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Land Productivity Enhancement by Sulfur Nutrient Management in Vertisol Rice Field

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ABSTRACT

Sulfur is a secondary soil macro nutrients needed by plants as the most important part of the essential amino acids *(cystine and methionine)*, protein synthesis, chlorophyll production and carbohydrate metabolism. The research aimed to study the land productivity improvement of Vertisol rice field by controlling the sulfur nutrient. The study was conducted in Dawu, Paron, and Guyung, Gerih, Ngawi, East Java, Indonesia, during the dry season 2013 and 2014. A randomized complete block design, with eight treatments and three replications were applied. The treatments were some rates of S-fertilizer application combined with *in situ* straw compost, ZA and Kieserit. Experimental plots dimension is 6 m x 5 m. Ciherang and Membramo were rice varieties grown in legowo 2:1 system. The results showed that S-fertilizer application can increase the weight of dry grain harvest and dry grain milled. The optimum doses of S-fertilizer were 24 kg S ha^{-1}. Kieserit application resulted in less grain yield than ZA. Manure can increase the weight of dry grain harvest and tend to increase the weight of dry milled grain compared to those of the control treatments.

Keywords: land productivity; nutrient management; sulfur; rice

INTRODUCTION

The rapid population increases resulted the increased needs for food, especially rice. The Indonesian Ministry of Agriculture has implemented the National Rice Improvement Program (P2BN), IP 400, Gerakan Mandiri Pangan (Food Autonomic Movement), Gema Palagung (Autonomic Movement of Rice, Soybean, and Corn), the development of new rice fields and Upsus pajale (Special Effort/ Projects on rice, corn, and soybeans). To support the programs mentioned above there has been implemented an intensification program on using organic and anorganic fertilizer on the integrated nutrient management. Factually the farmers usually used a high dose of N and P fertilizer without using any K fertilizer, it was expensive and difficults to find K fertilizer in the field.

It is important to encourage the farmer to use the NPK compound fertilizer to overcome the problems and to increase the rice productivity. But still it needs support for the use of in situ organic material. Habits of most farmers burn straw the rest of the crop will reduce the levels of C-organic content of mostly intensified rice field is < 2 % (Kasno, Nurjaya, & Setyorini, 2003). Straw burning reduced the C content of straw from 9.32 to 0.36 million t $year^{-1}$ in Thailand (Kanokkanjana & Garivait, 2013) and could lose 5-60 % S content depending on how the combustion (Dobermann & Fairhurst, 2002). Some little loss of S, P and K happened when the straw burning was conducted just after the harvest, and actually most straw was burned after harvesting. It was reported a higher N and K content of rice field with straw drowned for 6 years than those with straw burned (Mutters, Horwath, van Kessel, & Williams, 2006). The use of organic fertilizer such as Manure in Borongloe, Bontomarannu, and Gowa was extremely low at only 1.66 % (Mulyani, Bella, & Hafid, 2006).

The increase use of fertilizer regardless of the balance can deplete the other macro nutrients such as S. The P and K maximum uptake by rice plants grown at the ACIAR experimental garden in Southeast Ratna in 2008-09 to 2010-11 was obtained by fertilizing 40 kg S ha^{-1} (Singh, Manibhushan, Meena, & Upadhyaya, 2012). It was reported by Widowati & Rochayati (2003) that 30 soil samples taken from Java, Lombok Island and South Sulawesi need additional S nutrients.

Secondary macro nutrients are Ca, Mg and S. Ca and Mg content of rice field derived from acidic mineral soils are generally low. It was assumed to be caused by the parent material that was poor of Mg (Widowati & Rochayati, 2003). The status of

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Mg content in soil is low when it is only < 1 $cmolc_{(+)}$ Mg kg^{-1} and considers to be high if it contains > 3 $cmolc_{(+)}$ Mg kg^{-1}. Ca fertilizers increased the weight of dry plant at Inceptisols of Tegallega, Sukabumi, while Mg, S, Zn and Cu fertilizers had no effect on weight of dry plant of maize (Nursyamsi, Budiarto, & Anggria, 2002).

Correlated experiments of S nutrient (Sulaeman, Supartini, Sudjadi, Adiningsih, 1984) showed that the best sulfur extraction for rice field was $Ca(H_2PO_4)_2$ 500 ppm P. It was known from a pot experiment that the response to S fertilizing occured in Vertisol, Entisol and Inceptisol. The map of S nutrient status of rice field was compiled with 3 categories: low (< 10 ppm S), medium (10-20 ppm S) and high (> 20 ppm S) (Purnomo, Santoso, Heryadi, & Moersidi, 1992). There was 3.04 million ha of rice fields in Java and the S status is low (52.8 %), medium (41.8 %) and high (5.4 %). According to Al-Jabri (2006) the soil containing < 10 ppm of sulfur was absolutely need a sulfur nutrient addition. Blair, Mamaril, Umar, Momuat, E. O., & Momuat, C. (1978) reported that rice field having the low status of S nutrient content made no response to the S-fertilizing. They were estimated that there was sulfur nutrient deficiency in 60-70 % of rice fields in South Sulawesi.

Sulfur fertilization significantly increased the grain weight in Takalar and the highest yield was 6.18 t ha^{-1} achieved in fertilization level of 10 kg S ha^{-1}, while in Sinjai S fertilization did not increase grain weight (Buntan and Rauf, 1995). Adiningsih, Santoso, & Sudjadi (1990) stated that the S nutrient status cannot be used as a parameter in predicting the plant needs of S nutrient. This research was aimed to study the enhancement of the productivity of rice grown on a Vertisol using S nutrient management.

MATERIALS AND METHODS

The experiments were conducted in Dawu village, Paron sub-district, Ngawi district (07° 45' 10" E, 111° 58' 04' E), and Guyung village, Gerih sub-district, Ngawi district (07° 31'13" N, 111° 22' 37" S), on the dry season of 2013 and 2014. Ciherang variety was the most commonly planted in this experimental site, and its planted three times per year. Water was provided by the rain fall, irrigation, and wells. Extremely high dose of inorganic fertilizers was applied there. They were 300 urea kg ha^{-1}, 300 kg ha^{-1} ZA, 500 kg ha^{-1} Phonska, 500 kg ha^{-1} Petroganik and 500 kg ha^{-1} Sari Organic Fertilizer. Ammonium sulphate (ZA) fertilizer was widely used by farmers in the rainy season. Harvesting was done using *treser*, so that the rice straw was only 50 % left, and the rest was mostly burnt. Immersing the harvest straw directly to the field could cause the plant to have yellows appearence in their early growth. The local farmers call it "*asem-asemen*".

The experimental site had clay texture, neutral pH (5.94 and 6.99), low content of C-organic and N-total, high content of P nutrient, medium content of K nutrient, the soil cultivation layer was dominated by Ca cations, and the base saturation was > 100 %. Soil in Ngawi was dominated by labradorit and hornblende sandstone, clay minerals was dominated by smectite, low content of C-organic and N-total, high content of P and medium content of K, cations dominated by Ca, and high CEC (Prasetyo, Suganda, & Kasno, 2007).

Randomized Complete Block Design with 8 treatments and 3 replications was used in this experiment of S nutrient management on intensification rice field with high pH. Some dose rates of S fertilizer, ZA fertilizer (21 % N and 24 % S) and Kieserite (27 % MgO and 22 % S) were used in this experiment combined with manure and *in situ* straw compost.

The treatments tested were: (1) control (with no S nutrient/S0), (2) S1 (50 kg ha^{-1} ZA), (3) S2 (100 kg ha^{-1} ZA), (4) S3 (150 kg ha^{-1} ZA), (5) S4 (200 kg ha^{-1} ZA), (6) Kieserite (24 kg ha^{-1} S), (7) S2 + 2 t ha^{-1} compost straw, (8) S2 + 2 t ha^{-1} manure. It used 300 kg Urea (135 kg N ha^{-1}), 50 SP-36 kg ha^{-1}, and 50 kg KCl ha^{-1} as a basic fertilizer.

A dose of basic fertilizer was decided concerning to the information of the local rice productivity, and the local nutrient status of P and K. The dose of N was added but concerning the N content of ZA fertilizer which was used to add sulfur purpose. Straw compost and manure were mixed with the soil and then spread over the plot surface one week before planting. Half dose of Urea, full dose of SP-36, KCl, ZA and Kieserite were spread over the plot surface 7 days after planting (DAP). Water inlet and outlet were closed to prevent nutrient loss, through lateral water flow, during fertilization.

The dimension of treatment plot was 6 m x 5 m. The rice plant used as indicator in Dawu was Membramo Variety, and Ciherang Variety in Guyung. Rice crop was planted in Legowo 2:1 row system with planting distance 40 cm x (20 cm x 10 cm), planted 21 days after seedling, 2-3 seeds per clump.

Observation was made to soil of experiment plot before treatment, and data was collected from analyzing the straw compost and manure used in the plot, the soil after harvest, and dry straw and grain sample. Observations also made to the rice plants on plant height and number of tillers, dry grain weight harvested and milled, and the dry weight of straw.

Composite soil samples were taken from 10 point of experiment plots, before treatment. The samples were blended to be a single sample, dried, pulverized and sieved with diameter 2 mm, and then analyzed. The soil analyses comprised texture (sand, silt, and clay) (pipet method), pH H_2O and 1 N KCl (1:5), C-organic, N-Kjeldal, P_2O_5 and K_2O extracted using HCl 25 %, P extracted using Olsen method, Ca, Mg, K, Na and CEC extracted in NH_4OAc in pH 7, Base Saturation, and sulfur extracted in $Ca(H_2PO_4)_2$ 500 ppm P. Soil samples were retaken after harvest and were analyzed to know the content of sulfur nutrient, P extracted using Olsen method, and cations. Straw and grain of the harvesting were analyzed to know the content of sulfur and phosphor. Straw compost and manure were analyzed to see the micro and macro nutrient content.

The effect of S can be seen from the increase of the land rice plant productivity. The curve relation of S dose, yield, and plant weight revealed the optimum dose of S. Comparison between the plant growth in one side and the rice yield and the soil fertility (physical and chemical analyses) of the plot treated with no organic matter, in other side, revealed the effect of organic matter. The optimum dose can be obtained from the relationship between the curve S with the production of fertilizers and plant weight. Influence of organic materials can be determined by comparing the growth and yield of rice and soil analysis with treatment without organic matter.

RESULTS AND DISCUSSION

Soil Characteristic in the Experiment Site

The soil of Dawu and Guyung sites have clay texture, neutral acidity (pH 5.94 and 6.99), and low content of C-organic and N-total (Tabel 1). It is caused by the burning of most straw and the farmers never immersed the straw into their rice fields. According to Husnain (2010), straw burning can lose 100 % TC and TN, 33 and 35 % Si, 36 and 47 % K, 34 and 59 % P, 44 and 38 % Ca, 42 and 48 % Mg, 61 and 55 % Na. Farmers never add manure to their rice field. Organic matters serve as soil restore/conditioner for it can restore soil properties physically, chemically and biologically. The low level of C-organic content in the soil was due to the rapid rate of decomposition caused by the high temperature in the tropic. Organic matter content in the soil is closely related to soil N content. It was reported by Haney et al. (2012) that the N and C-organic soil content had a close correlation (r^2=0.93), and so did between N and the water extracted C-organic (r^2=0.84) on farms of Idaho, Georgia, Maine, Mississippi, Oklahoma, Texas and Wyoming. N is a mobile nutrient and easily lost through evaporation, leaching and lateral flow.

The level content of P (extracted in HCl 25 %) was high, but K was low and medium. It revealed that the farmers used P fertilizer intensively but they gave little heed to K fertilizing. Cation content in the soil was dominated by Ca (77.3 and 79.8 %) and Mg (21.1 and 19.4 %), while K was only 0.4 %. Although the content level of K was medium (individually), but the K saturation level was low. The composition of optimum saturated Ca, Mg and K for maize on Vertisols was 77, 20 and 0.6-0.7 % (Kasno, Iskandar, & Adiningsih, 2005). The CEC and the Base Saturation was high, and it indicated that there were no acidic cations, as Al and H, in the soil. Vertisol Soil in Ngawi was dominated by smectite clay minerals, had clay texture, and high level of CEC (Prasetyo, Suganda, & Kasno, 2007).

The nutrient content of sulfur extracted in $Ca(H_2PO_4)_2$ 500 ppm P was low and is below the critical limit. According to Sulaeman, Supartini, Sudjadi, Adiningsih (1984) the critical limit of S extracted in Ca $(H_2PO_4)_2$ 500 ppm P for rice was 120 ppm SO_4^{2-} (40 ppm S).

Organic Matters Properties Used in the Experiment

The prominent nutrient content in organic matter used as experimental material in Dawu was K_2O. The source of animal feed might be derived from straw so that the level content of K in the manure was high (Table 2). While the nutrient content level of organic materials used in Guyung were relatively lower. This might be caused by the low concentration of nutrients in the soil where the plants grow. By adding 1 t straw compost and manure, it equal with adding 25.3 and 30.4 kg K_2O in Dawu, and 5.2 and 6.7 kg K_2O in Guyung.

Table 1. Result of soil chemistry analyses of experiment plots in Ngawi

Soil chemistry parameter	Unit	Dawu	Guyung
Texture		Clay	Clay
Sand	%	4	15
Silt	%	30	29
Clay	%	66	56
pH H_2O		6.99	5.94
1 N KCl		6.30	5.70
Organic matter			
C-organic	%	1.74	1.62
N-total	%	0.15	0.09
C/N		12	18
Extract HCl 25 %			
P_2O_5	mg 100 g^{-1}	103	96
K_2O	mg 100 g^{-1}	18	9
Olsen (P_2O_5)	mg kg^{-1}		88
1 N NH_4OAc pH 7			
Ca	$cmol_{(+)}$ kg^{-1}	55.78	38.46
Mg	$cmol_{(+)}$ kg^{-1}	13.57	10.52
K	$cmol_{(+)}$ kg^{-1}	0.30	0.19
Na	$cmol_{(+)}$ kg^{-1}	0.26	0.60
CEC	$cmol_{(+)}$ kg^{-1}	68.86	31.61
Base Saturation	%	> 100	> 100
S $Ca(H_2PO_4)_2$ 500 ppm P	ppm	7	38

Table 2. Analyses result of organic matters used in Ngawi experiment plots

Parameter	Dawu		Guyung	
	Straw compost	Manure	Straw compost	Manure
	.... kg t^{-1}			
N	13.1	13.2	17.2	10.7
P_2O_5	5.7	23.0	0.7	0.2
K_2O	25.3	30.4	5.2	6.7
S	1.3	4.1	3.2	3.6
Ca	8.9	11.8	11.1	37.1
Mg	2.7	5.0	3.7	11.4
Fe	0.76	10.22	3.63	11.5
Mn	1.90	0.67	0.88	0.90
Cu	0.007	0.032	0.014	0.028
Zn	0.051	0.110	0.34	0.15

There were same levels of N nutrient content in both organic matter, while manure had higher content of P_2O_5 nutrient. There was higher content of secondary macro nutrients (Ca, Mg and S) and micronutrients (Fe, Cu and Zn) in manure than those in straw compost. The nutrient content of the experiment sites (Dawu and Guyung) were relatively equal.

Effect of S Nutrient Management on the Rice Growth and Yield

Sulfur fertilizing using both ZA and kieserite made no significant effect to increase the plant height and the total tillers (Table 3 and Table 4). Adding both straw compost and manure at 100 kg ZA ha^{-1} treatment also made no effect to increase both plant height and total tillers. Using Kieserite as the source of S tended to decrease the plant height in Dawu, and was clearly different from the S-fertilizing plus 2 t manure ha^{-1}.

Sulfur fertilizing using ZA significantly increased the weight of the dry harvested grain and the dry milled grain compared with the control plot (added no S, see Table 5). The 48 kg ha^{-1} S-fertilizer (200 kg ZA) significantly increased both the weight of dry grains harvested and dry grain milled. The maximum yield can reach at 48 kg S ha^{-1}.

Table 3. The effect of S-fertilizing on the plant height in Ngawi experiment plots at DS. 2013 and 2014

Treatment	The height of rice plan (cm)	
	Dawu	Guyung
Control (without S)	113.5 ab	86.7 a*
50 kg ZA ha^{-1} (12 kg S ha^{-1})	113.5 ab	86.6 a
100 kg ZA ha^{-1} (24 kg S ha^{-1})	113.6 ab	89.7 a
150 kg ZA ha^{-1} (36 kg S ha^{-1})	114.3 ab	91.4 a
200 kg ZA ha^{-1} (48 kg S ha^{-1})	113.6 ab	88.0 a
Kiserite (24 kg S ha^{-1})	112.8 b	87.3 a
100 kg ZA + 2 t straw compost ha^{-1}	113.7 ab	89.2 a
100 kg ZA + 2 t manure ha^{-1}	116.4 a	89.1 a

Remarks: * in a column, mean followed by common letter are not significantly different at the 5 % level by DMRT

Table 4. The effect of S-fertilizer application on the number of rice tillers in Paron, Gerih, and Ngawi, DS. of 2013 and 2014

Treatment	Number of tillers	
	Dawu	Guyung
Control (without S)	14.7 a	19.6 a*
50 kg ZA ha^{-1} (12 kg S ha^{-1})	14.1 a	17.0 a
100 kg ZA ha^{-1} (24 kg S ha^{-1})	14.9 a	19.4 a
150 kg ZA ha^{-1} (36 kg S ha^{-1})	14.3 a	20.7 a
200 kg ZA ha^{-1} (48 kg S ha^{-1})	14.5 a	19.9 a
Kieserite (24 kg S ha^{-1})	15.1 a	20.1 a
100 kg ZA + 2 t straw compost ha^{-1}	15.4 a	18.4 a
100 kg ZA + 2 t manure ha^{-1}	16.4 a	19.5 a

Remarks: * in a column, mean followed by common letter are not significantly different at the 5 % level by DMRT

Table 5. The effect of S-fertilizer on the weight of dry grain harvest, dry grain milled and dry straw in Dawu village

Treatment	Weight of dry grain harvested	Weight of dry grain milled	Weight of dry straw
	.... t ha^{-1}		
Control (without S)	6.69 bc*	6.00 b	5.39 a
50 kg ZA ha^{-1} (12 kg S ha^{-1})	6.92 abc	5.95 b	5.80 a
100 kg ZA ha^{-1} (24 kg S ha^{-1})	7.04 abc	6.07 b	6.06 a
150 kg ZA ha^{-1} (36 kg S ha^{-1})	7.20 abc	6.18 ab	5.91 a
200 kg ZA ha^{-1} (48 kg S ha^{-1})	7.47 a	6.65 a	6.17 a
Kieserite (24 kg S ha^{-1})	6.62 c	5.70 b	5.25 a
100 kg ZA + 2 t straw compost ha^{-1}	7.21 abc	5.96 b	5.84 a
100 kg ZA + 2 t manure ha^{-1}	7.26 ab	6.20 ab	5.94 a

Remarks: * in a column, mean followed by common letter are not significantly different at the 5 % level by DMRT

The weight of the dry grain harvested at S-fertilizing using Kieserite was less than the S-fertilizing using ZA. Kieserite used, beside containing S also contain Mg. Magnesium nutrient which content on the kieserite fertilizer can be effect the cations balance in the soil and negatively affect rice yield.

The 24 kg S ha^{-1} treatment resulted the same weight of the dry grain harvested and the dry grain milled as did in the straw compost and manure treatment. Compared to the control plot, adding manure was significantly increased the weight of the dry grain harvested and tended to give higher weight of dry grain milled. This might be caused by the availability of S in organic matter to be up taken by rice plant and also the microorganism supported the availability level of S nutrient in the soil.

Adding S nutrient could significantly increase the weight of dry harvested grain (Fig. 1). The highest increase of the grain weight occurred on the 0-24 kg ha^{-1} S fertilizing, but adding more S made no more increase to the weight of the grain weight. The optimum dose of S fertilizing was 24 kg ha^{-1}, equal to 100 kg ZA.

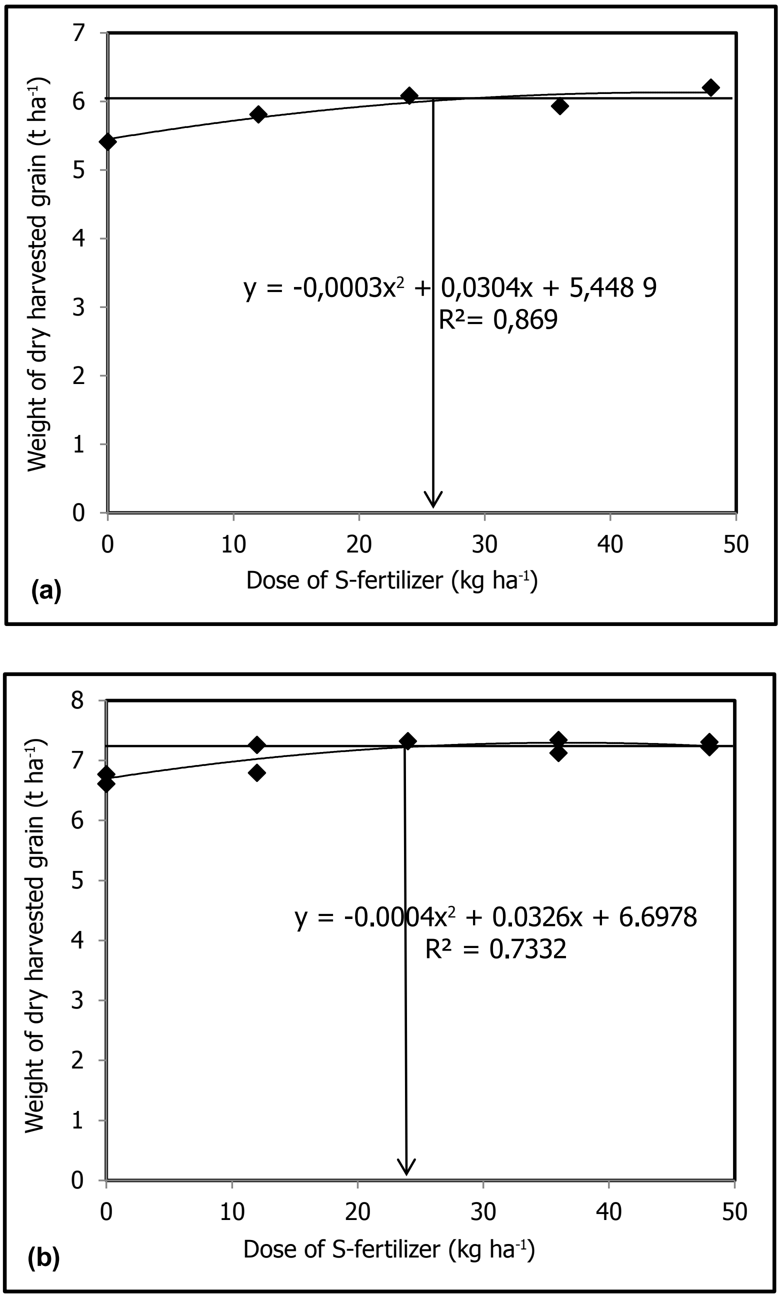

Fig. 1. Relationship between dose of S-fertilizer with the weight of dry grain harvested (a) and dry straw (b)

The addition of S also increases the weight of dry straw, the highest increase occurred in the addition of nutrients S between 0-24 kg ha^{-1} and the addition of a higher dose did not increase the weight of straw. Adding higher dose of S increased no more weight of dry straw. So the optimal dose of S-fertilizer for rice in vertisol was around 25 kg ha^{-1} S.

Giving S nutrient using ZA and Kieserit did not increase the weight of dry harvested grain, nor the weight of dry milled grain and the weight of the dry straw in Gerih (Table 6). Adding organic matter during the first season did not increase the weight of dry harvested grain, nor the weight of dry milled grain, and the weight of dry straw as well.

Table 6. The effect of S-fertilizer on the weight of dry grain harvest, dry grain milled and dry straw in Gerih village

Treatment	Weight of dry grain harvested	Weight of dry grain milled	Weight of dry straw
	....	t ha^{-1}	....
Control (without S)	8.37 a	6.89 a	4.86 a
50 kg ZA ha^{-1} (12 kg S ha^{-1})	7.79 a	6.58 a	4.91 a
100 kg ZA ha^{-1} (24 kg S ha^{-1})	8.44 a	6.95 a	4.46 a
150 kg ZA ha^{-1} (36 kg S ha^{-1})	7.82 a	6.72 a	5.69 a
200 kg ZA ha^{-1} (48 kg S ha^{-1})	8.23 a	6.77 a	5.69 a
Kieserite (24 kg S ha^{-1})	7.22 a	6.20 a	6.23 a
100 kg ZA + 2 t straw compost ha^{-1}	8.23 a	7.11 a	5.42 a
100 kg ZA + 2 t manure ha^{-1}	7.71 a	6.55 a	5.23 a

Remarks: * in a column, mean followed by common letter are not significantly different at the 5 % level by DMRT

Table 7. The effect of S-fertilizer on the content of S, P, Ca, Mg and K in the soil on Dawu village experiment plots

Treatment	S-$Ca(H_2PO_4)_2$ 500 ppm P	P-Olsen	NH_4OAc 1N pH 7		
			Ca	Mg	K
	ppm S	ppm P_2O_5	cmol$_{(+)}$ kg^{-1}		
Control (without S)	64.1 a	55.2 a	46.91 a	5.03 a	0.60 a
50 kg ZA ha^{-1} (12 kg S ha^{-1})	64.9 a	57.2 a	45.47 a	5.19 a	0.49 a
100 kg ZA ha^{-1} (24 kg S ha^{-1})	59.3 a	47.2 a	50.82 a	5.10 a	0.84 a
150 kg ZA ha^{-1} (36 kg S ha^{-1})	59.1 a	52.7 a	50.72 a	5.03 a	0.62 a
200 kg ZA ha^{-1} (48 kg S ha^{-1})	60.3 a	55.5 a	53.07 a	5.13 a	0.95 a
Kieserite (24 kg S ha^{-1})	57.4 a	50.7 a	50.97 a	5.06 a	0.63 a
100 kg ZA + 2 t straw compost ha^{-1}	52.5 a	53.9 a	50.82 a	5.14 a	0.72 a
100 kg ZA + 2 t manure ha^{-1}	54.1 a	53.9 a	51.04 a	5.15 a	0.54 a

Remarks: * in a column, mean followed by common letter are not significantly different at the 5 % level by DMRT

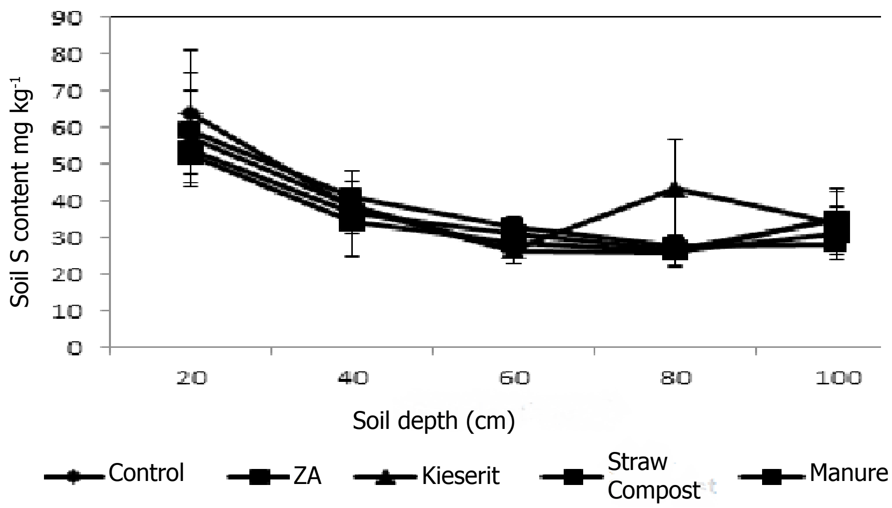

Fig. 2. Sulfur content of various soil depths treated with ZA, kieserite, straw compost, and manure in vertisol

Giving S nutrient both by using ZA and Kieserite made no effect to increase of S, P, Ca, Mg and K nutrients on the soil. Adding straw compost and manure to the rice field having clay texture made no effect to the content increase of S, P, Ca, Mg and K in the soil (Table 7). Application of 5 t ha^{-1} of straw compost every season could increase C-organic, K and Mg exchangeable, CEC and Si available (Adiningsih, 1986).

The S nutrient was high concentrated on 0-20 cm depth, and lessen on 20-40 cm depth. The S concentration was relatively the same on the 60-100 cm depth (Fig. 2), and adding once organic matter made no effect to the S nutrient dynamic.

Application of S nutrient by using ZA and Kieserit, and straw compost and manure, made no effect to the increase of P, K, Ca, Mg, and S content of rice straw (Table 8). Application of S nutrient by using ZA and Kieserit fertilizers, no effect to the increase of P dan S on the straw and grain in Dawu Village (Table 9) and Guyung Village (Table 10).

Table 8. The effect of S-fertilizer on the content of S, P, Ca, Mg and K of dry soil in Guyung village experiment plots

Treatment	S-$Ca(H_2PO_4)_2$ 500 ppm P	P-Olsen	NH$_4$OAc 1N pH 7		
			Ca	Mg	K
	ppm S	ppm P_2O_5	cmol$_{(+)}$ kg^{-1}		
Control (without S)	53.3 a	68.3 a	23.05 ab	8.06 a	0.047 a
50 kg ZA ha^{-1} (12 kg S ha^{-1})	33.7 b	68.3 a	22.52 ab	8.56 a	0.053 a
100 kg ZA ha^{-1} (24 kg S ha^{-1})	36.3 b	46.7 ab	20.04 b	8.22 a	0.043 a
150 kg ZA ha^{-1} (36 kg S ha^{-1})	34.3 b	66.3 ab	21.73 ab	8.31 a	0.043 a
200 kg ZA ha^{-1} (48 kg S ha^{-1})	36.7 b	60.3 ab	23.31 a	8.00 a	0.043 a
Kieserit (24 kg S ha^{-1})	35.7 b	66.7 ab	23.30 a	8.50 a	0.047 a
100 kg ZA + 2 t straw compost ha^{-1}	29.0 b	46.7 ab	20.61 ab	8.12 a	0.047 a
100 kg ZA + 2 t manure ha^{-1}	32.0 b	40.7 b	22.40 ab	7.88 a	0.040 a

Remarks: * in a column, mean followed by common letter are not significantly different at the 5 % level by DMRT

Table 9. The effect of S-fertilizer on the content of P and S of straw and grain in Dawu village experiment plots

Treatment	Nutrient content on straw (%)		Nutrient content on grain (%)	
	P	S	P	S
Control (without S)	0.143 ab	0.27 a	0.52 a	0.15 a*
50 kg ZA ha^{-1} (12 kg S ha^{-1})	0.162 ab	0.31 a	0.65 a	0.11 a
100 kg ZA ha^{-1} (24 kg S ha^{-1})	0.166 a	0.26 a	0.63 a	0.18 a
150 kg ZA ha^{-1} (36 kg S ha^{-1})	0.168 a	0.27 a	0.53 a	0.14 a
200 kg ZA ha^{-1} (48 kg S ha^{-1})	0.160 ab	0.23 a	0.56 a	0.10 a
Kieserite (24 kg S ha^{-1})	0.153 ab	0.26 a	0.56 a	0.13 a
100 kg ZA + 2 t straw compost ha^{-1}	0.152 ab	0.24 a	0.54 a	0.15 a
100 kg ZA + 2 t manure ha^{-1}	0.112 b	0.24 a	0.51 a	0.15 a

Remarks: * in a column, mean followed by common letter are not significantly different at the 5 % level by DMRT

Table 10. The effect of S-fertilizer on the content of P and S of straw and grain in Guyung village experiment plots

Treatment	Nutrient content in straw (%)		Nutrient content in grain (%)	
	P	S	P	S
Control (without S)	0.103 c	0.06 a	0.52 a	0.15 a*
50 kg ZA ha^{-1} (12 kg S ha^{-1})	0.113 c	0.05 a	0.65 a	0.11 a
100 kg ZA ha^{-1} (24 kg S ha^{-1})	0.130 bc	0.04 a	0.63 a	0.18 a
150 kg ZA ha^{-1} (36 kg S ha^{-1})	0.113 c	0.04 a	0.53 a	0.14 a
200 kg ZA ha^{-1} (48 kg S ha^{-1})	0.113 c	0.23 a	0.56 a	0.10 a
Kieserite (24 kg S ha^{-1})	0.103 c	0.26 a	0.56 a	0.13 a
100 kg ZA + 2 t straw compost ha^{-1}	0.177 a	0.24 a	0.54 a	0.15 a
100 kg ZA + 2 t manure ha^{-1}	0.143 b	0.24 a	0.51 a	0.15 a

Remarks: * in a column, mean followed by common letter are not significantly different at the 5 % level by DMRT

CONCLUSION

Experiment of S nutrient management have been implemented in rice fields having low content of S nutrient (7 ppm S), with clay texture, neutral soil, low content of C-organic and high of P content. Sulfur fertilizing could increase the weight of dry grains harvested and dry grain milled, but could not increase plant height, number of tillers and the weight of dry straw in Paron. The optimum dose of S fertilizing for Vertisol rice field with low content of S nutrient was 24 kg S ha^{-1}. The weight of dry harvested and dry milled grain in S fertilizing using ZA was higher than using Kieserite. Organic matter application using straw compost and manure could not increase the weight of the dry grain harvested and tended to increase the weight of dry milled grain compared with the control plot.

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