IMPROVEMENT OF SOIL FERTILITY BY RICE STRAW MANURE

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ABSTRACT

A long-term experiment has being conducted on the effects of rice straw manure (RSM) on rice production and soil fertility. So far, rice was cultivated twenty seven times (14 wet seasons (WS) and 13 dry seasons (DS) with chemical fertilizer and RSM applications in 7 fertilizer treatments. Compared with the control treatment (no chemical fertilizer, no RSM), solo application of the RSM (6 Mg ha^{-1}) increased the average rice yield 38.46% and 13.56% in the wet season (WS) and in dry season (DS), respectively. While, solo application of chemical fertilizer (NPK) increased the yield over the control by 45.77% in WS and 22.41% in DS. Rice yields of treatments in which different doses of chemical fertilizer combined with RSM (6t. ha^{-1}) was applied (T4 and T5) were from 48.08% to 81.15% and from 23.35% to 40.30% higher than T1 in wet season and in dry season, respectively. Generally, the results of the rice yield indicated that the chemical fertilizer input can be decreased 40 to 60% from the present recommended application rate by using RSM without decreasing rice yield. The continuous application of RSM maintained available Si in soil. The microbial population and total protein content in soil where RSM was applied was higher than that in soil compared without RSM application.

Keywords: *Long-term field experiment, rice straw manure, soil fertility, soil micro organisms*

INTRODUCTION

Rice is the most important crop in Mekong Delta. With the introduction of high yield rice varieties and the adoption of intensive rice cultivation, a large quantity of rice straw is available on farms. Rice straw can not be applied or ploughed directly into the soil because of their high C:N ratio. That is known to reduce the availability of important mineral nutrients to growing plants through immobilization into organic forms and also to produce phyto-toxic substances during their decomposition (Martin *et al.,* 1978; Elliott *et al.,* 1981). Therefore, most of rice straw was burnt and the straw burning will cause air pollution through smoke and particulate emission. It is estimated that every million tons of straw burned releases 56000 tons of carbon dioxide (CAM, 1991). To solve such problems, rice straw can be composted in heaps or pits with adequate moisture and suitable microbial inoculants and be applied as organic manure (Gaur *et al.,* 1990; Tran Thi Ngoc Son *et al.*, 2013) on to the rice fields.

Cuu Long Delta Rice Research Institute (CLRRI) has collaborated with Japan International Research Center for Agricultural Sciences (JIRCAS) to carry out a long-term experiment in which rice straw was decomposed by suitable fungal inoculants to produce manure to study “improvement of soil fertility by rice straw manure” with the following objectives (1) to determine the effect of continuous application of rice straw manure (RSM) and inorganic fertilizer alone or in combination on rice yield and (2) their effect to microbial communities in paddy soil.

MATERIALS AND METHODS

Fungal inoculant (*Trichoderma* spp.) in powder-form was produced by CLRRI’s Department of Soil science and Microbiology and applied to rice straw heaps with adequate moisture to promote composting. Composted rice straw was applied into the experimental fields 30 to 45 days after the inoculation.

The experiment started in the 2000's wet season at the experimental field in CLRRI (Omon, Can Tho city). From 2000 wet season to 2005 dry season, germinated seeds (IR64: 100-day growth duration) were broadcasted on the field (30 m^2 for each plot) at 200 kg ha^{-1} seedling rate; from 2006 dry season germinated seed (OM 2517: 90-day growth duration) and from 2009 dry season germinated seed (OM 4900: 90-day growth duration) were seeded by row seeder with 100 kg ha^{-1} seedling rate. The experimental field was set up with randomized block design with three replications and the treatments were prepared as following :

T1: control (0 N - 0 P_2O_5 - 0 K_2O)

T2: 100% RSM (6 Mg ha^{-1})

T3: 100% RSM (6 Mg ha^{-1}) + 20% NPK (16N-6P_2O_5 -6K_2O kg ha^{-1})

T3 ✓: 40 % NPK

T4: 100% RSM (6 Mg ha^{-1}) + 40% NPK (32N-12P_2O_5 -12 K_2O kg ha^{-1})

T5: 100% RSM (6 Mg ha^{-1}) + 60% NPK (48N-18P_2O_5 -18 K_2O kg ha^{-1})

T6: 100% RSM (6 Mg ha^{-1}) + 80% NPK (64N-24P_2O_5 -24 K_2O kg ha^{-1})

T6 ✓: 60% NPK

T7: 100% inorganic fertilizer (wet season: 80N-30P_2O_5 -30 K_2O kg ha^{-1}

and dry season: 100N- 30P_2O_5 -30 K_2O kg ha^{-1})

+ Treatment: T1,T2,T4,T5,T7 maintained from W.S 2000 to D.S 2014

+ Treatment T3 and T6 was changed to treatment T3 ✓ and T6 ✓from D.S 2010 to D.S 2014

RSM and phosphorus fertilizer was applied at the time of land preparation before broadcasting rice seeds. Nitrogen fertilizer was applied in three equal splits at 10, 20 and 30 days after sowing (DAS). Potassium fertilizer was applied in two equal splits at 10 and 30 DAS. The recommended fertilization rate in dry season is (100N- 30P_2O_5 -30 K_2O kg ha^{-1}) and wet season is (80N- 30P_2O_5 -30 K_2O kg ha^{-1}).

The soil of the experimental field is Fluvaqentic Humaquepts (Soil survey staff, 2010). The Total C, N and P concentrations measure in the experimental field surface soil taken after harvest of the first crop were 35.1 g C kg^{-1}, 3.3 g N kg^{-1} and 240 mg P kg^{-1} in dry soil. The rice straw after harvesting was decomposed as rice straw manure (RSM). The dry matter content of RSM was 170-210 g kg^{-1} and N,P and K concentration of the dry matter were 17.2-23.0 g kg^{-1}, 2.2-2.6 g kg^{-1}, and 5.3-14.9 g kg^{-1} as N,P and K, respectively and the C/N ratio of the RSM was 13.4-17.7. Hence, 6 ton ha^{-1} (wet weight basic) of RSM per season was equivalent to 22.1-25.6 kg ha^{-1}, 6.1-6.7 kg ha^{-1}, 7.7-18.5 kg ha^{-1} as N, P_2O_5 and K_2O, respectively, and 0.32-0.39 Mg ha^{-1} of organic C (Takeshi Watanabe and *et al*., 2009).

Soil microbial populations and total protein content in soil were estimated at harvesting time. Total protein content in soil was mg kg^{-1} dry soil (Herbert *et al*., 1971). Microbial populations were estimated by plate counting method, by using following media (Subbarao, 1977):

- Nutrient agar medium for bacteria counting.
- PDA for fungi counting.
- Kenknight and Munaier's medium for Actinomycetes counting.
- Bristol's medium for algae counting.

SPAD value was measured by Chlorophyll meter (SPAD-502) at 50 DAS, disease- insect incidence during growth period and yield and yield components were recorded. The data under this study was statistically analyzed for a randomized complete block design by IRRISTAT program.

RESULTS AND DISCUSSION

Effect of rice straw manure and inorganic fertilizer in combination or alone application on rice yield:

SPAD value in wet season (Table 1) and in dry season (Table 2) shows that the more inorganic fertilizer was applied, the higher SPAD value was obtained. Average SPAD values at T7 in wet season and dry season were significantly higher than other treatments. It was reported that SPAD value reflects nitrogen concentration in rice and the optimum value for high yield directly seeded rice ranges from 32 to 36 in the dry season and 29 to 32 in the wet season (Huan *et al.*, 1998, 2000). The 2000-2009 average and 2010-2013 average results in the wet season showed that all treatments gave optimum or higher SPAD value, with exception of treatment T1 gave optimum SPAD value, this phenomenon may due to phosphorous deficiency. The results in the dry seasons gave optimum SPAD value at treatments T3, T3✓ T4, T5, T6. While the treatment T6✓ and T7 gave highest SPAD value.

Table 1. Effect of RSM and chemical fertilizer on SPAD value at 50 days after sowing of wet season

Treatment	Wet season					
	Average 2000-2009	2010	2011	2012	2013	Average 2010- 2013
T1. Control	30.45 de	32.4 d	30.36 d	29.32 f	31.95 d	31.01 e
T2. RSM (6 t/ha)	29.47 e	31.87 d	29.16 d	29.45 f	31.66 d	30.54 e
T3. RSM + 20% NPK	31.69 d					
T3 ✓: 40% NPK		35.77 c	34.51 c	32.89 e	35.60 c	34.69 d
T4. RSM + 40% NPK	33.03 c	35.67 c	35.11 bc	34.07 d	36.18 bc	35.26 d
T5. RSM+ 60% NPK	34.32 bc	37.41 bc	37.00 ab	35.03 c	37.86 ab	36.83 c
T6. RSM+80% NPK	34.82 ab					
T6 ✓: 60% NPK		38.04 ab	37.73 a	37.49 b	38.83 a	38.02 b
T7. NPK (80:30:30)	35.99 a	39.22 a	38.13 a	38.41 a	39.54 a	38.83 a
F	**	**	**	**	**	**
CV (%)	3.70	2.80	3.50	1.10	2.70	1.60

***Means in a column followed by the same letter are significantly different at p < 0.01*
**Means in a column followed by the same letter are significantly different at p < 0.05*

Table 2: Effect of RSM and chemical fertilizer on SPAD value at 50 days after sowing of dry season

Treatment	Dry season						
	Average 2000-2009	2010	2011	2012	2013	2014	Average 2010-2014
T1. Control	27.41 g	29.39 e	28.79 f	28.42 d	28.55 d	29.49 e	28.93 f
T2. RSM (6 t/ha)	28.75 f	31.71 d	30.85 e	28.89 d	28.99 d	30.88 d	30.26 e
T3. RSM + 20% NPK	31.60 e						
T3 ✓: 40% NPK		34.63c	35.17 d	33.84 c	33.72 c	34.74 c	34.42 d
T4. RSM + 40% NPK	33.62 d	35.39 bc	35.53 cd	35.70 b	34.25 c	34.93 c	35.16 d
T5. RSM+ 60% NPK	34.94 c	37.32 ab	36.45 c	36.52 b	36.74 b	36.88 b	36.78 c
T6. RSM+80% NPK	36.29 b						
T6 ✓: 60% NPK		37.49 a	37.82 b	38.12 a	37.77 b	37.69 b	37.78 b
T7. NPK (100:30:30)	37.76 a	38.90 a	39.81 a	39.09 a	39.22 a	39.02 a	39.21 a
F	**	**	**	**	**	**	**
CV (%)	3.20	3.30	2.00	1.80	2.30	2.10	1.60

***Means in a column followed by the same letter are significantly different at p < 0.01*
**Means in a column followed by the same letter are significantly different at p < 0.05*

The average rice yield (2000-2009) in the wet season (Table 3) showed that the treatment T4 gave higher grain yield than treatment T7 but was not significantly difference in grain yield as compared with treatments T5 and T6. Similarly, treatments T4, T5, T6 gave significantly higher grain yield than treatment T7 in dry season (Table 4).

While, the data for 2010-2013 showed that there were significant differences in average rice yield among treatment T4, T5, T6 ✓, and T7 in the wet season. Same tendency was found that the average rice yield (2010 – 2014) showed that there were significant differences in average rice yield among treatment T4, T5, T6 ✓, and T7 in the dry seasons. Compared with T1, grain yield in T2 was 38.46 % and 13.56 % higher in the wet season and dry season, respectively. While, solo application of chemical fertilizer (T7) increased the yield over the T1 by 45.77% in wet season and 22.41% in dry season. Rice yields of treatment in which different doses of chemical fertilizer combined with RSM were applied (T3 ✓, T4, T5 and T6 ✓) were 48.08% to 81.15% and 23.35% to 40.30 % higher than T1 in wet season and in dry season, respectively.

A study carried out on five crops in Japan showed that applications of organic matter enhance root growth and nutrient uptake, resulting in higher yields (FFTC, 1998). While from this study it was observed that the chemical fertilizer of rice yield input can be decreased 40% to 60% from the present recommended application rate by using RSM without decreasing rice yield, or one may expect higher yield with RSM added to the full chemical fertilizer input.

Table 3: Effect of RSM and chemical fertilizer on rice yield of wet season.

Treatment		Wet season					
	Average 2000-2009	2010	2011	2012	2013	Average 2010- 2013	Grain yield over control (%)
T1. Control	2.15 e	2.84 e	2.87 d	2.36 c	2.32 d	2.60 d	-
T2. RSM (6 t/ha)	2.54 d	3.55 d	3.62 c	3.63 b	3.58 c	3.60 c	38.46
T3. RSM + 20 %NPK	3.09 c						
T3 ✓: 40% NPK		3.85 bc	3.87 bc	3.79 b	3.87 b	3.85 b	48.08
T4. RSM + 40% NPK	3.36 abc	4.54 a	4.57 a	4.60 a	4.65 a	4.59 a	76.54
T5. RSM+ 60%NPK	3.54 a	4.63 a	4.69 a	4.74 a	4.76 a	4.71 a	81.15
T6. RSM+80% NPK	3.44 ab						
T6 ✓: 60% NPK		3.92 b	3.99 b	3.87 b	3.90 b	3.92 b	50.77
T7. NPK (80:30:30)	3.25 bc	3.67 cd	3.72 bc	3.85 b	3.93 b	3.79 bc	45.77
F	**	**	**	**	**	**	-
CV (%)	10.0	3.50	4.70	4.10	3.60	3.50	

***Means in a column followed by the same letter are significantly different at $p < 0.01$*
**Means in a column followed by the same letter are significantly different at $p < 0.05$*
ns; Means in a column followed by the same letter are not significantly different

Table 4: Effect of RSM and chemical fertilizer on rice yield of dry season.

Treatment	Dry season							
	Average 2000-2009	2010	2011	2012	2013	2014	Average 2010- 2014	Grain yield over control (%)
T1. Control	4.46 c	5.48 c	5.60 e	5.36 e	5.12 e	4.98 e	5.31 e	-
T2. RSM (6 t/ha)	4.73 c	6.18 c	6.15 d	6.17 d	5.83 d	5.84 d	6.03 d	13.56
T3. RSM + 20% NPK	5.72 b							
T3 ✓: 40% NPK		6.97 ab	6.60 c	6.56 c	6.21 c	6.43 c	6.55 c	23.35
T4. RSM + 40% NPK	6.15 a	7.35 a	7.48 a	7.63 a	7.36 a	7.43 a	7.45 a	40.30
T5. RSM+ 60% NPK	6.16 a	7.09 a	7.43 ab	7.48 a	7.18 a	7.23 ab	7.28 a	37.10
T6. RSM+80% NPK	6.07 a							
T6 ✓: 60% NPK		7.19 a	7.17 b	6.94 b	6.80 b	6.91 bc	7.00 b	31.83
T7. NPK (100:30:30)	5.71 b	6.24 bc	6.45 c	6.61 c	6.55 b	6.66 c	6.50 c	22.41
F	**	**	**	**	**	**	**	-
CV (%)	5.90	6.50	2.40	1.60	2.70	4.40	2.60	

***Means in a column followed by the same letter are significantly different at p < 0.01*

Table 5. Rice Blast disease and Neck blast disease of 2003 dry season and grain discoloration of 2005 dry season

Treatment	Leaf blast disease (%) *	Neck blast disease (%)**	Grain discoloration (%)
T1. Control	1.48	1.38	34.60
T2. RSM (6 t/ha)	2.94	0.90	35.70
T3. RSM + 20 %NPK	12.54	1.42	40.03
T4. RSM + 40% NPK	14.87	1.54	46.10
T5. RSM+ 60%NPK	30.70	2.66	44.97
T6. RSM+80% NPK	38.27	3.60	59.02
T7. NPK (100:30:30)	72.00	4.52	60.50
CV (%)	26.5	22.5	11.2
LSD (5%)	11.62	0.91	9.15

* Number disease leaves/total leaves observation; using arcsine transformation; 35 DAS.
** Number disease panicles / total panicles observation; using square-root transformation $(X + 0.5)^{1/2}$; 85 DAS.
✓ Grain discoloration of 2005 DS was observed at harvesting time.

In the 2003 dry season, grain yields were lower than in other dry seasons because of an outbreak of blast disease. Symptoms of leaf blast disease and neck blast disease were found at 35 and 85 DAS in the season. Rice at the T6 and especially T7 treatments was more severely damaged by the disease (Table 5).

In the 2005 dry season, grain discoloration at T6 and T7 was more severe than other treatments (Table 5). Similarly, population of brown plant hopper (Dry season 2008), leaf folder (Dry season 2008, Wet season 2011 and Dry season 2013) at treatment T7 was more higher than other treatments (Table 6).

The effect of resources rice straw manure also showed that there were significant differences in average rice yield among treatment T4, T5, T6 ✓, and T7 in the wet seasons. When applied continuously for rice straw manure and chemical fertilizer reduced the amount of rice pest infestation less than as compared with only applied chemical fertilizer (Luong Minh Chau and Heong, 2005). They also showed the impact of rice straw manure on the growth of rice plants and decrease minimize outbreaks of pests and diseases (BPH, stem borer, worm leaf, rice blast and sheath blight) on rice.

Table 6. Leaf blast disease and leaf folder on rice growth

Treatment	Dry season 2008 Observed at 49 days after sowing		Leaf folder * (%)/m^2		
	BPH / m^2	Leaf blast Disease (%) *	Dry season 2008	Wet season 2011	Dry season 2013
T1. Control	220	5.72	1.61	8.63	2.06
T2. RSM (6 t/ha)	206	5.19	1.61	7.78	1.81
T3. RSM + 20% NPK	231	6.49	2.24		
T3 ✓: 40% NPK				11.34	3.59
T4. RSM + 40% NPK	197	5.77	2.33	23.78	3.14
T5. RSM+ 60% NPK	247	6.46	1.65	19.75	5.36
T6. RSM+80% NPK	288	6.31	1.66		
T6 ✓: 60% NPK				28.22	5.52
T7. NPK (100:30:30) D.S (80:30:30) W.S	317	7.09	3.00	51.02	5.50
CV (%)	19.4	19.6	45.0	58.60	28.40
LSD (5%)	83.98	2.14	1.65	22.41	1.95

* Number disease leaves or folder leaves/total leaves observation

These plots had applied rice straw manure were higher silicon concentrations in rice straw than as compared with plots which received only applied chemical fertilizer (Table 7).

Silicon has an important role for the growth of rice and makes for thicker rice leaves and trunks were thicker (Heinai *et al.*, 2005; Hayasaka *et al.*, 2008) hence helping to resist the rice insects and diseases better.

Table 7. N and SiO_2 concentration in straw and grain in 2005 dry season

Treatment	**N (%)**		**SiO_2 (%)**	
	Straw*	**Grain***	**Straw****	**Grain ***
T1. Control	0.57a	1.16a	8.97	4.27a
T2. RSM (6 t/ha)	0.58a	1.14a	9.54	4.39a
T3. RSM + 20% NPK	0.59a	1.18a	9.17	3.59b
T4. RSM + 40% NPK	0.67a	1.23a	9.19	3.50b
T5. RSM+ 60% NPK	0.69a	1.29ab	9.64	3.51b
T6. RSM+80% NPK	0.94b	1.40 bc	9.47	3.40b
T7. NPK (100:30:30)	0.94b	1.49c	8.36	2.75 c

* Means in a column followed by the same letter are not significantly different at $p< 0.01$, based on LSD test
** Significant difference was not detected between treatments

Nitrogen concentration in grain and straw taken at sampling time showed that N concentrations increased as applied chemical fertilizer increased (Table 7).

It seemed that silica (Si) concentrations in rice straw in treatments without RSM were somewhat lower than other treatments, although the difference was not significant (Table 8). As rice straw contains much silica, replicated removal of rice straw at T1 and T7 might lead to the decrease of available Si in soil. This phenomenon was demonstrated by the result of the available Si in soil after harvest time of Dry season 2013 at 0 - 10 cm depth of soil, the results (Table 9) indicated that the treatments with RSM application gave higher available Si in soil as compared with the treatments without RSM application

Table 8. Si O_2 (%) concentration in straw at 35, 49, 75 DAS and harvesting time in 2007 dry season

Treatment	**Time**			
	35 DAS	**49 DAS**	**75 DAS**	**Harvesting**
T1	71.07	65.67	No – data	88.15
T2	73.06	65.67	85.59 a	95.86
T3	73.63	67.41	83.94 a	85.02
T4	73.25	67.99	83.26 a	92.23
T5	71.26	68.39	80.21 a	85.16
T6	74.04	39.80	77.70 ab	95.76
T7	65.42	57.94	70.24 b	83.99
F	ns	ns	*	Ns
CV (%)	8.6	10.4	6.1	20.1

Table 9. Available Si in soil collected (mg Si/kg air dry soil) at after harvest time of dry season 2013

Treatment	**Si in soil collected (mg Si/kg air dry soil)**	
	0-10 cm	**10- 20 cm**
T1. Control	24.20 b	24.03
T2. RSM (6 t/ha)	36.27 a	25.33
T3. RSM + 20% NPK		
T3 ✓: 40% NPK	27.40 b	26.00
T4. RSM + 40% NPK	38.73 a	26.00
T5. RSM+ 60% NPK	36.67 a	25.87
T6. RSM+80% NPK		
T6 ✓: 60% NPK	30.03 b	27.07
T7. NPK (100:30:30)	27.27 b	25.80
F	**	ns
CV (%)	10.80	12.20

***Means in a column followed by the same letter are significantly different at $p < 0.01$*
ns; Means in a column followed by the same letter are not significantly different

While, there was not significant difference among treatments in the available Si at 10-20 cm depth of soil. It is reported that the rice plant is more susceptible to fungal attack and also to insect when N concentration was high and Si was low (Tisdale *et al.* 1985). We may decrease the risk of several diseases and insects (Table 5, Table 6) by decreasing chemical fertilizer input with RSM application.

Microbial communities under rice soil conditions: Sound and diverse microbial communities in soil are essential factors for sustainable agriculture. Soil organisms are some of the most sensitive sensors to detect degradation or contamination of arable soil. Populations or activities of soil microorganisms such as facilitate soil respiration and enzyme activities. The continuous application of organic matter will energize the living soil micro-organisms, involved in biochemical activity of importance to soil fertility and plant nutrition (Gaur *et al.*, 1990). In this long-term experiment we have estimated the microbial population, as well as total protein content in soil at harvest time. (Table 10, Table 11, Table 12 and Table 13).

The average of microbial population (2000-2009 W.S and D.S) in soil where RSM was applied was higher than that in soil without RSM application. Same tendency was found in soil protein content.

However the average of soil microbial population (2010-2014 W.S and D.S) in soil showed that treatment T3 ✓ and T6 ✓have trend to increase. The microbial population may be due to plots under treatment T3 and T6 was effected by RSM application in long past times (2000-2009).

Table 10. Effect of RSM chemical fertilizer on microbial population of soil in $\log_{10}$ of **C.F.U / g dry soil (Wet season)**

Treatment	Wet seasons					
	2000-2009	**2010**	**2011**	**2012**	**2013**	**Average 2010-2013**
T1. Control	7.38	7.72	8.90	8.17	7.48	8.07
T2. RSM (6 t/ha)	7.77	8.98	9.12	8.94	8.43	8.87
T3. RSM + 20% NPK	7.64					
T3 ✓: 40% NPK		8.17	9.29	9.14	8.32	8.73
T4. RSM + 40% NPK	7.47	7.70	9.44	9.19	8.48	8.70
T5. RSM+ 60% NPK	7.84	7.99	9.42	9.14	8.48	8.76
T6. RSM+80% NPK	7.69					
T6 ✓: 60% NPK		8.60	9.20	9.03	7.96	8.70
T7. NPK (80:30:30) W.S	7.46	8.71	9.27	8.76	7.79	8.63
Mean	7.61	8.27	9.23	8.91	8.13	8.64
Sd (±)	0.17	0.50	0.19	0.36	0.40	0.26

C.F.U/ g dry soil: cell forming unit / gram of dry soil.

Table 11. Effect of RSM chemical fertilizer on microbial population of soil in $\log_{10}$ of **C.F.U / g dry soil (Dry season)**

Treatment	**Dry seasons**					
	2001-2009	***2011***	***2012***	***2013***	***2014***	***Average 2011-2014***
T1. Control	7.19	7.91	7.95	7.78	7.48	7.78
T2. RSM (6 t/ha)	7.52	8.32	8.43	8.43	8.48	8.41
T3. RSM + 20% NPK	7.60					
T3 ✓: 40% NPK	-	8.38	8.56	8.26	8.43	8.41
T4. RSM + 40% NPK	7.67	8.31	8.71	8.56	8.65	8.56
T5. RSM+ 60% NPK	7.54	8.21	8.56	8.48	8.59	8.46
T6. RSM+80% NPK	7.64					
T6 ✓: 60% NPK		8.32	8.38	8.32	8.38	8.35
T7. NPK (100:30:30) D.S	7.42	8.08	8.18	8.38	7.96	8.15
Mean	7.51	8.22	8.40	8.32	8.28	8.30
Sd (±)	0.16	0.17	0.26	0.26	0.42	0.26

C.F.U/g dry soil : cell forming unit / gram of dry soil.

Table 12: Effect of RSM chemical fertilizer on total protein* of soil (Wet season)

Treatment	Wet seasons					
	2000-2009	2010	2011	2012	2013	Average 2010-2013
T1. Control	81.0	80.20	78.02	76.14	73.61	76.0
T2. RSM (6 t/ha)	100.2	103.41	85.66	87.03	86.30	90.6
T3. RSM + 20% NPK	99.0					
T3 ✓: 40% NPK		102.11	74.41	80.11	79.19	84.0
T4. RSM + 40% NPK	103.8	129.98	103.87	104.83	104.64	110.8
T5. RSM+ 60% NPK	108.2	165.72	125.85	104.55	104.36	125.1
T6. RSM+80% NPK	103.9					
T6 ✓: 60% NPK		143.27	106.14	95.71	83.26	107.1
T7. NPK (80:30:30) W.S	94.00	115.15	91.78	78.28	77.99	90.8
Mean	98.60	119.98	95.10	89.52	87.05	97.91
Sd (±)	8.95	28.67	18.09	12.24	12.57	16.97

** Total protein content = mg/ kg dried soil*

Table 13: Effect of RSM chemical fertilizer on total Protein* of soil (Dry season)

Treatment	Dry seasons					
	2001-2009	***2011***	***2012***	***2013***	***2014***	***Average 2011-2014***
T1. Control	92.47	97.94	76.96	74.27	70.15	79.83
T2. RSM (6 t/ha)	109.88	101.08	101.66	95.95	104.26	100.74
T3. RSM + 20% NPK	110.44					
T3 ✓: 40% NPK		114.79	91.47	83.73	81.75	92.93
T4. RSM + 40% NPK	116.15	145.79	121.09	104.47	101.74	118.27
T5. RSM+ 60% NPK	112.09	141.65	117.15	114.62	116.01	122.36
T6. RSM+80% NPK	118.31					
T6 ✓: 60% NPK		115.93	95.90	92.36	92.83	99.25
T7. NPK (100:30:30) D.S	92.93	129.06	94.67	93.68	94.45	102.97
Mean	109.9	120.89	99.84	94.15	94.46	102.34
Sd (±)	10.53	18.70	15.22	13.14	15.10	14.50

**Total protein content = mg/ kg dried soil*

CONCLUSIONS

The results of this twenty seven seasons experiment leads to the following conclusions

1. The chemical fertilizer input can be decreased to 40 to 60% of the present recommended application rate by using RSM without decreasing rice yield. or we may expect higher yield with that treatment in Wet season and Dry season.
2. Application of RSM with reduced chemical fertilizer decreased the risk of several diseases such as leaf blast disease, neck blast disease, grain discoloration and insects as brown plant hopper, leaf folder.
3. The continuous application of RSM maintained available Si in soil.
4. Microbial population and protein content in soil where RSM was applied was higher than that in soil without RSM application.

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Cải thiện độ phì đất canh tác bằng hữu cơ có nguồn gốc từ rơm rạ

Thí nghiệm dài hạn "Cải thiện độ phì đất canh tác bằng hữu cơ rơm rạ" nhằm tận dụng nguồn rơm rạ sau thu hoạch được xử lý bằng chế phẩm sinh học (nấm *Trichoderma* sp) để tạo thành nguồn phân hữu cơ. Qua 27 vụ lúa liên tục (14 vụ Hè Thu và 13 vụ Đông Xuân), kết quả ghi nhận được như sau:

Bón hoàn toàn phân hữu cơ rơm rạ (6 tấn / ha) gia tăng năng suất lúa so với đối chứng không bón phân 38,46 % trong vụ Hè Thu (**HT**) và 13,56% trong vụ Đông Xuân (**ĐX**). Trong khi đó, bón hoàn toàn phân hóa học (NPK) cho năng suất cao hơn đối chứng 45,77% trong vụ **HT** và 22,41% trong vụ **ĐX**. Năng suất lúa ở những nghiệm thức bón phân hữu cơ rơm rạ kết hợp với các mức phân hóa học (NPK) cho năng suất cao hơn đối chứng từ 48,08 % đến 81,15% trong vụ **HT** và từ 23,35% đến 40,30% trong vụ **ĐX**. Kết quả còn chỉ ra rằng khi áp dụng phân hữu cơ dài hạn chúng ta có thể giảm lượng phân hóa học theo mức khuyến cáo từ 40% đến 60% mà không làm giảm năng suất so với lượng phân hóa học theo mức khuyến cáo. Việc bón phân hữu cơ rơm rạ liên tục còn duy trì hàm lượng Silic trong đất. Kết quả cũng cho thấy ở nghiệm thức bón hoàn toàn phân hữu cơ rơm rạ hoặc bón kết hợp phân hóa học từ 40% NPK đến 60% NPK có mật số vi sinh vật và tổng số protein trong đất cao hơn so với những nghiệm thức chỉ bón hoàn toàn phân hóa ở các mức khác nhau.