

Chemical Properties of Inceptisol and Rice Yields Applied with Mixed Source Fertilizer (MSF)

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Received 14 June 2017/ accepted 28 December 2017

ABSTRACT

One effort that can be done to improve soil fertility and crop yields is fertilization. Fertilization using a mixed source fertilizer (MSF) is an option to overcome the impact of inorganic fertilizer use and organic fertilizer drawbacks. This study aims to evaluate the effects of MSF application on the chemical properties of Inceptisol and rice yields. A field experiment was conducted using a completely randomized block design (RCBD) with two factors and three replications. The first factor was the three formulas of MSF (F1, F2, F3) and the second factor was MSF doses (0, 2.5, 5, 7.5, 10 Mg ha⁻¹). The results show that there is no significant difference on the total soil N, available soil P, plant height and total number of tillers of rice plants applied with the three MSF formulas. The increased MSF doses applied significantly improve the soil chemical properties of Inceptisol and rice yields. The application of 10 Mg ha⁻¹ MSF increases total-N (57.89%), available-P (29.13%), exchangeable-Ca and -Mg (117% and 250%, respectively), plant height (40%) and total number of tillers (43.2%) in comparison to those without MSF application. There are interaction effects between formulas and doses of MSF on the amount of exchangeable-K, organic-C content, and CEC of the soil and rice yields. The application of 10 Mg ha⁻¹ MSF F3 results in better effects on the amount of exchangeable-K, organic-C content and CEC of the soil, and number of productive tillers and rice yields than the application of other MSF formulas. The MSF can be used as an alternatif fertilizer that can improve Inceptisol productivity.

Keywords: Inceptisol, organic farming, rice, soil chemical properties

ABSTRAK

Salah satu upaya untuk meningkatkan kesuburan tanah dan hasil tanaman adalah dengan pemupukan. Pemupukan dengan campuran sumber pupuk organik dan anorganik dilakukan untuk mengatasi dampak penggunaan pupuk anorganik serta kendala pupuk organik. Penelitian ini bertujuan untuk mengkaji berbagai sifat kimia tanah dan hasil padi pada tanah Inceptisol yang diberi campuran sumber pupuk. Penelitian lapangan ini menggunakan rancangan acak kelompok lengkap (RAKL) dengan dua faktor perlakuan dan tiga ulangan. Faktor pertama adalah 3 formula campuran sumber pupuk *Mixed Source Fertilizer* (MSF) (F1, F2, F3) dan faktor kedua adalah dosis MSF (0; 2,5; 5; 7,5; 10 Mg ha⁻¹). Hasil penelitian menunjukkan bahwa tidak ada perbedaan N-total, P-tersedia, C-organik, KTK, Ca dapat ditukar pada tanah yang diaplikasikan dengan 3 formula MSF. Peningkatan dosis MSF nyata meningkatkan sifat kimia tanah dan hasil padi. Aplikasi MSF pada dosis 10 Mg ha⁻¹ mampu meningkatkan N-total (57,89%), P-tersedia (29,13%), Ca dan Mg dapat ditukar (117% dan 250 %), tinggi tanaman (40%) dan total jumlah anakan tanaman padi (43,2%) dibandingkan tanpa aplikasi MSF. Terdapat pengaruh interaksi antara formula dan dosis MSF terhadap K dapat ditukar, C-organik, KTK dan hasil padi. Pemberian 10 Mg ha⁻¹ F1 memberikan hasil yang superior dibandingkan perlakuan lain pada K tertukar, C-organik dan CEC, jumlah anakan produktif dan hasil padi. MSF adalah pupuk alternatif yang dapat digunakan untuk meningkatkan produktivitas tanah Inceptisol.

Kata kunci: Inceptisol, dosis pupuk, pertanian organik, padi, sifat kimia tanah

INTRODUCTION

Inceptisol is potential to be developed as agricultural land, because it is widely spread in Indonesia, covering of 70.25 million ha of land (Puslittanak 2000; Muyassir *et al.* 2012). However, the low contents of organic-C, N, P, and K (Tuherkih and Sipatuha 2009) are the challenges in developing the Inceptisol as agricultural land, or in other words the fertility status of Inceptisol is low (Abdurrahman *et al.* 2008). Therefore, in order to improve the productivity of Inceptisol, a proper fertilization is required.

Recently, farmers tend to use inorganic fertilizer continuously for the cultivation. The use of inorganic fertilizers in a relatively high amount and the use of unbalanced nutrients can decrease soil fertility status, so the productivity of soil is less optimum (Khairatun *et al.* 2013). In addition, the excessive use of chemical or inorganic fertilizers has forced the Indonesian government to keep subsidies on fertilizers (Idris 2017) and also has caused environmental pollution both during its manufacturing processes (Mirlean and Roseinberg 2006; Kassir *et al.* 2012) and its use (Suharsih *et al.* 2002)

On the other hand, farmers tend to ignore in utilizing organic fertilizers. This is due to the organic fertilizer has a low nutrient content so that the farmers need it in a large amount to maximize the crop yields, consequently, the transportation cost of the fertilizer becomes high (Sentana 2010). In addition, the organic fertilizer is known as a slow release fertilizer so it would take a longer time to be available in soil for plant uptake (Brady and Weil 2008).

Therefore, to overcome the problems mentioned above (especially in using whether organic or inorganic fertilizers), looking for natural resources that have high nutrient content, such as N from Azolla and quail manure, P from phosphate rocks, K from coconut shell and feldspar rocks, Ca and Mg from dolomite and S from sulfuric rocks, can be an option in which those natural resources are further mixed together to become a kind of fertilizer. It is expected that this mixture could give positive impacts in increasing the soil fertility status and productivity of agricultural land (Roidah 2013).

A pot experiment conducted in the study of Sumarno (2015) indicated that the application of the three formulas of fertilizers showed a significant effect on the growth of mustard and shallot. Therefore, a field experiment was conducted in the current study as a further study to obtain a formula of mixed source fertilizer (MSF) that can result in

the best effects in improving Inceptisol fertility status and rice yields.

MATERIALS AND METHODS

Study Site

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

Research Design

The experiment was arranged in a Completely Randomized Block Design (RCBD) with two factors and three replications. The first factor was the three formulas of mixed source fertilizer (MSF), namely **F1** (50% quail manure, 20% rock phosphate, 18% coconut husk ash, 6% dolomite, 1% sulfuric element, 5% feldspar), **F2** (60% quail manure, 20% rock phosphate, 14% coconut husk ash, 6% dolomite, 1% sulfuric element) and **F3** (20% quail manure, 30% Azolla, 16% rock phosphate, 23% coconut husk ash, 10% dolomite, 1% sulfuric element). The second factor was 5 doses of MSF 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). 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 according to the doses.

Soil Chemical Analysis

The soil samples were taken before and after the experiment then the soil samples were analyzed in the Laboratory of Soil Chemistry and Soil Fertility, Faculty of Agriculture, Sebelas Maret University. The soil characteristic including total-N (Kjedhal), available-P (Bray 1), exchangeable-K (NH₄OAc 1 N pH 7), organic-C (Walkley and Black) and Cation Exchange Capacity (CEC) (NH₄OAc 1 N pH 7) were determined.

Rice Planting

The IR 64 variety (in accordance with the variety of rice plant used by farmers around the study site) were germinated in a plot. After 21 days of seed planting, the rice seedlings were transplanted with spacing of 25cm x 25cm in a plot with the size of 2m x 3m. The MSF was applied along with the preparation of the land by the local farmers. The data of plant parameters were collected from 5 plant samples per plot. The plant height was measured started from soil surface to the end of the longest

Table 1. Characteristics of Inceptisol from Karanganyar, Central Java.

Soil Properties	Unit	Value	Category*
pH H ₂ O	-	5.5	Acid
Organic-C	%	1.16	Low
CationExchange Capacity	cmol (+)kg ⁻¹	10.4	Low
Total-N	%	0.1	Low
Available-P	ppm	1.9	Very low
Exchangeable-K	cmol(+)kg ⁻¹	0.1	Low
Exchangeable-Ca	cmol (+)kg ⁻¹	1.06	
Exchangeable-Mg	cmol (+)kg ⁻¹	2.69	
Exchangeable-Na	cmol (+)kg ⁻¹	0.33	

*) Based on the category proposed by Soil Research Institute (1983).

leaf at the maximum vegetative growth of rice plants. The number of tillers, number of productive tillers, and rice yields were also recorded.

The data were analyzed using one-way ANOVA test followed by Duncan's Multiple Range Test at 5% level ($p < 0.05$) to compare the average values obtained from each treatment. In addition, a correlation test was also performed to understand the correlation between variables. The entire statistical analysis was performed using SPSS 17.0 and Microsoft Excel (Stell and Torrie 1980).

RESULTS AND DISCUSSION

Characteristics of Inceptisol and Mixed Source Fertilizer (MSF)

Table 1 shows that the Inceptisol used in the current study has a pH of 5.5 (acid), which is less suitable for rice crops since at this pH the nutrient availability is limited (Brady and Weil 2008). This condition is obviously seen on the total-N content, the amount of available-P, and the CEC of the soil that are considered low. This condition exists due to the low organic matter content in the soil. The study

of Tisdale *et al.* (2010) suggested that organic matter is a source of nutrients N, P, and S for plants and the source of negative charges that can affect the soil CEC (Brady and Weil, 2008; Suntoro 2013).

The organic-C contents of the three MSF formulas are quite high and meet the criteria of the minimum amount of organic-C content in organic fertilizers (*i.e.* 12%) regulated by the Indonesian Ministry of Agriculture. Similarly, the N, P, and K contents of the three MSF formulas are almost similar, although the K content in the MSF F1 is higher than that in other MSF formulas (Table 2). The addition of 5% feldspar is suspected to cause a higher K content in the MSF F1. Feldspar is the source of K in soil (Tisdale *et al.* 2010). Moreover, the high total-N in the MSF F1 is correlated with the high organic carbon content and the low C/N ratio of the MSF F1. The low C/N ratio indicates that the decomposition process of the organic fertilizer has been going well (Brady and Weil 2008). The organic materials have been decomposed into amino acids and the amino acids are further mineralized into ammonium, which is the main form of inorganic-N in soil (Tisdale *et al.* 2010; Suntoro 2003).

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 ₂ O ₅ (%)	1.21 ± 0.09	1.17 ± 0.06	1.10 ± 0.08	< 6
K ₂ O (%)	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

Note: All the MSF formulas have met the minimum technical requirement of organic fertilizer proposed in the regulation of the Indonesian Ministry of Agriculture Number 70/Permentan/SR 140/10/2011.

Chemical Properties of Inceptisol after Application of MSFs

Soil pH

The results of F-test at 5% level indicate that the effects of MSF dose, MSF formula, and the interaction between dose and formula show no significant effect on soil pH ($p > 0.05$). All the treatments resulted in almost the same soil pHs and the soil pHs are classified as neutral. This phenomenon is because the three MSF formulas show almost similar properties (Table 2). Moreover, the presence of dolomite about 6% until 10% in the formulas did not result in a significant difference in soil pHs although the soil pHs increased in all the treatments in comparison to the initial soil pH. This is due to the MSF F1, F2 and F3 have the low C/N ratio and the three MSFs are already in a matured condition. According to the study of Suntoro (2003), the addition of decomposed or matured organic materials can increase the soil pH because in the mineralization process, the organic materials will release the elements, including the basic cations.

Total-N

The results of analysis of variance showed that there is no interaction effect between formulas and doses of MSF applied to the soil on the total-N content in the soil ($p > 0.05$). Similarly, the application of different MSF formulas shows no effect on the total-N content in the soil ($p > 0.05$). The total soil N contents are almost similar because the three MSF formulas have almost the same properties (Table 2). Similar results are also reported by Afandi *et al.* (2015) that indicated that there is no difference in the effects of applications of chicken manure, cow dung and compost on the total soil N content

since all the three organic fertilizers have similar properties. The increase of MSF doses applied to the soil significantly increases the total-N content in the soil ($p < 0.001$). Adding MSF at doses 2.5, 5, and 7.5 Mg ha⁻¹ resulted in similar total N content in the soil (Table 3). The highest total content reached at the application of 10 Mg ha⁻¹ MSF, which increased by 58% in comparison to that in the soil without MSF application. The increase of the total-N content measured in the current study is higher than that in the study of Padmanabha *et al.* (2014), which showed that the application of 10 Mg ha⁻¹ manure increased the total-N content in the soil by 10.34%. The increase of total soil N observed in the current study is due to the increased amount of fertilizer applied to the soil and its relation to organic C content in the soil. The result of the correlation analysis indicates that there is a positive correlation between total-N and organic-C contents in the soil ($r = 0.45$, $p < 0.001$). The result of current study is in line with the study of Han *et al.* (2016) about the use of organic and inorganic fertilizers at the germination period of *Liriodendron tulipifera* Lin. They concluded that the use of organic manure significantly increased the concentration of soil total-N at the germination period. This result is also supported by the result from Rong *et al.* (2016) that concluded that the use of organic manure significantly increased the total soil N in the farmland. Organic matter is the predominant source of N in soil (Brady and Weil 2008; Tisdale *et al.* 2010).

Available-P

The application of MSF formulas, and the interaction between doses and formulas of MSF do not significantly affect the amount of available-P in the soil ($p > 0.05$). On the other hand, doses of MSF have a significant effect on the amount of

Table 3. Soil pH, total-N, available-P, and exchangeable-Ca and -Mg in the soil applied with MSF.

Treatments	pH	Total-N	Available-P	Exchangeable-Ca	Exchangeable-Mg
		%	ppm	(cmol(+) kg ⁻¹)	
Formula MSF	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p < 0.05$
F 1	6.24 ± 0.17 a	0.24 ± 0.04 a	2.40 ± 0.23 a	1.99 ± 0.75 a	11.64 ± 5.68 ab
F 2	6.27 ± 0.28 a	0.24 ± 0.07 a	2.41 ± 0.25 a	1.99 ± 0.76 a	10.21 ± 3.74 a
F 3	6.32 ± 0.32 a	0.26 ± 0.07 a	2.43 ± 0.23 a	1.96 ± 0.52 a	13.35 ± 5.32 b
Dose, Mg ha ⁻¹	$p > 0.05$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$
0	6.2 ± 0.18 p	0.19 ± 0.03 p	2.06 ± 0.15 p	1.12 ± 0.40 p	5.25 ± 1.37 p
2.5	6.2 ± 0.17 p	0.25 ± 0.06 p	2.33 ± 0.08 q	1.99 ± 0.58 q	10.57 ± 2.48 q
5	6.3 ± 0.22 p	0.23 ± 0.06 p	2.45 ± 0.08 r	2.01 ± 0.53 q	12.07 ± 2.41 q
7.5	6.3 ± 0.39 p	0.24 ± 0.03 p	2.58 ± 0.06 s	2.17 ± 0.31 q	12.38 ± 3.54 q
10	6.3 ± 0.35 p	0.30 ± 0.07 q	2.66 ± 0.09 s	2.45 ± 0.75 q	18.41 ± 3.70 r

The values followed by the same letters in the same column are not significantly different at 5% level.

available-P in the soil ($p < 0.001$). Table 3 shows that the amounts of available-P in the soil applied with MSF F1, F2 and F3 are not significantly different since the MSF F1 and F2 have the same amount of rock phosphate added, although the amount of rock phosphate in the MSF F3 is slightly lower than that in the MSF F1 and F2. Rock phosphate is a primary rock containing P that is difficult to dissolve in water and at neutral pH (Tisdale *et al.* 2010). Table 3 shows that the pHs of the soils applied with MSFs are almost equal and close to neutral pH, thus it will limit the solubility of P from rock phosphate. It is in line with the study of Khalil (2013) that indicates that the use of apatite rock ($\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH})$) as P fertilizer is not suitable at high pH soils. The study of Khasawneh and Doll (1978) shows that the rock phosphate contains a very small amount of water-soluble-P, therefore, when it is used in soil, a dissolution of P from rock phosphate only occurs when there is a reaction between the rock phosphate and the hydrogen ion. At a neutral pH, the hydrogen and hydroxyl ion contents are almost the same, so the P dissolution from the rock phosphate is low. The amount of available-P measured in the current study increased along with the increased doses of MSF applied. Adding 2.5 Mg ha⁻¹ MSF increased 13.1% of available P in comparison to that in the soil without MSF application. The highest amount of available-P was measured after application of 10 Mg ha⁻¹ MSF to the soil, although it is not different

from that in the soil applied with 7.5 Mg ha⁻¹ MSF. The amount of available-P is positively correlated to soil organic-C content because organic matter is one of the P sources in soil (Tisdale *et al.* 2010).

Exchangeable-K

The results of analysis of variance indicate that there is an interaction effect between doses and formulas of MSF on the amount of exchangeable-K in the soil ($p < 0.001$). The application of 2.5 Mg ha⁻¹ of MSF F1, F2 and F3 significantly increased the amount of exchangeable-K in the soil by 252.3%, 114.7% and 88.9%, respectively, in comparison to that in the soil without MSF application. From the three MSF formulas, the application of MSF F1 resulted in the highest increase of exchangeable-K in the soil because the MSF F1 contains higher K₂O than MSF F2 and F3. The increase doses of MSF (2.5, 5 and 7.5 Mg ha⁻¹) resulted in no significant difference on the amounts of exchangeable-K in the soil applied with MSF F1, F2 and F3 (Table 4). On the other hand, the application of MSF F3 at 10 Mg ha⁻¹ increased the amount of exchangeable-K by 33.3% in comparison to that in the soil applied with the same dose of MSF F2 and by 1.8% in comparison to that in the soil applied with the same dose of MSF F1. It happens because the MSF F3 contains higher coconut husk ash. According to the study of Imaduddin *et al.* (2008), palm-oil ash is the source of K. The addition of feldspar in the

Table 4. The interaction effect between doses and formulas of MSF on the amount of exchangeable K, organic-C content, CEC.

Treatments	Exchangeable-K (cmol(+)kg ⁻¹)	Organic-C (%)	CEC (cmol(+)kg ⁻¹)
F1, 0 (Mg ha ⁻¹)	0.23 ± 0.02 a	1.10 ± 0.10 a	17.08 ± 3.81 a
F1, 2.5	0.81 ± 0.16 bcd	1.26 ± 0.01 b	38.24 ± 5.55 de
F1, 5	0.89 ± 0.11 cd	1.29 ± 0.05 bc	36.00 ± 2.37 cde
F1, 7.5	1.01 ± 0.07 de	1.38 ± 0.04 cd	42.13 ± 4.90 fg
F1, 10	1.14 ± 0.09 e	1.72 ± 0.09 g	48.40 ± 7.36 h
F2, 0	0.34 ± 0.10 a	1.14 ± 0.02 a	31.64 ± 4.78 bc
F2, 2.5	0.73 ± 0.12 bc	1.27 ± 0.03 b	31.20 ± 4.20 bc
F2, 5	0.73 ± 0.17 bc	1.27 ± 0.01 b	37.33 ± 6.46 de
F2, 7.5	0.76 ± 0.06 bc	1.40 ± 0.04 de	43.60 ± 9.41 fgh
F2, 10	0.87 ± 0.14 cd	1.26 ± 0.02 e	47.60 ± 3.84 h
F3, 0	0.36 ± 0.14 a	1.13 ± 0.02 a	27.91 ± 2.94 b
F3, 2.5	0.68 ± 0.13 bc	1.32 ± 0.04 b	34.20 ± 2.72 bcd
F3, 5	0.74 ± 0.13 bc	1.33 ± 0.01 bcd	39.20 ± 3.88 ef
F3, 7.5	0.62 ± 0.13 b	1.37 ± 0.04 cd	45.73 ± 7.19 gh
F3, 10	1.16 ± 0.09 e	1.60 ± 0.07 f	62.13 ± 3.81 i

Notes: F= MSF formula; The values followed by the same letters in each column are not significantly different according to DMRT at 5% level.

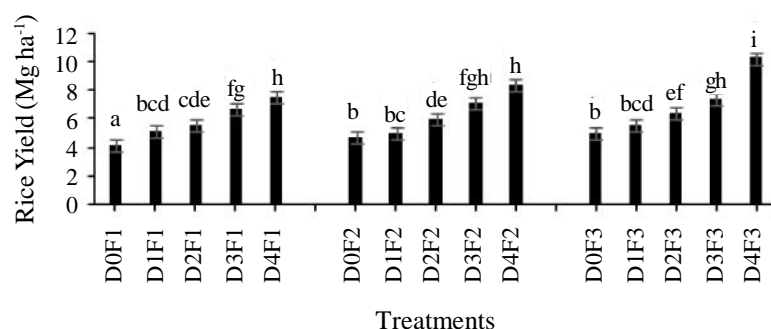


Figure 1. The effects of MSF application on rice yields. D = dose; F = formula.

MSF F1 showed no effect on the amount of exchangeable-K in the soil. This is due to feldspar is the primary mineral that releases available-K slowly and considered as a long-term K source (Tisdale *et al.* 2010), so that until the end of the experiment, not all K in the feldspar has been released as exchangeable-K.

Exchangeable-Ca and -Mg

The results show that there are no differences in the amount of exchangeable-Ca in the soil applied with various MSF formulas (Table 3). This is because both MSF F1 and F2 contain the same amounts of dolomite and rock phosphate, while the MSF F3 contains higher amount of dolomite and lower amount of rock phosphate than MSF F1 and F2. Dolomite and rock phosphate are the sources of Ca (Brady and Weil 2008). It is also reported that the Ca content in the rock phosphate is 24-33% (Zin *et al.* 2005). The increased MSF doses applied to the soil significantly increased the amount

of exchangeable-Ca ($p < 0.001$). Addition of 2.5 Mg ha⁻¹ MSF significantly increased the amount of exchangeable-Ca by 6.5% in comparison to that in the soil without MSF application. However, the amounts of exchangeable-Ca in the soil applied with various doses of MSF (2.5, 5, 7.5 and 10 Mg ha⁻¹) are not really different. The study of Kavitha *et al.* (2016) about the application of various doses of dolomite on soil nutrient availability indicated that the application of dolomite at 4 Mg ha⁻¹ did not affect the amount of exchangeable-Ca in the soil. The amounts of exchangeable-Mg in the soil applied with the three MSF formulas are different (Table 3). The amount of exchangeable-Mg in the soil applied with MSF F3 is 16.6% higher than that in the soil applied with MSF F1 and 30.7% higher than that in the soil applied with MSF F2, due to higher dolomite content in the MSF F3 than that in the MSF F1 and F2. Dolomite is the source of Mg (Brady and Weil 2008).

The results of analysis of variance showed that the MSF doses significantly affect the amount of exchangeable-Mg in the soil ($p < 0.001$). This result is in line with the study of Olego *et al.* (2016) that showed that the application of dolomite significantly enhances the amount of exchangeable-Mg in the soil of Mediterranean wineries. Table 3 indicates that the increasing amount of exchangeable-Mg in the soil is in accordance with increased doses of MSF. The application of 2.5 Mg ha⁻¹ MSF significantly increased the amount of exchangeable-Mg by 101.3% in comparison to that in the soil without MSF application. The application of different doses of MSF (2.5, 5, and 7.5 Mg ha⁻¹) show no difference in the amount of exchangeable-Mg. The application of 10 Mg ha⁻¹ MSF resulted in the highest the amount of exchangeable-Mg in the soil. The increasing trend of soil exchangeable-Mg was also found in the study of Kavitha *et al.* (2016) about the application of various doses of dolomite on the nutrient availability in the soil of tea plantation.

Table 5. The effects of MSF application on the plant height and number of tillers of rice.

Treatments	Plant Height (cm)	Tiller number
Formula MSF	$p < 0.01$	$p > 0.05$
F 1	84.15 ± 10.77 a	20.37 ± 4.81 a
F 2	88.58 ± 9.82 b	21.57 ± 3.89 a
F 3	90.93 ± 10.16 c	21.40 ± 5.17 a
Dose (Mg ha ⁻¹)	$p < 0.01$	$p < 0.01$
0	72.91 ± 3.52 p	18.13 ± 2.91 p
2.5	83.21 ± 5.25 q	19.53 ± 4.00 p
5	88.56 ± 3.64 r	20.33 ± 3.19 p
7.5	92.76 ± 1.43 s	21.53 ± 2.60 p
10	102.00 ± 3.86 t	26.04 ± 5.73 q

Notes: F = MSF formula; The values followed by the same letters in each column are not significantly different according to DMRT at 5% level.

Organic-C

The application of various MSF formulas shows no significant effect on the organic-C content in the soil ($p > 0.05$). On the other hand, the increase of MSF doses and the interaction between formulas and doses of MSF significantly affect the soil organic C-content ($p < 0.05$). The application of MSF F1, F2 and F3 at 2.5 Mg ha⁻¹ resulted in a significant increase in organic-C content in the soil in comparison to that in the soil without MSF application (Table 4), with the increase of 14.5% in the MSF F1 treatment, 10.2% in the MSF F2 treatment and 16.8% in the MSF F3 treatment. There is no difference in the organic-C content in the soil applied with 2.5 and 5 Mg ha⁻¹ of MSF F1, F2 and F3. The highest soil organic C content was measured after application of 10 Mg ha⁻¹ MSF F1, followed by MSF F3 at the same dose. This phenomenon happens because both MSF F1 and F3 contain higher amount of coconut husk ash/coconut shell than MSF F2. The study of Nurida *et al.* (2012) indicates that the application of coconut shell charcoal increases soil organic-C content.

Cation Exchange Capacity (CEC)

The application of various doses and formulas of MSF significantly affect the soil CEC ($p < 0.05$). The application of MSF F1 at 2.5 Mg ha⁻¹ resulted in an increase of CEC by 123.9% in comparison to that in the soil without MSF application. However, the application of MSF F2 and F3 at 2.5 Mg ha⁻¹ showed no significant difference on the soil CEC in comparison to that in the soil without MSF application. The application of MSF F3 at 10 Mg ha⁻¹ resulted in the highest soil CEC. At the same dose, the CEC increased by 28.4% in comparison to that in the soil applied with MSF F1 and by 30.5% in comparison to that in the soil applied with MSF F2. It happens because the MSF F3 contains a higher amount of coconut husk ash and Azolla in which both are the sources of organic C in soil. The study of Briljan (2014) shows that the application of *Azolla pinnata* in West Java Inceptisol can increase the soil CEC by 24.4 cmol(+) kg⁻¹. On the other hand, the study of Elmizan *et al.* (2014) concludes that the application of Azolla as green manure or compost affects soil organic-C content and CEC. The results of our study show that there is a significantly positive correlation between soil organic-C content and CEC ($r = 0.598^{**}$, $p < 0.001$). Organic matter is the source of the soil negative charges that will affect the CEC (Brady and Weil 2008).

Plant Growth and Rice Yields

The result of F test shows that the MSF formula does not significantly affect the height of rice plants ($p > 0.05$) and the total number of tillers ($p > 0.05$) (Table 5), which is consistent with no difference in the total N and available-P in the soils applied with the three MSF formulas. Meanwhile, the increased doses of MSF significantly increased the plant growth ($p < 0.01$). The highest plant height and number of tillers were measured at the soil applied with 10 Mg ha⁻¹ MSF, which were increased by 39.9% and 43.6%, respectively, in comparison to those in the soil without MSF application. The increases are due to the increase of nutrient availability in the soil for the plants. The study of Siswanto *et al.* (2015) indicates that the higher the fertilizer dose applied to the soil, the higher the nutrient content in the soil, so that the optimal plant growth seen in the current study was indicated by the positive correlations between plant height and total soil N ($r = 0.491$; $p < 0.001$), available-P ($r = 0.469$; $p < 0.001$), and exchangeable-K ($r = 0.512$; $p < 0.001$); and the correlations between total number of tillers and total soil N ($r = 0.368$; $p < 0.05$), available-P ($r = 0.816$; $p < 0.001$), and exchangeable-K ($r = 0.781$; $p < 0.001$). The study of Rauf *et al.* (2000) and Patti *et al.* (2013) suggest that N has an important role for rice crops, which stimulates growth, while P and K are the macronutrients needed by plants for metabolism energy and enzyme activity during the plant growth (Tisdale *et al.* 2010).

The rice yields are significantly influenced by various doses and formulas of MSF applied to the soil ($p < 0.001$). There are no significant differences in rice yields due to the application of the three MSF formulas at doses of 2.5, 5 and 7.5 Mg ha⁻¹. However, the application of 10 Mg ha⁻¹ MSF F3 resulted in significantly higher rice yield than the application of MSF F1 and F2. Application of 10 Mg ha⁻¹ F3 resulted in the highest rice yield (*i.e.* 10.28 Mg ha⁻¹), which was 37.3% higher than that in the application of MSF F1, 4.2% higher than that in the application of MSF F2 and 120.1% higher than that without MSF application. It is assumed that 30% azolla added in the MSF F3 can maximize the N uptake by plants. The application of azolla can increase the total-N, organic-C, available-P and exchangeable-K in soil (Mandel *et al.* 1999). The results show that there is a positive correlation between rice yield and total soil N ($r = 0.497$, $p < 0.001$) and the number of productive tillers ($r = 0.916^{**}$, $p < 0.000$). The same results are reported by Siavoshi *et al.* (2011) on the use of organic fertilizer

for rice plants, which concluded that the rice productivity is significantly influenced by the number of productive tillers in comparison to the total number of tillers. The dolomite content in the MSF F3 is higher than that in the MSF F1 and F2. According to the study of Domagoj *et al.* (2014), dolomite can increase soil pH, so that the N, P, K contained in the soil can be utilized properly by the plants. The application of 10 Mg ha⁻¹ MSF F3 resulted in the highest amount of exchangeable-K, organic-C content and CEC of the soil. In other words, the application of 10 Mg ha⁻¹ MSF F3 to the soil resulted in the best effect on rice yield, and the MSF F3 can be used as an alternative fertilizer for rice plants.

CONCLUSIONS

The application of various formulas of MSF shows no significant differences on the total soil N and available-soil P, plant height and number of tillers of rice plants. The application of 10 Mg ha⁻¹ MSF significantly increases the total-N (57.89%), available-P (29.13%), plant height (40%) and number of tillers (43.2%) in comparison to those without MSF application. The application of 10 Mg ha⁻¹ MSF F3 significantly increases the amount of exchangeable-K, organic-C content, CEC, number of productive tillers and rice yields. The MSF F3 is the fertilizer formula that resulted in the best effects on the growth and yields of rice plants grown on Inceptisol.

ACKNOWLEDGEMENTS

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

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