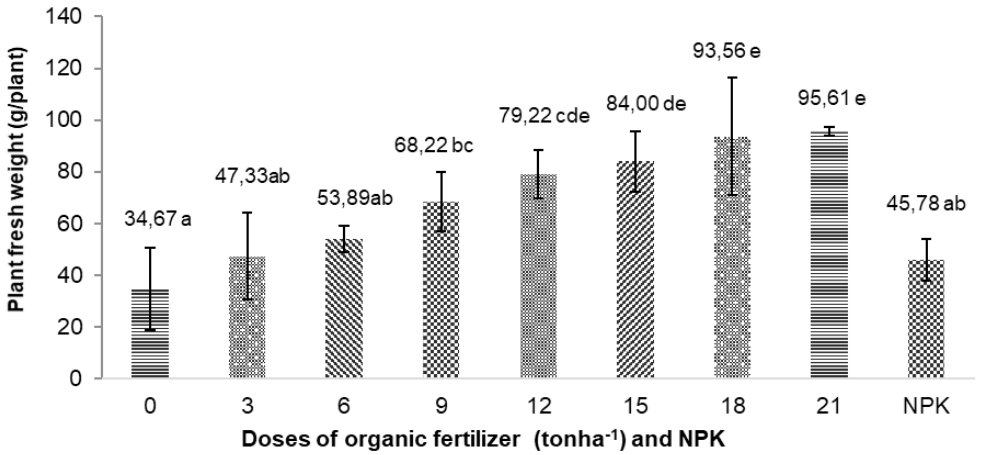

Figure 8. Effect of the doses of organic fertilizer decomposed with biofilm biofertilizer on the plant fresh weight of upland kale in Vertisols. The values followed by the same letters are not significantly different based on the DMRT 95%.

of 3 to 6 tonha^{-1} of this organic fertilizer resulted in the better growth of upland kale compared to the application of NPK as indicated by plant height, fresh and dry weight (Figure 6-8). Organic fertilizer can improve soil chemical, physical and microbiological properties that stimulate better plant growth. NPK fertilizer contains high available nutrients but it cannot stimulate soil physical and microbiological improvement as organic fertilizer. The increasing doses of organic fertilizer tended to increase the plant height linearly up a dose of 21 tonha^{-1}, indicating that this soil needs more organic fertilizer to achieve its optimal productivity. This result might be due to the low initial soil organic matter content (Table 1).

Number of leaves per plant significantly (P = 0.000) increased concomitantly with the increasing dose of organic fertilizer used (Figure 7). As well as plant height, number of leaves increase liniearly with the increase of organic fertilizer doses. According to Edi S. (2014), the increasing number of leaves indicate a quantitative increase in the cell development. The higher number of leaves means more carbohydrates produced from the process of photosynthesis. Carbohydrates affect the amount of yield of a plant. The application of NPK fertilizer produced equal number of leaves compared to the application of 3 – 6 tonha^{-1} organic fertilizer. This because as vegetable crop, upland kale needs more organic matter to grow well.

Upland kale is vegetable crop usually harvested for both shoot and whole crop. Thus, plant fresh weight is one of the main indicators of crop yield. The effect of organic fertilizer doses on the upland kale fresh weight was very significant (P = 0.0001) (Figure 8). The increase of upland kale fresh weight was linearly with the increase of the doses of organic fertilizer applied (Figure 8). This result might be caused by the increasing of available plant nutrients from organic fertilizer applied, either directly or indirectly (Parawansa and Hamka, 2014) and especially because of the improvement of the soil physical, chemical, and microbiological properties. The application of NPK fertilizer only resulted crop yield as high as the application of 3 - 6 tonha^{-1} organic fertilizer. Although NPK fertilizer provide high amount of available plant nutrients, but it cannot improve soil physical and microbiological properties as good as organic fertilizer. The highest fresh weight (95.61 gplant^{-1}) was resulted by the application of 21 tonsha^{-1}organic fertilizer, which was not significantly different from the yield of 18 tonha^{-1} organic fertilizer application (Figure 8). There was an increase in plant fresh weight with the increasing dose of organic fertilizer applied, but the enhancement tended to decrease. This result might because it will reach optimal dose of application. As shown by the effect of the doses on the plant nutrients available (Figure 1 – 5), the optimal dose of organic fertilizer applied was 15 – 18 tonha^{-1}, and this was corresponding to the effect on the plant dry weight .

The effect of organic fertilizer dose on the upland kale dry weight was similar to its effect on the plant nutrients available and soil organic matter content (Fig. 1 – 5). There was a very significant effect (P = 0.000) on the dry weight with an optimum dose of 15 tonha^{-1}. It showed that there was a high correlation between plant nutrients available and plant growth as indicated by its dry weight. Prawiranata cit. Priyono and Sarwono (2015) stated that plant dry weight depends on the rate of photosynthesis. The plant needs nutrients to carry out photosynthesis. It shows that vegetative growth of upland kale was going well. The best result was obtained at the application of 15 tonha^{-1} (7.22 gplant^{-1}) organic fertilizer, while the NPK treatment only produced 3.13 gplant^{-1}, and control treatment produced 2.82 gplant^{1}. The yield of upland kale fertilized with NPK was lower than

that treated with t 3 tonha^{-1} of organic fertilizer. This result might because organic fertilizer, besides providing plant nutrients, also improves soil physical, chemical and microbiological properties better than NPK fertilizer does. It indicates that upland kale does not only need sufficient plant nutrients, but it also needs a good soil chemical, physical and microbiological conditions. Organic fertilizer can support this improvement of soil properties better than NPK fertilizer. There was strong correlation between plant height and number of leaves (r = 0.784 **), as well as between plant fresh and dry weight (r = 0.918 **).

CONCLUSION

The increasing doses of organic fertilizer decomposed with biofilm biofertilizer significantly enhanced the available P, exchangeable K, soil pH, and soil organic matter content, as well as plant height, numbers of leaves, and fresh and dry weight of upland kale. The optimum dose of organic fertilizer applied was between 15 – 18 tonha^{-1} for plant nutrients available and upland kale growth and yield. The application of 3 tonha^{-1} organic fertilizer resulted better yield of upland kale than NPK fertilizer.

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