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Application of Rice Straw and Tithonia for Increasing Fertilizer Use Efficiency on Paddy Soil

Gusnidar[1*], Syafrimen Yasin[1], Burbey[2], Yulnafatmawita[1], Sulaiman Saleh[1] and Rantau Andhika[1]

[1]Soil Laboratory, Faculty of Agriculture, Andalas University, Padang, West Sumatera, Indonesia,
email: eni_tanah@yahoo.co.id
[2] Assessment Institute for Agricultural Technology (AIAT) Sukarami, Jl. Padang-Solok Km 40, Sukarami, Kabupaten Solok, Sumatera Barat, Indonesia.

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ABSTRACT

The research was aimed to obtain a combination of rice straw (S) and tithonia (*Tithonia diversifolia*) (T) to increase chemical fertilizers use efficiency (FUE) on paddy soil which was conducted in Sicincin, Padang Pariaman Regency in 2008. The experiment consisted of 8 treatments (A= recommendation input: 200 kg Urea ha^{-1} (Ru) + 100 kg SP-36 ha^{-1} (Rp) + 75 kg KCl ha^{-1} (Rk)), B = Ru + 2Rp, C = 2.5 Mg Tithonia (T) ha^{-1} + 75% Ru+10 kg SP36 ha^{-1} as a starter P fertilizer (P-s), D = T + 75% Ru, E = 5 Mg Rice Straw (S) ha^{-1} (Sr) + Ru + Rp + Rk, F = Sr + Ru + P-s, G = T + 0.5Sr + 75% Ru + P-s, H = T + 0.5S + 50% Ru + P-s) with three replications. The treatments were randomly allocated in each block Randomized Block Design (RBD). The results showed that application of fresh organic matter (OM) from tithonia + 75% recommended Urea without KCl and P-starter addition on intensification rice field increased synthetic FUE on paddy soil. Application of tithonia for 2.5 Mg ha^{-1} + 75% of recommended Urea (150 kg Urea), without synthetic P and K fertilizers seemed to be the best treatment to get the highest yield (8.08 Mg Harvested Dry Seed (HDS) ha^{-1} (= 7.05 Mg Milled Dry Seed (MDS) ha^{-1}) of rice, then it was followed by the treatment based on farmer tradition input with the yield was 7.25 Mg HDS ha^{-1} (= 6.41 Mg MDS ha^{-1}). The use of fresh tithonia as much as 2.5 Mg ha^{-1} based on its dry weight could be considered as an alternative fertilizer for rice crops in intensification rice field.

Keywords: Efficiency, fertilizer, paddy soil, rice straw, tithonia

INTRODUCTION

High P-residual in soil of intensification rice field (Taher 1999; Barus 2007; Gusnidar 2007) is due to high dosage of synthetic-P fertilizer application for a long period as well as due to the nature of the fertilizer which is hard to be solved in water and easy to be adsorbed on soil components. Yulnafatmawita and Gusnidar (1997) reported that P-potential (HCl 25%) content of paddy soil in Sicincin, Padang Pariaman Regency was 85 mg kg^{-1} soil. Ten years later, Gusnidar (2007) found that P-potential (HCl 25%) content of paddy soil in that area had reached > 1.000 mg kg^{-1} soil. Taher (1999) also reported that soil P content in Sicincin in 1995 was 30.10 mg kg^{-1} (Olsen methods). This problems were also reported by Murni (2006) at South Lampung districts. Rice field having been programmed for intensification > 10 years contained high P soil, therefore, it is not suggested to apply P-fertilizer in every cropping season (CS). It will be enough to apply 50 kg SP-36 ha^{-1} in every CS. Taher (1999) reported that P fertilization for rice could also be done through P-starter (10-15 kg TSP/SP-36 ha^{-1}) which could be combined with organic matter (OM) application.

At rice field, the available OM *in situ* is rice straw (RS) which can substitute K nutrient. Dobermann and Fairhurst (2000) reported that RS contained nitrogen (N) 0.43% and silicate (Si) 13.6%. Besides RS, Jama *et al.* (2000) published that tithonia contained N (0.5-0.8 %), P (0.07-0.12 %) and K (1.2-1.7 %). Gusnidar (2007) had calculated the amount of tithonia biomass growing on the small disk in rice field which equaled to 0.5 kg dry matter per meter row. The average nutrient content was 4.25% N; 4.34% K; 0.42% P for once trims (2 months), therefore, it resulted 71 g N, 72 g K, and 7 g P in every meter row. Besides N, P, and K, tithonia also contained Ca (1.14%), Mg (0.78%), ratio C/N 13.96%, C/P 154.40, lignin 16.90%, and cellulose 52.99%. Tithonia is easy and faster to grow after being trimmed, or it can produce more buds during rainy season. It is considered as perennial weed that can grow all year long, therefore it is suggested to cultivate it as an *in situ* OM source for rice field. Utilization of tithonia in intensification rice field will increase concentration of available P and reduce the using of N (Urea), P (TSP or SP-

36), and K (KCl). How ever, the effect of both OM (rice strow and thitonia) applications on several synthetic fertilizer (SF) dosages was needed to be studied.

The objective of the research was to find out the combination of rice straw and tithonia in reducing the use and increasing the efficiency of commercial fertilizer N (Urea), P (TSP or SP-36), and K (KCl) in intensification rice field.

MATERIALS AND METHODS

Study Site

This research was conducted at intensification rice field in Sicincin, Padang Pariaman Regency from July to December 2008. The chemical characteristics of the soil are presented in Table 1.

Experiment Preparation and Maintainance

The experiment consisted of 8 treatments (Table 2) and 3 replications which were set on the randomized block Design (RBD). Rice straw and tithonia were chopped into 3-5 cm length, then incorporated and mixed with soil. It was led to stay (incubated) for 3 weeks under moist condition before soil samples were taken for chemical analyses and the 12-day old rice seedlings were transplanted in 30 × 30 cm distance. The field was kept moist until 3 days before removing the weeds. Commercial fertilizer as P-starter was applied at

Table 1. Soil chemical characteristics of paddy soil at Sicincin Padang Pariaman district, West Sumatera, Indonesia.

Parameters	Value	Criteria
pH H_2O	6.09	Slightly acid*
Org-C (%)	6.27	Very high*
Tot. N (%)	0.57	high*
Ratio C/N	11.00	Medium**
Avail.P. mg kg^{-1}	177.35	Very high*
P_{ot-P} mg kg^{-1}	1230.29	Very high**
Exch-Ca cmol kg^{-1}	0.01	Very low*
Exch-Mg cmol kg^{-1}	2.66	high*
Exch-K cmol kg^{-1}	0.58	Medium*
CEC cmol kg^{-1}	38.00	high*
Cu mg kg^{-1}	14.37	Very low****
Zn mg kg^{-1}	75.41	Medium****
Si mg kg^{-1}	60.12	Less***

*Hardjowigeno (2003); **Joint Project between Team 4 Architects and Consulting Engineer Agriculture Faculty, Andalas University (1981); ***Technical Team of Soil and Water technique Fatemeta IPB); ****Rosmarkam and Yuwono (2002).

Table 2. Treatments and fertilizer applied to paddy soil at Sicincin Padang Pariaman district, Indonesia.

Treatments	Urea	Fertilizer SP-36	KCL	OM Rice straw (S)	Tithonia (T)
	……………… Kg ha^{-1}	………………		……………. Mg ha^{-1}	…………….
A	200	100	75	-	-
B	200	200	-	-	-
C	150	10	-	25	4.5
D	150	-	-	25	4.5
E	200	100	75	-	-
F	200	10	-	-	-
G	150	10	-	25	4.5
H	100	10	-	25	4.5

Note: A (recomendation input; Urea 200 kg ha^{-1} (Ru) +SP-36 100 kg ha^{-1} (Rp)+KCl 75 kg ha^{-1} (Rk)), B (Ru + 2Rp), C (T 2.5 Mg ha^{-1} + 75% Ru + 10 kg P-starter SP-36 ha^{-1}(P-s), D (T + 75 % Ru), E (S 5 Mg ha^{-1} (Sr) + Ru + Rp + Rk, F (Sr + Ru + P-s), G (T + 0.5Sr + 75% Ru + P-s), H (T + 0.5 S + 50 % Ru + P-s).

seedling transplantation, while Urea was applied twice (1/3 part at 2 weeks and 2/3 part at 6 weeks after transplanting) and KCl was applied 2 weeks after transplantation. The field was flooded continously from the beginning of generative stage to 2 weeks before harvest time.

Soil and Plant Analysis

Soil parameters were analyzed before and after incubation which included total N (Kjeldahl), available P (Bray II), exchangeable K, Ca, Mg, Na as well as CEC (1 N NH4-Ac leaching), organic carbon (Walkley and Black), ratio C/N the available of Si, Cu, and Zn. While, plant parameters were plant height, amount of productive seedlings, seed dry weight, biomass dry weight, weight of 1,000 grains, N-P-K uptake and Si content.

Data Analysis

Soil data were compared to the criteria, while the plant data were statistically analysed using F-test and then continued using least significance different (LSD) at 5% level of significance if F calculated > F-table.

RESULTS AND DISCUSSION

Soil Chemical Characteristics after a 3-Week OM Incorporation

The results showed that all chemical characteristic parameters (Table 3) were generally relative similar to all treatments after incubation with the combination of OM and chemical fertilizers. Based on the criteria (Hardjowigeno 2003) organic C content of all treatments were classified into very high. This is due to the nature of the tithonia which is easy to decompose (C/N = 13.96) and contains 47.9% total C. More over, the paddy soil used was belong to Andisol (high OM content). Based on (Ponnamperuma 1984), rice straw is an agricultural waste that have high potentcy to use as an OM source for soils. The sooner the OM decomposed in soil is assumed to be needed a small amount of using synthetic fertilizers. Gusnidar and Prasetyo (2008) reported that the mixture of OM from tithonia and rice straw had not increased the criteria of total N of the soil which was high (0.57%). According to, Francinsco *et al*. (2004) organic N will decompose into mineral N and increase soil N content. In the other hand, Indriyati *et al.* (2008) reported that if organic materials were added into soils in the anaerobic condition more longer, nitrification would sharply decreased, so that nitrate availability limited denitrifications.

Table 3. Soil chemistry characteristics after OM incubation on paddy soil at Sicincin Padang Pariaman district, West Sumatera, Indonesia.

Soil properties	Treatments							
	A	B	C	D	E	F	G	H
Total-N (%)	0.62^{h}	0.64^{h}	0.63^{h}	0.67^{h}	0.66^{h}	0.65^{h}	0.62^{h}	0.68^{h}
Org-C(%)	7.73^{vh}	7.99^{vh}	8.81^{vh}	8.90^{vh}	8.54^{vh}	9.53^{vh}	9.05^{vh}	8.84^{vh}
C/N ratio	12.08^{m}	12.08^{m}	13.98^{m}	11.42^{m}	12.94^{m}	16.20^{m}	14.60^{m}	13.00^{m}
Avail-P (mg kg^{-1})	230.17^{vh}	260.97^{vh}	295.20^{vh}	262.48^{vh}	283.30^{vh}	229.19^{vh}	289.89^{vh}	273.89^{vh}
Si (mg kg^{-1})	95.05^{e}	88.67^{e}	84.45^{e}	87.32^{e}	98.09^{e}	97.54^{e}	75.97^{e}	76.96^{e}
Exch-K (cmol kg^{-1})	0.93^{h}	0.83^{h}	1.24^{vh}	1.28^{vh}	1.22^{vh}	1.59^{vh}	1.45^{vh}	1.48^{vh}
Exch-Ca (cmol kg^{-1})	0.02^{vl}	0.02^{vl}	0.02^{vl}	0.02^{vl}	0.02^{vl}	0.02^{vl}	0.02^{vl}	0.02^{vl}
Exch-Mg (cmol kg^{-1})	3.42^{l}	3.20^{l}	4.19^{l}	3.82^{l}	3.89^{l}	4.55^{l}	4.33^{l}	4.42^{l}
CEC (cmol kg^{-1})	54.50^{vh}	54.00^{vh}	53.00^{vh}	55.50^{vh}	54.00^{vh}	55.30^{vh}	53.00^{vh}	51.00^{vh}
Cu (mg kg^{-1})	1.39^{vl}	1.73^{vl}	1.00^{vh}	1.08^{vl}	0.79^{vl}	0.6^{vl}	0.64^{vl}	1.03^{vh}
Zn (mg kg^{-1})	5.33^{vl}	3.58^{vl}	3.86^{vh}	4.16^{vl}	4.90^{vl}	5.39^{vl}	6.34^{vl}	5.81^{vh}
Eh in field (Mv)	52.03	46.71	58.07	54.60	58.73	52.27	62.07	57.47
pH in field	6.52^{m}	6.50^{sa}	6.66^{n}	6.60^{n}	6.75^{n}	6.65^{n}	6.66^{n}	6.72^{n}

Note: sa = soft acid, n = neutral, vl = very low, l = low, m = medium, h = hight, vh = very high, e = enough. A (recomendation input; Urea 200 kg ha^{-1} (Ru) + SP-36 100 kg ha^{-1} (Rp) + KCl 75 kg ha^{-1} (Rk)), B (Ru + 2Rp), C (T 2.5 Mg ha^{-1} + 75% Ru + 10 kg P-starter SP-36 ha^{-1} mg kg^{-1} (P-s), D (T + 75%Ru), E (S 5 Mg ha^{-1} (Sr) + Ru + Rp + Rk, F (Sr + Ru + P-s), G (T + 0.5Sr + 75% Ru + P-s), H (T + 0.5 S + 50% Ru + P-s).

Soil N content was affect the C/N ratio. Treatments A, B, C, D, E, G, and H were had high N content and low C/N ratio. Increasing of soil total N was due to N contribution from tithonia in which have high N content (3.43%). Jama *et al.* (2000) reported that tithonia application in order to substitute commercial fertilizer of N and K it would increase 0.2% total N of the soil.

Besides N, tithonia application also increased avalaible P in soil. Available P content was found to be the highest under C and the lowest under F treatment. This was due to the effect of the tithonia which had high P content (0.31%). Furthermore, higher available P concentration under intensification rice field was due to high P fertilization dosage for more than 30 years. The synthetic P fertilizers added are accumulated in soils, because the fertilizer is hard to disolve in wáter and easy to adsorped by soil components. Then, Supriyadi (2003) as well as Gusnidar and Prasetyo (2010) reported that OM application could release organic acids causing adsorped P become available.

Silicate (SiO_2) concentration in soil also increased as rice straw and tithonia incorporated to the paddy soil. Hardjowigeno and Rayes (2001) stated that disolved Si will increase as soil is flooded. This was due to the release of adsorped Si in oxyhidroxides as well as the increase of soil pH after being flooded, besides the product of the OM decomposition.

Fresh tithonia and rice straw application did not significantly affect soil CEC values. However, it tended to increase after soil cultivation, flooding, and OM incubation. This could be caused by the effect of the increasing soil pH after flooding and OM degradation. Morever, exchangable-K of the paddy soil was belonged to high criteria, either for treatment with or without OM (tithonia and rice straw) application. As CEC, OM application also tended to increase exchangeable K in soil applied with OM, because organic acids released during OM decomposition are able to release adsorbed-K.

Exchangable Ca and Mg had also the same criteria between soil with and without OM application, eventhough soil with OM application was tended to increase the Ca and Mg content. It means that the OM still contributed the elements during degradation. On the other hand, Cu and Zn content was generally very low. Low Zn could be due to the fact that intensification rice field used to contain high P and low Zn, because of high Zn demand for microbial activities. Then, it was also caused by increasing soil pH after flooding which caused Zn precipítate ($Zn(OH)_2$) which was not solved.

Plant Height, Total Seedlings, and Total Panicles

Plant height and number of seedlings were relatively equal for all treatments (Table 4), while the highest amount of panicles was found under treatments based on farmer and recommendation input.

Tithonia as an OM source containing 2.5-4 % N and K could substitute Urea and KCl fertilizer (Jama *et al*. 2000; Supriyadi 2003; Hakim and Agustian 2005; Gusnidar 2007). Gusnidar and Prasetyo (2008) found that rice straw contained N, P, K, Ca and Mg which contribute to plant nutrients in soils as well as to slower the diminish of Si and K soil. Additionally, Departemen Pertanian (2004) stated that rice straw could also enhance organic C, exchangeable K and Mg, CEC, as well as available Si in the soil.

Tabel 4. Effect of fresh OM and synthetic fertilizer application on plant height, number of total seedlings, and amount of malai at intensification rice field in Sicincin Padang Pariaman distric, West Sumatera, Indonesia.

Treatments	Plant Height	Total Seedlings	Total panicles
	............cm............	....stem clump^{-1}....	......stalk clump^{-1}......
A	85.27 a	41.00	25.36
B	84.52 a	37.10	28.62
C	76.48 c	39.75	24.07
D	82.47 ab	39.50	27.37
E	79.66 bc	35.89	27.91
F	81.04 abc	36.25	23.39
G	83.17 ab	41.08	23.61
H	80.83 abc	40.14	24.64
CV	3.30%	9.25%	9.78%

Means followed by different letter at the same column are significantly different based on LSD test at 5% level of significance.

Table 5. Effect of fresh OM and synthetic fertilizer application on dry weight of rice straw and 1000 grains at intensification rice field in Sicincin Padang Pariaman distric, West Sumatera, Indonesia.

Treatments	DW of Biomass	DW of 1000 grains
	….Mg ha^{-1}….	……g……
A	5.58 bc	19.10
B	5.34 bc	19.63
C	4.89 c	18.77
D	6.87 a	19.63
E	6.36 ab	18.67
F	5.01 c	18.83
G	4.98 c	19.13
H	5.29 bc	18.40
KK	12.53 %	5.83 %

Numbers at the same column followed by different words are significantly different based on LSD at 5% level of significance.

Dry Weight of Biomass, Yield, and 1000 Grains

Dry weight (DW) of the biomass (Table 5) under D treament was significantly higher than the others, but not for the dry weight of the 1000 seeds. Dry weight of the seed yield (Table 6) under D treament was also the highest among treatments and different from the other treatments, but it was not different for treatment B (farmer tradition input). This meant that fresh tithonia application was able to increase Urea (N) fertilizer use efficiency and to reduce K and P into zero dosage in intensification rice field. In other words, the use efficiency of the all three synthetic fertilzers could be increased. Bhatti *et al.* (1998) reported that oxalate and OM can desorp phosphate onto soluble in soil.

Based on above discussion, both fresh OM applied in this research could be used as alternatif fertilizers to reduce synthetic fertilizer application especially Urea by 25% recommended (=150 kg Urea), as well as P and K by 100% for rice growth. Therefore, the use efficiency of the synthetic fertilizers became increasing. It is suggested to apply straw to rice field in order to increase production and fertilizer use efficiency. If it was compared to treatment B (farmer tradition input) and A (recommendation input), the rice yield under D treatment (2.5 Mg tithonia ha^{-1} + 25% recommended Urea (=150 kg Urea) + without P and K) increased by 0.83 Mg HDS ha^{-1} (= 0.64 Mg MDS ha^{-1}) and 1.11 Mg HDS ha^{-1} (= 1.18 Mg MDS ha^{-1}), respectively. Based on the yield results, it means that fresh tithonia application could increase yield of rice under intensification rice field.

CONCLUSIONS

Based on the data resulted from application of rice straw and tithonia which were combined with synthetic fertilizers for rice growth at intensification rice field in Sicincin, it could be concluded as follows: (1) application of tithonia for 2.5 Mg ha^{-1} + 75% of recommended Urea (150 kg Urea), without synthetic P and K fertilizers could reduce fertilizer use of Urea by 25% (100 kg ha^{-1}) as well as KCl and TSP by 100%, and (2) application of tithonia for 2.5 Mg ha^{-1} + 75% of recommended Urea (150 kg Urea), without synthetic P and K fertilizers were likely to be the best treatment to get the highest

Table 6. Effect of fresh OM and synthetic fertilizer application on yield of rice intensification rice field in Sicincin Padang Pariaman distric, Indonesia.

Treatments	OM		Synthetic fertilizer			Production	
	RS	Tithonia	Urea	SP-36	KCl	HDS	MDS
	.........Mg ha^{-1}..........		.............kg ha^{-1}................			...........Mgha^{-1}..........	
A	-	-	200	100	75	6.97	5.86 ab
B	-	-	200	200	-	7..25	6.41 ac
C	-	2.5	150	10	-	6.28	5.18 d
D	-	2.5	150	-	-	8.08	7.05 a
E	5.0	-	200	100	75	.70	5.66 cd
F	5.0	-	200	10	-	6.87	5.53 cd
G	2.5	2.5	150	10	-	6.30	5.25 cd
H	2.5	2.5	100	10	-	6.72	5.79 bcd
KK							6.48%

Note: HDS-harvest dry seeds and MDS = mill dry seeds. Numbers at the same column followed by different words is significantly different based on LSD at 5% level of significance.

yield (8.08 Mg HDS ha^{-1} (= 7.05 Mg MDS ha^{-1}) of rice, then it was followed by the treatment based on farmer tradition input with the yield was 7.25 Mg HDS ha^{-1} (= 6.41 Mg MDS ha^{-1}). It is suggested that application of tithonia as an organic matter source for 2.5 Mg ha^{-1} based on the dry matter could be considered as an alternatif fertilizer for rice field.

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