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Research Paper

IMPROVEMENT OF SOIL QUALITY AND RICE CROP PRODUCTION USING PLUS-ORGANIC FERTILIZER

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The decrease of soil quality is occurred due to chemical fertilizer application in high quantity, within long period and lack of organic matter use in production system of paddy field rice. The research objective was to obtain formula of plus-organic fertilizer that can increase soil quality and rice crop production. It was conducted from October 2013 to May 2014 and the study method was identification of nutrients content in raw materials as well as nutrients content in plus-organic fertilizer formula. The greenhouse study used Factorial Randomized Block Design with 2 treatment factors (4 formula and 4 dose levels) and 3 replications for each factor. The field study used Factorial Randomized Block Design with 2 treatment factors (3 fertilizer types and 3 rice varieties) and 3 replications for each factor. The results showed that wastes from plant and livestock can be utilized as raw materials for plus-organic fertilizer. There was 4 formula of plus-organic fertilizer which agree with SNI 19-7030-2004 that consisted of formula 4 to formula 9. Formula 9 treatment with dose of 750 kg.ha^{-1} was the best treatment in term of rice crop production in greenhouse and in irrigated land which produced 8.16 ton.ha^{-1} for Ciliwung rice variety as well as 7.04 ton.ha^{-1} in tidal swamp land for Gogo Aromatik rice variety, respectively.

Keywords: Formula, Irrigation land, Tidal swamp land, Greenhouse, Rice production

INTRODUCTION

Rice intensification with chemical fertilizers input in high quantity and long time period as well as lack consideration in term of organic matter utilization in production system of paddy field rice had results in the decrease of paddy field soil quality (Pramono, 2004). The decrease of paddy field soil quality is indicated by decrease of C-organic content of soil. Soils at rice production centers in South Sumatra, especially in OKU Timur District, had average C-organic content of less than 1.5% (Budianta dan Tambas, 2004).

Effort to increase soil quality and plant production is through organic fertilizer application.

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Organic fertilizers usually have disadvantages as follows: (1) application volume (ton.ha^{-1}) of organic fertilizer is high; and (2) organic fertilizers have very low nutrients content. Results of study by Gofar *et al.* (2009) showed that PUSRI organic fertilizer enriched with biofertilizer at dose of 15 ton.ha^{-1} could increase production of string bean, mustard greens, lettuce and chili (red pepper). In addition, Andika (2006) had reported that organic fertilizer dose for organic rice cultivation was 10 tons of manure. Organic fertilizer usually has very low nutrients content, for instance nutrients content for organic fertilizer of cow dung has 14.5% organic matter, N=0.32%, P=0.11 % and K= 0.12%, whereas organic fertilizer of chicken dung has 29% organic matter, N=1.55%, P=0.8% and K=0.07% (Sutanto, 2006).

Effort to decrease volume of organic fertilizer application is by extracting it into humate acid so that its application volume (kg.ha^{-1}) is low, whereas effort to increase its nutrients content is by addition of nutrient-containing materials from mineral of natural fertilizer such as cow urine, cow blood flour, cow bone flour, natural phosphate rocks, dolomite and rice husk ash as well as minerals of inorganic fertilizer such as Urea, SP-36 and KCl as the model of plus-organic fertilizer (Syafrullah, 2011).

The research objective was to utilize local natural resources found at villages as raw materials in making of plus-organic fertilizer, to obtain plus-organic fertilizer formula that capable to decrease its application volume, to gain the best formula related to the growth and production of rice crop that agree with SNI of organic fertilizer as well as to obtain the best dose of plus-organic fertilizer formula in increasing paddy field soil quality and rice crop production either in greenhouse, irrigation paddy field and tidal swamp paddy field.

MATERIALS AND METHODS

This study was conducted from October 2013 to May 2014 at Laboratory of Agricultural Faculty, UNSRI; Greenhouse of Agricultural Quarantine Council, South Sumatra Province; Irrigation paddy field in Belitang, OKU Timur District and tidal swamp paddy field in Banyuasin District. The method used in this study was nutrients identification from raw materials and plus-organic fertilizer formula by conducting nutrients analysis in laboratory and greenhouse experiment. Design experiment used in this study was Factorial Randomized Block Design which consisted of 16 treatments combination with 3 replication. These treatments were 4 levels of plus-organic fertilizer formula and doses of plus-organic fertilizer formula (250 kg.ha^{-1}, 500 kg.ha^{-1}, 750 kg.ha^{-1} and 1000 kg.ha^{-1}).

The field experiment used Factorial Randomized Block Design which consisted of 9 treatment combinations and 3 replications with 10 sample plants. Treatment factors were fertilizer types (recommended chemical fertilizer = 250 kg urea.ha^{-1} + 150 kg SP-36.ha^{-1} + 50 kg KCl.ha^{-1}, organic fertilizer dose of 3 ton.ha^{-1} and plus-organic fertilizer formula 9 with dose of 750 kg.ha^{-1}) as well as rice varieties (Mentik Wangi, Gogo Aromatik and Ciliwung). Treatment plot numbers at each location was 36 (size of 2.5 x 2.5 m) with planting distance of 50 cm x 30 cm. Each plot consisted of 40 plants with 10 sample plants.

The observed parameters at greenhouse expriment and field expriment were as follows : nutrients content analysis of C-Organic, N-Total,

P-Total and K-Total from each formula; comprehensive soil analysis before the study implementation; soil analysis after the study; CEC (KTK), Base Saturation (KB), C-organic and available P; growth response observation consisting of plant height, tiller numbers per clump was conducted for every 2 weeks; plant production observation: productive tiller numbers, weight of 1000 grains, numbers of empty unhulled rice, numbers of fully unhulled rice, production per plots as well conversion of production per hectare was conducted at the end of the study.

RESULTS AND DISCUSSION

Local resources found at villages such as rice straw waste, livestock waste, cow dung, cow urine, cow blood and cow bone could be utilized as fertilizer raw materials because they contain nutrients (Table 1). Enriching nutrient materials such as cow bone flour contain Calcium of 39.24% and Phosphorus of 13.66% (Trilaksani *et al.*, 2006). Cow blood flour contains N of 12.18%, P_2O_5 of 5.28%, K_2O of 0.15%, C-Organic of 19.01%. The cow urine fermented for 20 days contains 2.7% of N, 2.4% of P_2O_5 , 3.8% of K_2O and 5.8% of Ca, whereas rice husk ash contains potassium in the range of 1.3% to 2.9% (Sutanto, 2006).

Table 2 showed that from 9 formula which had been developed, there was 4 formula which agree with organic fertilizer standard based on SNI 2004. Relatively high content of organic matter in the range of 23% to 27% and C-organic in the range of 13% to 16% available in these formula showed relatively high content of humate acid that has a role as carrier substance and nutrients provider. According to Stevenson (1994), humate acid has a role as carrier substance because it is

Table 1: Nutrients content from raw materials of plus-organic fertilizer

Raw materials	N %	P %	K %	Ca %	Mg	S	CEC
Humate acid of rice straw compost	1.60	0.44	0.25	0.37	0.58	0.7	65.23
20 days fermented cow urine	2.22	0.31	0.18	0.62	-	-	-
Cow blood flour	6.51	1.69	0.125	-	-	-	-
Cow bone flour	-	13.55	-	38.20	-	-	-
Natural phosphate rock	0.03	6.02	0.04	20.15	2.68	0.01	-
Rice husk ash	0.00	0.26	1.80	-	-	-	-
Dolomite	-	-	-	20	38		
Zeolite	-	-	1.28	3.39	0.85	-	80.08
Urea *	46	-	-	-	-	-	-
SP-36 *	-	36	-	-	-	-	-
KCl *	-	-	60	-	-	-	-

Source : Laboratory of Soil Chemistry, Biology and Fertility, Agricultural Faculty, Sriwijaya University, 2012.

Remarks : * it is indicated at its production bag label.

Table 2: Nutrients content of plus-organic fertilizer formula

Parameters	F1	F2	F3	F4	F5	F6	F7	F8	F9	Organic Fertilizer Standard (SNI 19-7030- 2004)
Water content (%)	17.3	17.0	15.6	15.0	14.8	14.5	14.1	13.8	1.0	< 50%
Organic matter (%)	21.6	22.5	22.9	23.7	24.8	25.7	26.3	27.1	27.5	27 – 58%
C-Organic (%)	13.2	14.2	15.6	16.2	16.1	16.5	16.6	15.9	15.8	9.80 – 32.00
N content (%)	1.43	1.79	2.98	2.98	4.05	5.64	7.38	10.8	14.5	>0.40
P content (%)	0.08	0.04	0.12	0.19	1.48	2.52	2.56	3.57	6.71	>0,10
K content (%)	0.60	0.66	0.70	0.70	1.23	2.34	2.35	3.40	5.01	>0,20
pH	6.58	6.68	6.72	6.75	6.86	7.06	7.20	7.25	7.40	6.80 – 7.49
Ca content (%)	0.79	0.81	0.85	0.88	0.90	0.97	0.99	1.01	1.10	-
Mg content (%)	1.46	1.95	2.48	2.78	2.96	3.19	3.2	3.32	3.86	-
S content (%)	0.001	0.002	0.004	0.006	0.008	0.01	0.03	0.05	0.09	-

polyelectrolite macro molecule containing functional cluster such as –COOH, –OH phenolate or –OH alcoholate which has opportunity to bound with base ions from fertilizer minerals, organic matter, natural minerals as well as to increase macro and micro nutrients.

The addition of inorganic fertilizer minerals such as Urea, SP36 and KCl is to enrich N, P and K nutrients if natural fertilizer addition is incapable to increase nutrients within plus-organic fertilizer which agree with organic fertilizer national standard (SNI 19-7030-2004). According to Gofar and Tambas (1998), addition of organic matter active substance in form of humate acid fraction combined with inorganic fertilizer was good alternative to solve nutrients deficiency from organic fertilizer. Futhermore, Darwin *et al.* (2012) had described that organic fertilizer addition (bokhasi) combined with half dose of recommended inorganic fertilizer could increase tomato production and saving in inorganic fertilizer use.

Results of greenhouse expriment (Table 3) showed that the best formula of plus-organic fertilizer for rice crop was formula 9. This was due to the fact that plus-organic fertilizer of formula 9 had higher nutrients content than other formula, i.e. 14.5% of N-total, 6.71% of P-total, 5.01% of K-total and 15.8% of C-organic. In addition, availability of high humate acid in formula 9 results in increase of crop growth. This was agree with the study results from Gofar and Tambas (1998) which showed that humate acid existence had function to improve crop growth directly by increasing cell permeability or through growth hormone activity.

Treatment dose of 750 kg.ha^{-1} was the best dose because it had N, P and K nutrients that was sufficiently available for crops. This was agree with statement from Salvagiotti dan Mirales (2008) which stated that if nutrients requirement for crop is fulfilled, then sunlight and water can be optimally utilized by crop which improve photosynthesis process and produce

photosyntate resulting in maximum production shown by good development of crop organs.

Treatment interaction of plus-organic fertilizer formula 9 with dose of 750 kg.ha^{-1} was the best treatment because this organic fertilizer was capable to improve growth environment and provide sufficient and suitable nutrients for crop. According to Rukka *et al.* (2006), soil physical condition and nutrients provided by soil is reflected by the quality of crop growth and crop production which grow above soil. This was shown by productive tiller numbers which consisted of 20 shoots and unhulled rice weight per plant of 21.3 grams which showed that this treatment was better than other treatments.

It is expected that addition of plus-organic fertilizer containing humate acid will increase soil pH because humate acid is capable to chelate Al and Fe that neutralize P fixation in soil which results in increase of P nutrient and other nutrients. Increase of soil pH in phosphorous-humate complex will increase P availability so that this nutrient will be easier to be absorbed by plants. The existence of humate acid will form Ca-Humate complex so that competitor for K^+ ion is decrease and results in increase of K^+ ion availability in soil solution (Lado and Ben Hur, 2009).

Table 3: Average value of observed parameters of rice crop growth and production in greenhouse

Treatments	Crop height (cm)	Tiller numbers (tillers)	Productive tiller numbers (tillers)	Weight of 1000 grains (gram)	Unhulled rice weight per plant (gram)
P_1T_1	104.5ab	14.0 a	13.0 a	27.0 b	15.2abc
P-$_1T_2$	110.1bc	16.2 c	15.0 c	27.0 b	17.0bcdef
P_1T_3	113.6bc	16.5cd	15.3cd	28.3bc	18.7efg
P_1T_4	110.8bc	15.1 b	14.0 b	27.6bc	17.4cdfg
P_2T_1	103.7ab	16.7cd	15.4cd	26.3 a	14.2 a
P_2T_2	109.1bc	16.5cd	15.4cd	27.0 b	14.6 ab
P_2T_3	112.8bc	18.3de	17.0e	27.0 b	18.3defg
P_2T_4	110.8bc	16.4ab	15.6cd	27.0 b	17.3cdef
P_3T_1	103.5 a	16.3ab	14.9bc	27.0 b	15.8abcd
P_3T_2	109.8bc	17.3d	15.9cd	27.7 c	16.4abcde
P_3T_3	113.8bc	17.5de	16.2de	29.1 e	19.6fg
P_3T_4	112.1bc	15.9ab	14.8bc	27.0 b	18.5cdef
P_4T_1	108.6 b	17.8de	1.6de	28.3 bc	15.9abcd
P_4T_2	110.7bc	18.0de	16.7de	28.3 bc	16.0abcd
P_4T_3	118.8 d	21.1fg	20.0 h	29.1 e	21.3g
P_4T_4	110.8bc	19.1e	18.00cd	28.4 d	17.8defg

Remarks : numbers in the same columns followed by the same letters are not significantly different.

Table 4: Soil fertility status of irrigation paddy field soil at Belitang and tidal paddy field soil at Banyuasin after the study implementation

Locations	Treat-ments	Status of Soil Chemical Characteristics								
		KTK	Status	KB	Status	C-Organic (%)	Status P (ppm)	Available	Status	Fertility status
Irrigation paddy field	P0	18a	S	15a	SR	1.44a	R	9a	S	R
	P1	29bc	T	71cd	ST	3.9cd	T	24bc	S	T
	P2	27bc	T	76cd	ST	3.2cd	T	23bc	S	T
Tidal swamp paddy field	P0	18a	S	36b	S	2.7b	S	17b	R	R
	P1	27bc	T	71cd	ST	3.6cd	T	24bc	T	T
	P2	26b	T	74cd	ST	3.4cd	T	22bc	T	T

Remarks : numbers followed by the same letters are not significantly different

Source : Soil Science Laboratory of UNSRI, 2012. Status Research was based on Soil Research Center (PPT), 1983.

Where
P0 = Recommended chemical fertilizer
P1 = Organik fertilizer dose of 3 ton.ha^{-1}
P2 = Plus-organic fertilizer dose of 750 kg.ha^{-1}
KTK = Cation Exchange Capacity (CEC)
KB = Base saturation
R = Low
S = Medium
T = High
SR = Very low
ST = Very high

Addition of plus-organic fertilizer will increase humate acid content in soil which create optimum growth environment of plant resulting in increase of plant growth and harvest yield. Futhermore, Syafrullah (2011) stated that humate acid also had significant effect in improving soil physical and chemical characteritics, rice crop growth and production as well as nitrogen content in plant tissue.

Soil fertility prior to this study at irrigation land was relatively low with pH of 4.36 and the same condition was found at tidal swamp land with pH of 4.10 which require effort to increase soil fertility. One of effort to increase soil fertility is by fertilizer addition. According to Pramono (2004), fertilizer addition is one of measure to increase soil fertility.

Table 4 showed that soil fertility at 2 study locations after fertilizer treatment had relatively high soil fertility than that of prior treatment due to the addition of organic fertilizer at dose 3 ton.ha^{-1} and plus-organic fertilizer at dose of 750 kg.ha^{-1} compared to soil fertility status at land with addition of recommended chemical fertilizer. This showed the occurrence of soil quality improvement indicated by increase of soil C-organic content after study implementation, i.e., from 1.44% to 3.2% at irrigation land and from 2.77% to 3.4% at tidal swamp land respectively before and after study implementation. This was estimated due to humate acid availability wich increase soil

Table 5: Production of several rice varieties after fertilizers application at irrigation paddy field soil and tidal paddy field soil

Locations	Fertilizer types	Rice variety production per plots (kg)		
		V1 (Metik Wangi)	V2 (Gogo Aromatik)	V3 (Ciliwung)
irrigation paddy field	Recommended chemical fertilizer (P_0)	2.6bc	2.9a	2.6a
	Organic fertilizer dose of 3 ton.ha $^{-1}$(P_1)	2.2a	3.9cd	3.5ab
	Formula 9 plus-organic fertilizer dose of 750 kg.ha^{-1} (P_2)	4.3df	4.4cd	5.1de
tidal swamp paddy field	Recommended chemical fertilizer (P_0)	2.47b	3.01ab	3.24b
	Organic fertilizer dose of 3 ton.ha $^{-1}$(P_1)	3.25de	3.46b	3.35bc
	Formula 9 plus-organic fertilizer dose of 750 kg.ha^{-1} (P_2)	3.67ef	4.51cd	3.59bc

Remarks: numbers followed by the same letters are not significantly different.

organic matter content after study implementation because humate acid is endure toward activity of soil microorganisms. Humate acid availability will increase soil C-organic content and resist to activity of soil microorganisms which results in improvement of soil physical, chemical and biological characteristics (Luttge *et al.,* 2005).

Organic fertilizer addition will also improve soil physical, chemical and biological characteristics (Melati *et. al.,* 2008). Futhermore, Riley *at al.* (2008) had stated that organic fertilizer addition can improve soil physical characteristics because organic matter is binding agent for loose soil grains or agregate stabilizer which capable to help roots plant to penetrate deeper into soil, so that it can absorb more nutrients and water. In addition, organic fertilizer can also improve rhizosphere which results in maintaining nutrients cycle, improving exudation by roots plant that capable to increase the degradation of soil organic matter and N mineralization (Morgan *et. al.,* 2005). Soil biological characteristics was also improved by organic matter because organic matter is energy source for most of soil microorganisms (Saviozzi *et.al.,* 2006).

According to Hsu *et al.* (2009), improvement of soil physical, chemical and biological characteristics through addition of plus-organic fertilizer because organic matter will improve soil biological activity and incrase soil water availability. The existence of soil water will produce better nutrients absorbtion and transportation so that photosynthetic rate is more secured to increase food supply for plant growth (Muhakka *et al.,* 2006).

Where

P0 = Recommended chemical fertilizer

P1 = Organik fertilizer dose of 3 ton.ha^{-1}

P2 = Plus-organic fertilizer dose of 750 kg.ha^{-1}

KTK = Cation Exchange Capacity (CEC)

KB = Base saturation

R = Low

S = Medium

T = High

SR = Very low

ST = Very high

especially at irrigation land so that chemical fertilizer application was less effective due to low soil C-organic content (1.44%) which results in low soil capability to hold up those nutrients. In addition, nutrients in chemical fertilizer are readily available so that only small part that can be absorbed by plant. This is agree with statement from Goenadi (2010) which stated that nutrients from chemical fertilizer had lost through surface flow leaching (21%), evaporation (19%), fixation by clay minerals (30%), leaching (13%) and microbe immobilization (5%) so that only 12% is left which can be utilized by plant.

Treatment of organic fertilizer at dose 3 ton.ha^{-1} and formula 9 of plus-organic fertilizer at dose 750 kg.ha^{-1} gave higher yield than that of recommended dose of chemical fertilizer because chemical fertilizer not only capable to provide nutrients quickly, but also lost its nutrients quickly in water, fixation by clay minerals, microbe immobilization and others. On the other hand, most of nutrients in organic fertilizer can be absorbed by plant due to slow release of nutrients. Nutrients from organic fertilizer are characterized by slow release so that crop growth process will also change gradually (Morgan *et al.,* 2005).

The plus-organic fertilizer is made of organic matters mixture consisting of humate acid from rice straw compost and minerals of natural fertilizer and inorganic fertilizer. Therefore, its nutrients content is higher than that of organic fertilizer at dose of 3 ton.ha^{-1} because it contains minerals of inorganic fertilizer that increase its nutrients resulting in optimum growth and production. This was agree with results of study from Darwin *et al.*(2012) which showed that bokhasi application or chicken dung fertilizer combined with half dose of recommended inorganic fertilizer was capable to increase crop production and to save inorganic fertilizer use. Furthermore, study results from Pangaribuan *et al.* (2011) also showed that organic fertilizer (bokhasi) from crops residue could reduce the use of inorganic fertilizer. In addition, Sudiarso (2004) stated that organic fertilizer combined with half dose of recommended inorganic fertilizer was capable to increase rice crop growth and production.

In addition to proper fertilizer application, other factor that determine the increase of rice plant production is rice variety. According to Atman (2007), variety is one of main factor in increasing rice crop production. The study results showed that rice variety which had high production at tidal swamp land was Gogo Aromatik. This rice variety was the one that usually cultivated by farmers at dry land as nonirrigated rice. Tidal swamp paddy field at study location is rainfed paddy field that had planted once a year during wet season which represent similar condition with dry land so that Gogo Aromatik rice variety had higher production than other rice varieties. The best rice variety at irrigation land is Ciliwung because this variety is recommended superior variety for paddy field area so that it is superior than Gogo Aromatik variety which is usually cultivated at dry land as nonirrigated rice. According to Bouman *et al.* (2007), genotype of nonirrigated rice is more tolerant to dryness compared to genotype of paddy field rice. Therefore, environment of crop growth has significant effect on rice crop production. Better crop growth due to proper use of variety which appropriate with location and proper fertilization results in increase of rice crop height, productive tiller numbers which produce more shoots, higher magnitude of 1000 grains weight, low percentage of empty unhulled rice as well as weight increase of mill dry unhulled rice (Tubur *et al.,* 2012).

Application of N nutrient on rice crop will increase N accumulaion in leaf and trunk due to increase of nitrogen nutrient availability which results in greener leaves, higher crop, a lot of shoots, higher size of leaves and unhulled rice, higher unhulled rice quality and higher protein content. Phosphorus nutrient is required specifically for growth of roots and fruits, faster flowering and fruit maturity, higher shoot numbers and good rice quality as well as several processes such as photosynthesis, synthesis of protein and lipid and energy transfer. Proper activity of the above processes results in perfect seeds filling so that produce fully unhulled rice (Atman, 2007).

The success of this study can be determined by comparing its results to description results of Gogo Aromatik rice variety at tidal swamp land and description results of Ciliwung rice variety at irrigation land. The study results showed that production of Gogo Aromatik rice variety at tidal swamp land was 7.04 ton.ha^{-1} compared to yield potential description from Gogo Aromatik rice variety with magnitude 6.4 ton.ha^{-1} and production of Ciliwung rice variety at irrigation land was 8.16 ton.ha^{-1} compared to average yield potential description from Ciliwung rice variety with magnitude 6.5 ton.ha^{-1}. These results showed that rice production from this study were higher than that of variety yield description either at tidal swamp land and irrigation land. It means that application of formula 9 plus-organic fertilizer was capable to increase rice crop production at tidal swamp land and irrigation land.

CONCLUSION

In conclusion, village local resources and rice crop waste as well as cow livestock waste can be utilized as raw materials for plus-organic fertilizer making. There was 4 formula of plus-organic fertilizer which agree with SNI 19-7030-2004, i.e., formula 6 to formula 9. Formula 9 with dose of 750 kg.ha^{-1} was the best treatment combination for rice crop growth and production at greenhouse and irrigation paddy field using Ciliwung variety that produced 5.1 kg.plot^{-1} or it can be converted into 8.16 ton.ha^{-1} and at tidal swamp paddy field using Gogo Aromatik variety that produced 4.51 kg.plot^{-1} or it can be converted into 7.04 ton.ha^{-1}.

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