Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2017.v22i3.139-148

The Effects of Mixed Source Fertilizer Application on Vertisol Fertility and Growth of Mustard

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Received 21 Juny 2017/ accepted 01 September 2017

ABSTRACT

Soil fertility is a crucial factor determining the growth and yield of plants. The increase of nutrient content and availability in soil can be achieved by fertilization. A field experiment was conducted using a Randomized Completely Block Design (RCBD) with two factors and three replications in order to study the effects of Mixed Source of Fertilizer (MSF) application on the nutrient contents in Vertisol and its relationship to the growth and yield of mustard. The first factor was the three MSF formulas (F1, F2, F3) and second factor was the doses of MSF (0; 2.5; 5.0; 7.5; 10 Mg ha^{-1}) applied to the soil. At the end of the experiment, the soil pH, CEC, organic-C, total-N, available-P and exchangeable-K contents were measured. The results show that there are no significant differences on the soil chemical characteristics, such as pH, organic-C content, available-P, exchangeable-K, -Ca and -Mg measured after application of different MSF formulas to the soil. Meanwhile, the increase of MSF doses applied to the soil significantly increases organic-C content, total-N, available-P and exchangeable-K in the soil. The significant increase of available-P (by 29.13%) and total-N (by 24.1%) occured after application of MSF at 5.0 Mg ha^{-1} and the increase of exchangeable-K (by 50%) is achieved after application of 7.5 Mg ha^{-1}, in comparison to that without MSF application. The height and fresh weight of mustard increase in accordance with the increase of MSF doses applied. The application of 10.0 Mg ha^{-1} MSF results in the highest height and fresh weight of the mustard up to 63.9% and 620%, respectively. The height and fresh weight of mustard are positively correlated to the total-N, available-P and exchangeable-K in the soil. The MSF is an alternative fertilizer that can be used to improve Vertisol fertility and plant growth.

Keywords: Coconut husk ash, feldspar, mixed source fertilizer, phosphate rock,Vertisol

ABSTRAK

Kesuburan tanah merupakan faktor yang sangat menentukan pertumbuhan dan hasil tanaman. Peningkatan hara dalam tanah dapat dicapai dengan pemupukan. Penelitian lapangan dilakukan dengan menggunakan Rancangan Kelompok Lengkap (RKL) dengan dua faktor perlakuan dan tiga ulangan, untuk mengkaji penggunaan *Mixed Source Fertilizer* (MSF) pada kandungan hara dalam tanah Vertisol dan hubungannya dengan pertumbuhan dan hasil sawi. Perlakuan yang dicobakan adalah formula MSF (F1, F2 dan F3) dan lima dosis MSF (0,25; 5,0; 7,5 dan 10 Mg ha^{-1}). pH tanah, C-organik, CEC, N-total, P-tersedia, Kation tertukar diukur pada akhir penelitian. Tidak ada perbedaan yang nyata yang diperoleh dari berbagai formula MSF pada pH tanah, C-organik, P-tersedia, K-, Ca- and Mg-dapat ditukar. Peningkatan dosis MSF nyata meningkatkan C-organik tanah, N-total, P-tersedia dan K-dapat ditukar. Pemberian MSF 5,0 Mg ha^{-1}dalam waktu 40 hari nyata meningkatkan P-tersedia (29,13%) dibandingkan kontrol. Sedangkan peningkatan N-total (24,1%), dan K-dapat ditukar (50%) dari kontrol tercapai dengan pemberian MSF 7,5 Mg ha^{-1}. Tinggi tanaman dan berat segar sawi meningkat sejalan dengan meningkatnya dosis MSF yang diberikan. Pemberian MSF 10,0 Mg ha^{-1} memberikan tinggi tanaman dan berat segar sawi tertinggi, berturut turut mencapai 63,9% and 620% . Tinggi tanaman dan berat segar sawi berkorelasi posistif dengan N-total, P-tersedia dan K-dapat ditukar di dalam tanah. Campuran berbagai sumber pupuk (*Mixed Source Fertilizer*) adalah pupuk alternatif yang dapat digunakan untuk memperbaiki status kesuburan tanah dan pertumbuhan tanaman.

Kata kunci: Abu sabut kelapa, feldspar, campuran berbagai sumber pupuk, batuan fosfat, Vertisol

INTRODUCTION

The availability of nutrients in soil is a factor that can affect the growth and yield of plants. The appropriate amount and the use efficiency of fertilizers applied will have a pronounced effect on crop production since fertilization will affect the nutrient content in soil (Elamin and Elagib 2001; Kuntyastuty *et al*. 2011). The use of organic and inorganic fertilizers has positive and negative effects on soil and plant growth. The disadvantages of using organic fertilizers among others are slow release fertilizer (release the nutrients gradually) and low nutrient content (Sentana 2010). On the other hand, the use of organic fertilizers also has several advantages namely providing balanced nutrients to plants, including macro and micro nutrients (Tisdale *et al*. 2010), preventing harmful effects caused by nutritional excess of certain plants, increasing the availability of nutrients in soil that is triggered by the increase of microbial activity, improving the nature of soil structure and root development as well as increasing the ability of soil to hold water (Nieder and Benbi 2005; Brady and Weil 2008). Some previous studies showed various effects of using organic fertilizers on nutrient content or availability in soil. The study of Kuntyastuti (2011) reported that organic fertilizer application showed no significant effect on organic-C content and macronutrient availability in soil after the first harvesting, and only increased the amounts of available-P and exchangeable-K after the second growing season. Besides, the study of Han *et al*. (2006) showed that the use of manure increased the concentration of nitrogen, available-P, exchangeable-K, -Ca and -Mg in soil during the plant nursery period.

On the other hand, inorganic fertilizers hold an important role in food production. In Indonesia inorganic fertilizers has been used intensively since the development of intensive farming system in which farmers depend a lot on inorganic fertilizer for their farms. Inorganic fertilizers contain high concentrations of nutrients, which can be absorbed immediately by plants, as well as they are practical and easy to apply (Tisdale *et al*. 2010). However, inappropriate and continuous use of inorganic fertilizers will cause various problems for soil and environment, such as nutrient loss, soil acidification, reduction of beneficial microbial population (Chen 2006), land productivity degradation (Khairatun *et al*. 2013) and environmental pollution (Suharsi *et al*. 2002; Kassir *et al*. 2012).

Vertisol covers approximately 2.1 million hectares of land in Indonesia (Subagyo *et al*. 2004). It spreads in many areas in Indonesia including Central Java (Subagyo *et al*. 2007). Vertisol is potential for agricultural land use because it has relatively good fertility status with high Cation Exchange Capacity (CEC), base saturation, water holding capacity, and pH (*i.e.* pH 6-8.5) (Deckers *et al*. 2001). Meanwhile, the availability of phosphorus in dry Vertisol is generally low because the phosporus is bound by Ca, and the amount of available-K is low as well (Munir 1996). A previous study also showed that Vertisol that is dominated by clay fraction has neutral pH, low organic-C and total-N contents, medium amount of P extracted using Olsen and HCl 25%, low amount of K extracted using HCl 25%, high CEC and high amount of exchangeable base cations (Harsanti *et.al.*2003).

In order to increase the fertility status of Vertisol and to overcome the lack of organic and inorganic fertilizer supplies, use of natural resources that are potential for fertilizers can be an option. The potential natural resources include Azolla and quail manure as sources of N, phosphate rocks as a source of P, coconut, coconut husk and feldspar rocks as sources of K, dolomite as a source of Ca and Mg, and sulfuric element as a source of S. By mixing these natural resources, it is expected to result in a fertilizer formula that has positive effects in increasing soil productivity and fertility. This study aimed to evaluate the effects of various Mixed Source Fertilizer (MSF) formulas and their doses on soil fertility status of Vertisol and its relationship to the growth of mustard.

MATERIALS AND METHODS

Study Site

A field experiment on Vertisol was conducted in Karanganyar, Central Java, Indonesia in April until December 2016.

Experimental Design

The study was arranged in a Completely Randomized Block Design (RCBD) with two factors and three replications. The first factor was 3 MSF formulas, namely **F1** (50% quail manure, 20% phosphate rock, 18% coconut husk ash, 6% dolomite, 1% sulfuric element, 5% feldspar), **F2** (60% quail manure, 20% phosphate rock, 14% coconut husk ash, 6% dolomite, 1% sulfuric element) and **F3** (20% quail manure, 30% Azolla, 16% phosphate rock, 23% coconut husk ash, 10% dolomite, 1% sulfuric element). Each MSF formula was made by mixing all the ingredients including composted Azolla, matured quail manure, phosphate rock, sulfur and feldspar (from Banjarnegara) and filtered coconut husk. All the ingredients were mixed homogeneously in accordance with their doses to obtain MSF formulas that have high nutrient content. The second factor was 5 doses of MSF applied, namely **D0** (no fertilizer), **D1** (2.5 Mg ha^{-1}), **D2** (5 Mg ha^{-1}), **D3** (7.5 Mg ha^{-1}), and **D4** (10 Mg ha^{-1}).

Application of MSF and Measurements of Soil and Plant Parameters

The MSF was applied on each plot according to the treatment three days before planting. The size of each plot was 1 m × 1.5 m. The mustard seeds of Choy Green variety (in accordance with the variety of mustard planted by farmers around the study site) were planted, *i.e.* 2 seeds for each planting hole, with the planting distance of 20 cm × 20 cm. The nurturing of plants was carried out in accordance with the local farmer practices.

Five plant samples were selected for each plot and the height of plants was measured started from soil surface till the end of the longest leaf at the maximum vegetative growth. In addition, the fresh weight of plants was measured after harvesting. Soil samples were taken from the experimental plots before and after the experiment. The chemical properties of the soil samples including total-N (Kjedhal), available-P (Bray-1), exchangeable base cations (NH_4OAc 1 *N* pH 7), organic-C (Walkley and Black) and CEC (NH_4OAc 1 *N* pH 7) were analyzed at the Laboratory of Soil Chemistry and Soil Fertility, Agriculture Faculty, Sebelas Maret University.

Data Analysis

The data were analyzed using F-variance test at 5% and 1% significance levels, continued with Duncan's Multiple Range Test (DMRT) test, and correlation test (Gomez and Gomez 2007).

RESULTS AND DISCUSSION

Characteristics of Vertisol and Mixed Source Fertilizers (MSFs)

Vertisol used in the experiment has a neutral pH, clay texture, and high CEC (Table 1). The high CEC of the soil is due to the high clay content in the soil. The study of Brady and Weil (2008) indicated

Table 1. Characteristics of Vertisol used in the current study.

Soil Properties	Value	Range of Criteria	Criteria
pH H_2O	6.7	6.6-7.5	Neutral*
Organic-C (%)	0.67	<1	Very low*
CEC (cmol(+) kg^{-1})	43.45	>40	Very high*
Total-N (%)	0.37	0.21-0.5	Moderate*
Available-P (ppm)	3.1	<5	Very low*
Exchangeable-K (cmol(+) kg^{-1})	0.14	0.1-0.3	Low*
Texture			
Sand (%)	8.76	Clay	
Silt (%)	24.77		
Clay (%)	66.47		

Note: *) According to the criteria proposed by the Soil Research Institute (2005)

Table 2. Characteristics of Mixed Source Fertilizer (MSF) Formulas.

Characteristics	MSF Formula			Standard values regulated by the Ministry of Agriculture Number 140/10/2011
	F1	F2	F3	
pH	6.41 ± 0.17	6.29 ± 0.26	6.74 ± 0.20	4 – 8
Organic-C (%)	21.0 ± 0.18	19.6 ± 0.60	19.8 ± 0.39	> 12
N (%)	1.72 ± 0.17	1.50 ± 0.08	1.52 ± 0.07	< 6
P_2O_5 (%)	1.21 ± 0.09	1.17 ± 0.06	1.10 ± 0.08	< 6
K_2O (%)	1.85 ± 0.07	1.42 ± 0.16	1.39 ± 0.10	< 6
C/N Ratio	12.2 ± 0.56	13.1 ± 0.23	13.0 ± 0.09	15 – 25

Table 3. pH and CEC of the soil applied with Mixed Source Fertilizers.

Dose ($Mg\ ha^{-1}$)	MSF Formula					
	F1		F2		F3	
	pH	CEC cmol(+) kg^{-1}	pH	CEC cmol(+) kg^{-1}	pH	CEC cmol(+)kg^{-1}
0	6.9±0.1	50.68±11.24	7.1±0.1	42.27±7.38	7.1±0.2	51.84±1.02
2.5	7.0±0.2	49.89±15.01	6.9±0.2	45.17±4.45	7.0±0.1	48.73±3.16
5.0	6.9±0.1	48.25±4.32	7.0±0.2	44.72±7.01	6.9±0.2	44.38±5.30
7.5	7.0±0.2	52.67±7.92	7.1±0.1	44.23±6.01	7.0±0.0	50.22±6.85
10.0	6.9±0.1	43.58±9.68	6.9±0.1	48.73±2.55	7.2±0.1	44.30±5.01

that clay particles have a negative charge, therefore, the soil with high clay content will have high CEC (Hanafiah 2005; Nursyamsi and Suprihati 2005). The Vertisol used in the current study contains low organic matter, *i.e.* 1.19%, which is in line with the study of Munir (1996) that suggested that Vertisols have low organic-C content. This condition causes the availability of nutrients in the Vertisols is low. According to Prasetyo and Suriadikarta (2006), soil organic matter is an important component of soil fertility and nutrient source for plants (Tisdale *et al.* 2010). The low content of organic matter in the Vertisol used in the current study results in a moderate total-N content and low amount of available-P. The amount of exchangeable-K is also low because most of K are fixed by 2:1 clay minerals that are commonly found in Vertisols (Borchardt 1989).

The organic-C contents in the three MSF formulas were quite high and above the minimum organic-C content in organic fertilizers according to the regulation proposed by the Indonesian Ministry of Agriculture, *i.e.* 12%. The N, P, and K contents of the three MSF formulas were almost the same, although the K content in the MSF F1 was higher than that in other MSF formulas (Table 2). It is supposed that by adding 5% feldspar in the MSF F1 will result in better advantage than other formulations especially on K content. Feldspar is the source of K in soil (Tisdale *et al.* 2010). The high total-N content in F1 formula is correlated with the high organic C content in this formula and low C/N ratio. The low C/N ratio indicates that the decomposition process of the MSF F1 has been going well (Brady and Weil 2008). Furthermore, organic materials will be decomposed into amino acids and then heterotrophic microorganisms decompose the amino acids into ammonium as the main form of inorganic-N in soil (Suntoro 2003; Tisdale *et al.* 2008).

Soil pH

Application of MSF with various formulas and doses did not significantly affect the pH of Vertisol ($p > 0.05$). The range of soil pH after application of MSF was 6.9 up to 7.2, which is considered as neutral. There was no significant difference on soil pH after application of the three MSF formulas although the soil pH applied with MSF F3 was slightly

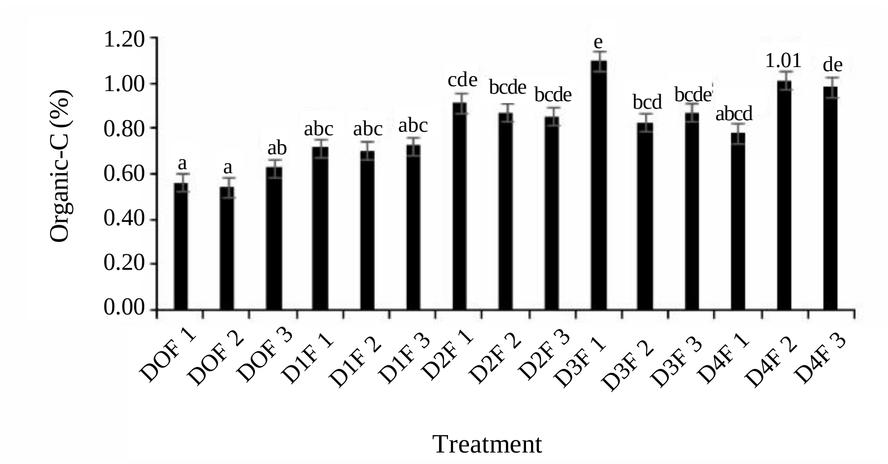

Figure 1. Organic-C content in the soil applied with various doses and formulas of MSF. D: dose, F: Formula. The same letters above the bart chart indicate no significant difference at 95%.

higher than that applied with MSF F1 and F2. This phenomenon is due to the three MSF formulas have almost similar properties (Table 2). However, the soil pHs after application of MSFs that were measured at the end of the experiment in general were higher than the soil pHs before application of MSFs. This was probably due to the effects of dolomite and coconut husk applied in the three MSF formulas. Dolomite contains Ca and Mg that can release OH ions that further could increase soil pH (Nurhayati 2013). In addition, application of coconut husk ash can increase soil pH (Risnah *et al*. 2013).

Cation Exchange Capacity (CEC)

The results of analysis of variance showed that the doses, MSF formulas and their interaction did not significantly affect the soil CEC ($p > 0.05$). This is because the three MSF formulas have almost similar properties (Table 2) and contain the same organic matterials, such as quail manure, coconut husk ash and Azolla. Allegedly, these organic materials have not all been decomposed within 40 days of application of MSF to the soil. This result is in line with the study of Giacomini *et al*. (2015) that indicated that for 40 days of incubation, the mineralization of C from sewage sludge is only <30%. Consequently, there has not been much functional groups of organic acids such as COOH and OH released into the soil. According to Brady and Weil (2008), the dissociation of the open hydroxyl ions on the functional groups of organic matter will produce a very negative charge that further determines the soil CEC. This is evident that there is a correlation between soil CEC and soil organic matter content.

Organic-C

The soil organic-C content significantly increased after application of various formulas and doses of MSF ($p<0.001$). Application of 2.5 Mg ha^{-1} MSF increased soil organic C content by 27.8% in the soil applied with MSF F1, 29.8% in the soil applied with MSF F2 and 15.7% in the soil applied with MSF F3 in comparison to that in the soil without MSF application, although the three organic-C contents were not statistically different (Figure 1). The significant increase of soil organic-C content occurred after application of 5.0 Mg ha^{-1} MSF. The

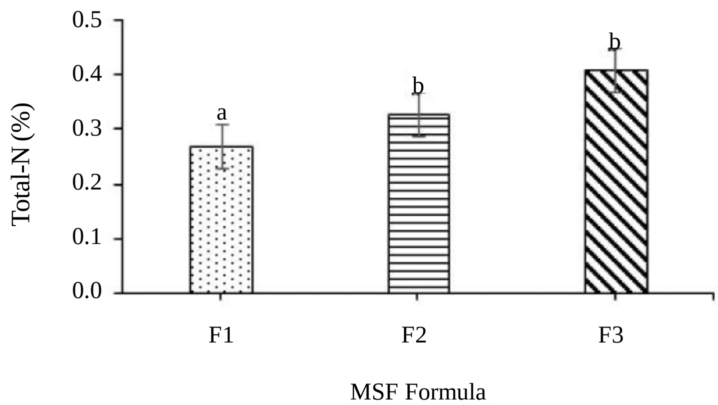

Figure 2. Total-N content in the soil applied with various formulas of MSF. F: Formula. The same letters above the bar chart indicate no significant difference at 5% significance level.

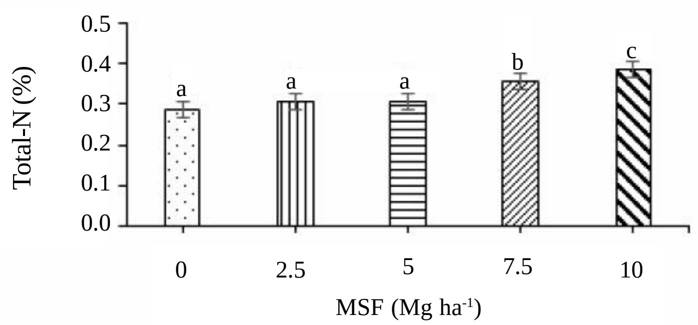

Figure 3. Total-N content in the soil applied with various doses of MSF. The same letters above the bar chart indicate no significant difference at 5% significance level.

increases were 62.9% in the soil applied with MSF F1, 57.4% in the soil applied with MSF F2 and 37.0% in the soil applied with MSF F3, although there was no significant difference among the three organic-C contents. In the soil applied with MSF F1, the highest organic-C content was obtained at 7.5 Mg ha^{-1}, whereas in the soils applied with MSF F2 and F3 were occurred at 10.0 Mg ha^{-1}. The MSF F1 contained higher organic C than MSF F2 and F3, so that the application of 7.5 Mg ha^{-1} has increased soil organic C, which is equal to the application of 10.0 Mg ha^{-1} MSF F2 or F3. The quail manure and Azolla are the sources of organic matter so that their applications to the soil can increase the soil organic C. According to Nugroho and Firmansyah (2016), quail manure has high C content (16.53%). Likewise, the application of Azolla will increase soil fertility by increasing the soil organic matter content (Mandal 1999).

Total-N

The results of analysis of variance showed that the MSF formula significantly affected the total-N content in the soil. Figure 2 shows that application of MSF F3 results in the highest total-N content in the soil with the increase of 24.2% in comparison to that in the soil applied with MSF F2 and 51.9% in comparison to that in the soil applied with MSF F1. This phenomenon is due to MSF F3 contains Azolla that is the source of N in soil. The result of this study is in line with the study of Mandal (1999) that indicated that Azolla application increases the availability of N in soil.

The increase of total-N content in the soil is in line with the increase of MSF doses applied. Figure 3 shows that the application of MSF at 2.5 and 5.0 Mg ha^{-1} resulted in an insignificant increase on the total-N in the soil. The application of MSF at 7.5

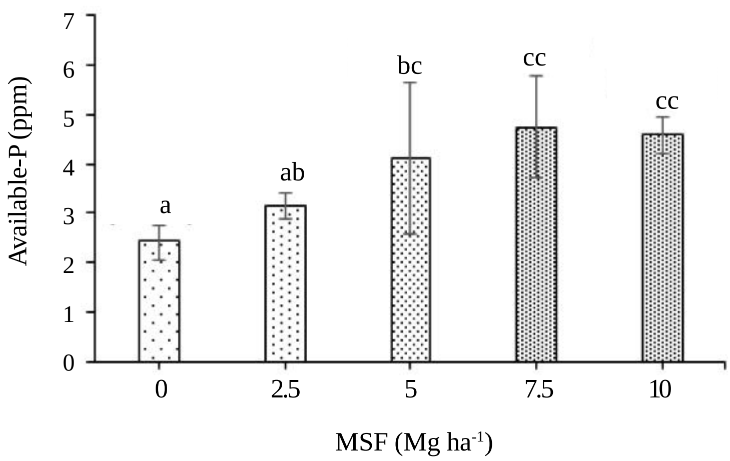

Figure 4. The amount of available-P in the soil applied with various doses of MSF. The letters above the bar chart indicate no significant different at 5% significance level.

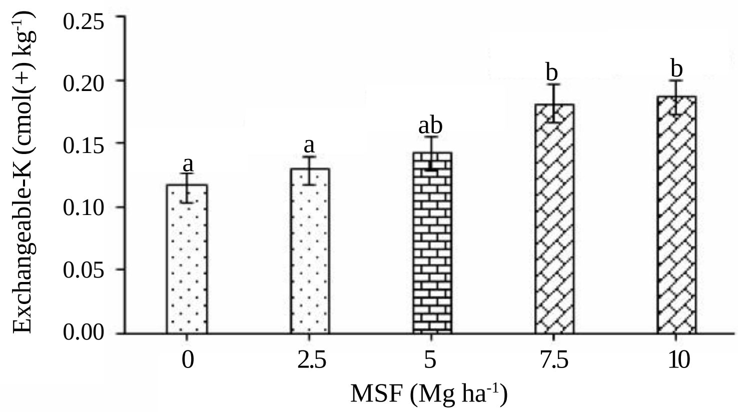

Figure 5. The amount of exchangeable-K in the soil applied with various doses of MSF. The letters above the bar chart indicate no significant different at 5% significance level.

Mg ha^{-1} was able to increase the total-N by 23.33% in comparison to that in the soil without MSF application, although the highest total N content in the soil was obtained after application of 10.0 Mg ha^{-1} MSF with the increase of 30% in comparison to that in the soil without MSF application. This result is due to the contribution of nitrogen derived from organic compounds in the MSF. The result showed that there was a significantly positive correlation between total-N content in the soil and soil organic matter content (p <0.005; r = 0.445**), indicating that the total-N content in the soil increases with the increase of soil organic matter content. According to Wahyudi (2009), decomposed organic materials will produce a number of proteins and amino acids that will be further mineralized into ammonium (NH_4^+) or nitrate (NO_3^-), and organic materials are the largest contributor of N to the soil.

Available-P

The result of analysis of variance showed that the MSF doses were significantly (p <0.01) affected the amount of available-P in the soil. Meanwhile, the MSF formulas and the interaction between doses and formula of MSF showed no significant effect (p > 0.05) on the amount of available-P in the soil. The amount of available-P increased by 69% after application of MSF at 5 Mg ha^{-1} in comparison to that in the soil without MSF application. The amount of available-P in the soil applied with 10.0 Mg ha^{-1} MSF is not significantly different from that in the soil applied with 5.0 Mg ha^{-1} MSF. The results indicated that organic fertilizers combined with phosphate rock can improve the amount of available-P in the soil.

At a dose of 5.0 Mg ha^{-1} MSF, the phosphate rock was completely dissolved within 40 days of application of MSF to the soil. However, at the doses of 7.5 and 10.0 Mg ha^{-1} MSF, some of the phosphate rock was not completely solubilized, so that it was unavailable for plants. According to Sulaeman *et al*. (2002), natural phosphate rocks are considered as the long-term fertilizer that releases relatively slow the available-P to the soil. Therefore, to increase the solubility of phosphate rocks, it is advisable to add biological fertilizers containing phosphate solubilizing microbes (Stamford *et al* 2006). The increase on the amount of available-P in the soil after MSF application is also caused by the increase of organic matter content in the soil since the soil organic matter content is positively correlated to the amount of available-P in the soil (p <0.001, r = 0.538**). The study of Brady and Weil (2008) suggested that soil organic matter is the source of P in soil for plant uptake.

Exchangeable-K

The amount of exchangeable-K in the soil after application of various MSF formulas was not different (p>0.05), however, it increased in accordance with the MSF doses applied (p<0.01) (Figure 5). The application of 5.0 Mg ha^{-1} MSF increased the amount of exchangeable-K in the soil, which was similar to that in the soil applied with 2.5 Mg ha^{-1} MSF and without MSF application. This phenomenon was due to the addition of coconut husk ash as the source of K to the MSF was not enough to provide an additional amount of exchangeable-K to the soil. The significant increase of exchangeable-K was achieved after application of 7.5 Mg ha^{-1} MSF, in which the amount of exchangeable-K was not different from that in the soil applied with 10.0 Mg ha^{-1} MSF. This result is in line with the study of Risnah (2013), which shows that the application of 150% coconut ash effectively increases the amount of exchangeable-K in soil although it is not different from that in the soil applied with 200% coconut ash within 4 months. The increase of MSF dose that is not followed by the increase of exchangeable-K in the soil observed in this study indicates that there are other K sources that contribute to the increase of the exchangeable-K in the soil, such as quail manure and feldspar.

Exchangeable-Ca and -Mg

The application of various MSF formulas and doses did not affect the amount of exchangeable-Ca (p>0.05) and -Mg (p>0.05) in the soil within 40 days of application to the soil (Table 4). The result indicated that the addition of 5.5 %, 10% and 16% dolomite or equivalent to 550, 1000 and 1600 kg ha^{-1} dolomite on 10 Mg ha^{-1} MSF dose did not provide significant addition to the amount of exchangeable-Ca and -Mg in the soil in comparison to other MSF doses applied. Similarly, the addition of other Ca and Mg sources such as 2 to 6 Mg ha^{-1} quail manure on 10 Mg ha^{-1} MSF dose also did not provide significant increases on the amounts of exchangeable-Ca and -Mg at 40 days of application of MSF to the soil, in comparison to other MSF doses applied. The study of Tabitha *et al*. (2017) showed that a significant increase on the amount of exchangeable-Ca and -Mg in soil is occurred after application of quail manure at 8.45 Mg ha^{-1}. The amount of exchangeable-Ca is in the

Table 4. The amount of exchangeable-Ca and -Mg in the soil applied with various MSF formulas and doses.

	Exchangeable-Ca (cmol(+) kg^{-1})	Exchangeable-Mg (cmol(+) kg^{-1})
Formula	$p > 0.05$	
F1	16.92 ± 0.85 a	3.77 ± 1.29 a
F2	16.67 ± 1.21a	4.02 ± 1.18 a
F3	16.93 ± 1.05 a	3.73 ± 0.90 a
Dose MSF (Mg ha^{-1})	$p > 0.05$	$p > 0.05$
0	16.02 ± 2.64 b	5.99 ± 0.71 b
2.5	16.71 ± 2.26 b	6.02 ± 3.23 b
5.0	16.98 ± 2.77 b	6.09 ± 1.89 b
7.5	17.14 ± 5.04 b	6.14 ± 2.20 b
10	17.63 ± 0.08 b	6.47 ± 1.54 b

Note: The numbers followed by the same letters indicate no significant difference at 5% significance level.

Table 5. The height and fresh weight of mustard applied with various formulas and doses of MSF.

	Plant Height (cm)	Fresh Weight of Plant (g)
Formula	$p > 0.05$	$p > 0.05$
F1	20.29 ± 3.28 a	72.31 ± 40.70 c
F2	20.27 ± 3.92 a	72.41 ± 42.70 c
F3	20.20 ± 3.66 a	58.75 ± 33.44 d
Dose MSF (Mg ha^{-1})	$p < 0.001$	$p < 0.001$
0	14.68 ± 0.60 p	16.31 ± 1.89 p
2.5	19.16 ± 0.28 q	47.18 ± 5.69 q
5.0	20.86 ± 0.29 r	66.76 ± 8.81 r
7.5	22.52 ± 0.12 s	92.91 ± 11.93 s
10	24.06 ± 0.41 t	115.96± 18.20 t

Note: The numbers followed by the same letters indicate no significant difference at 5% significance level.

range of 13.06 up to 19.21 cmol (+) kg^{-1}, while the amount of exchangeble-Mg is in the range of 2.1 up to 5.7 cmol (+) kg^{-1}.

The Growth of Mustard

The result of analysis of variance showed that the increase of MSF doses applied to the soil significantly increased the height of mustard (p <0.01). The application of 2.5 Mg ha^{-1} MSF increased the plant height by 30%, while the highest plant height was obtained after application of 10.0 Mg ha^{-1} MSF, which was 63.9% higher than that without MSF application (Table 5). This phenomenon is due to the higher dose of fertilizer applied to the soil, the more nutrient will be absorbed by plants, consequently the plant growth will also increase (Rizqiani *et al.* 2007). The plant height is positively correlated to total soil N (p<0.001, r = 0.637**), available-P (p<0.001, r = 0.547**), and exchangeable-K (p<0.05; r = 0.369 *). Nitrogen, phosphor, and potassium are essential macronutrients for plant growth and development (Tisdale *et al.* 2010). The more nitrogen absorbed by the plant, the growth of the plant will increase as well as the plant height (Erawan *et al.*2013). Phosphorus plays a role in the transfer of energy used for the whole plant metabolic activities (Marschner 2006). In addition, phosophorus can stimulates root growth and a good root system. Potassium (K) plays a role in enzyme activity, absorption and transport of water and nutrients from soil to plants (Marschner 2006; Tisdale *et al.*2010).

The differences in the MSF formulas applied to the soil did not show significant differences on the plant height (p>0.05). This phenomenon is due to the three MSF formulas have almost similar characteristics (Table 2). The fresh weight of mustard was significantly influenced by the doses (p<0.05) and formulas (p<0.05) of MSF applied to the soil. The increased doses of MSF caused an increase on the fresh weight of mustard. The applications of 2.5 Mg ha^{-1} and 10.0 Mg ha^{-1} MSF to the soil increased the fresh weight of mustard by 189% and 610.1%, respectively, in comparison to that without MSF application. This phenomenon is due to the increase on the amount of available-N, -P and -K in the soil that can be taken up by the plants. The results showed that there are positive correlations between fresh weight of mustard and total soil N (p<0.001; r = 0.714**), available-P (p <0.001; r = 0.564**) and exchangeable-K (p <0.001; r = 0.422**). In addition, the increase of fresh weight of mustard is due to the increase of plant height (p <0.001; r = 0.926**).

CONCLUSIONS

The application of MSF with various doses significantly increases total-N, available-P, and exchangeable-K in the soil but it does not increase the pH and CEC of the soil. There is a difference on the amount of total-N in the soil and the fresh weight of mustard after application of the three MSF formulas. The application of MSF with various formulas and doses significantly increases organic-C content in the soil. The increase of total-N and available-P is positively correlated to soil organic-C content. The application of 5.0 Mg ha^{-1} MSF significantly increases the amount of available-P (by 29.13%) and total-N content (by 24.1%) in the soil in comparison to that in the soil without MSF application. Meanwhile, the significant increase of exchangeable-K (by 50%) is achieved after application of 7.5 Mg ha^{-1} MSF. The height and fresh weight of mustard increase in accordance with the increase of MSF doses applied. The application of 10.0 Mg ha^{-1} MSF results in the highest height and fresh weight of the mustard up to 63.9% and 620%, respectively. The height and fresh weight of mustard are positively correlated to the total-N, available-P and exchangeable-K in the soil. The MSF is an alternative fertilizer that can be used to improve Vertisol fertility and plant growth.

ACKNOWLEDGEMENT

I would like to thank Ministry of Research, Technology, and Higher Education of Republic of Indonesia for the research funding, and The Dean of Faculty of Agriculture and The Rector of Sebelas Maret University for supporting me in finishing the project.

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