

IMPROVEMENT OF SOIL FERTILITY BY RICE STRAW MANURE

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ABSTRACT

A long-term experiment has been conducted on the effects of rice straw manure (RSM) on rice production and soil fertility. So far, rice was cultivated eleven times (6 wet seasons (WS) and 5 dry seasons (DS) with chemical fertilizer and RSM applications designed for each 7 treatment. Compared with control treatment (no chemical fertilizer, no RSM), solo application of the RSM (6 t. ha⁻¹) increased average rice yield 19.26 % and 5.18 % in wet season (WS) and in dry season (DS), respectively. While, solo application of chemical fertilizer (NPK) increased the yield over the control 56.68 % in WS and 23.97 % in DS. Rice yields of treatments in which different doses of chemical fertilizer combined with RSM (6t. ha⁻¹) was applied were 47.14 to 67.61 % and 26.65 to 33.93 % more than the control in WS and DS, respectively. The result showed that we can decrease chemical fertilizer input 20 to 60 % from the present recommended application rate by using RSM without decreasing rice yield in wet season. While, chemical fertilizer input 40 % from the present recommended application rate by using RSM gave higher yield than treatment in which 100% chemical fertilizer application in dry season. Rice with high application of chemical fertilizer was more severely damaged by leaf blast disease, neck blast disease and grain discoloration than other treatments at the time of outbreak. The microbial population and their activity in the soil indicated that the solo application of chemical fertilizer and the control treatment had lower microbial population as compared with the treatment where RSM was applied solely or in combination with chemical fertilizer. There were positive correlations between the population of soil microorganisms and ETS activities, and, between the population of soil microorganisms and total protein in soil.

Keywords: Long-term field experiment, rice straw manure, soil fertility, soil microorganisms

INTRODUCTION

Rice is the most important crop in Mekong Delta. With the introduction of high yield rice varieties and adoption of intensive rice cultivation, large quantity of rice straw is available on farms. However, most of rice straw was burnt or removed after harvesting. 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 produce phyto-toxic substances during their decomposition (Martin *et al.* 1978; Elliott *et al.* 1981). 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) onto rice field.

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 effects to microbial communities in paddy soil.

MATERIALS AND METHODS

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

The experiment started in 2000's wet season at the experimental field in CLRRI (Omon, Cantho city). From 2000 wet season to 2005 dry season, germinated seeds (IR64: 100-day growth duration) were broadcasted on the field (30 m² for each plot) at 200 kg ha⁻¹ seedling rate; from 2006 dry season germinated seed (OM 2517: 90-day growth duration) was seeded by row- seeder with 100 kg ha⁻¹ seedling rate. Seven treatments were prepared and the experimental field was set up with randomized block design with three replications:

T1: control (0 N - 0 P₂O₅ - 0 K₂O)

T2: 100% RSM (6 t.ha⁻¹)

T3: 100% RSM (6 t.ha⁻¹) + 20% NPK (16N- 6P₂O₅ -6K₂O kg ha⁻¹)

T4: 100% RSM (6 t.ha⁻¹) + 40% NPK (32N- 12P₂O₅ -12 K₂O kg ha⁻¹)

T5: 100% RSM (6 t.ha⁻¹) + 60% NPK (48N- 18P₂O₅ -18 K₂O kg ha⁻¹)

T6: 100% RSM (6 t.ha⁻¹) + 80% NPK (64N- 24P₂O₅ -24 K₂O kg ha⁻¹)

T7: 100% inorganic fertilizer (wet season: 80N-30P₂O₅ -30 K₂O kg ha⁻¹ and dry season: 100N- 30P₂O₅ -30 K₂O kg ha⁻¹)

RSM and phosphorus fertilizer was applied at the time of land preparation before broadcasting rice seeds. Nitrogen fertilizer was applied in three splits: each one third was applied at 10, 20 and 30 days after sowing (DAS). Potassium fertilizer was

applied in two splits: each half was applied at 10 and 30 DAS. Recommended fertilization rate in dry season is (100N- 30P₂O₅ -30 K₂O kg ha⁻¹) in the region.

Total-C, N and P concentrations measure in the experimental field surface soil taken after harvest of 1st crop were 35.1 g C kg⁻¹, 3.3 g N kg⁻¹ and 240 mg P kg⁻¹ (in dry soil).

Soils microbial populations were estimated before sowing and at harvesting time. Total protein content in soil (mg kg⁻¹ dry soil) (Herbert *et al.* 1971) and electron transport system (ETS) activities (n mol INTF g⁻¹ dry soil) or dehydrogenises (Chendrayan *et al.* 1980) were estimated at harvesting time. Soil was sampled at 10 days before harvesting to analyze chemical property of the soil.

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

Moisture content and Total-C, N, P and K concentrations of RSM applied into the field were shown in table 1.

Table 1. Moisture and C, N, P, K concentration of RSM.

Season	Moisture (%)*	N (%)	C(%)	P(%)	K(%)
2003 WS	367	1.72	30.40	0.23	No-data
2004 WS	483	2.30	30.74	0.26	1.49
2005 DS	no-data	2.13	33.72	0.22	0.53

* Water/ dry mater (w/w)

According to the data, 22.1 to 25.6 kg N ha⁻¹, 6.1 to 6.7 kg P₂O₅ ha⁻¹ and 7.7 to 18.5 kg K₂O ha⁻¹ was applied into the field accompanied with RSM (6 Mg ha⁻¹).

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

SPAD value in wet season (Table 2) and in dry season (Table 3) shows that the more chemical 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. However, there was not significant difference among treatments T5, T6 and T7 in wet season and non significance

between T6 and T7 was also recorded in dry season. 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 dry season and 29 to 32 in wet season (Huan *et al.*, 1998, 2000). It seemed that SPAD value at T3, T4 agreed with the optimum range in wet season, with exception of treatment T1 gave highest SPAD value in 2007 wet season, this phenomenon may due to phosphorous deficiency. SPAD value at T4, T5 and T6 agreed with the optimum range in dry season. There were positive correlation between SPAD value and grain yield (Fig. 1) in wet season and dry season, respectively.

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

Treatment	Wet Season					Average
	2000	2001	2002	2003	2007	
T1	27.0	27.2	27.7	28.1	37.7	29.55 e
T2	27.4	27.5	27.9	28.5	32.9	28.84 e
T3	28.6	28.5	30.0	30.6	36.7	30.88 cd
T4	30.9	30.2	32.0	32.8	34.5	32.08 bc
T5	30.8	32.2	32.6	33.6	36.6	33.17 ab
T6	31.7	32.9	33.1	34.6	35.8	33.64 ab
T7	35.2	33.1	33.8	34.9	37.1	34.81 a
CV (%)	4.73	2.8	2.8	3.2	4.3	4.30
LSD (5%)	2.53	1.51	1.55	1.84	0.87	-

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

Table 3: Effect of RSM and chemical fertilizer on SPAD value at 50 days after sowing of Dry Season

Treatment	Dry season				Average
	2001	2002	2003	2007	
T1	27.8	25.9	26.7	26.2	26.65 f
T2	28.2	26.5	29.6	28.8	28.27 e
T3	31.2	29.8	31.4	31.3	30.94 d
T4	35.1	31.2	31.7	34.6	33.40 d
T5	36.4	33.4	34.7	36.0	35.14 b
T6	36.4	33.6	35.2	38.2	35.85 ab
T7	38.3	34.4	36.1	40.2	37.26 a
CV (%)	3.3	3.0	2.5	3.6	3.3
LSD (5%)	1.94	1.63	1.45	2.14	

- Means in a column followed by the same letter are not significantly different at $p < 0.01$, based on LSD test

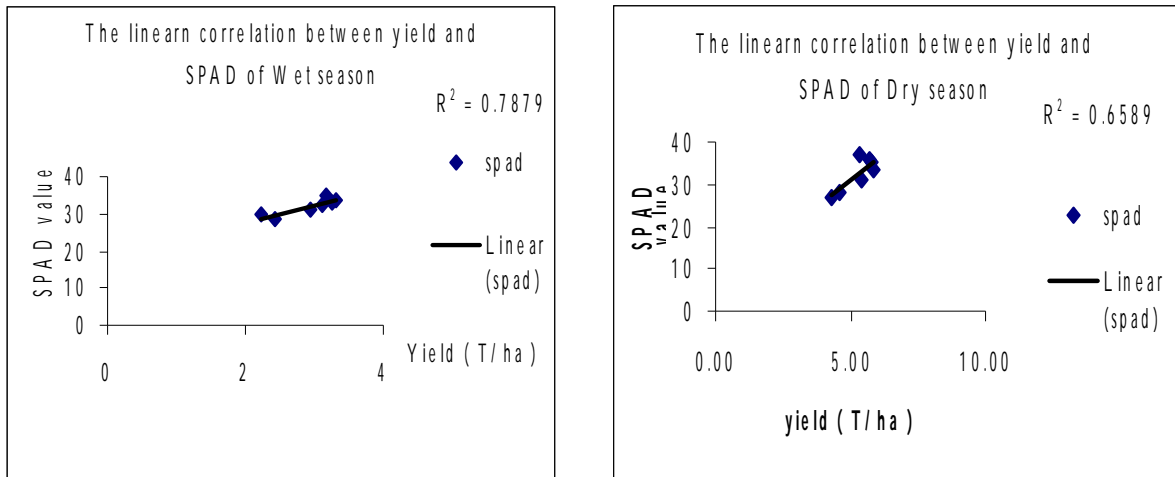


Figure 1. The correlation between SPAD index and grain yield

Note: The grain yield average of 5 WS (2000-2007) and 4 DS (2001 – 2007)

There was not significant difference in average rice yield among treatment T4, T5, T6 and T7 in wet season (Table 4). However, treatment T4 gave higher grain yield as compared with treatment T7 in dry season (Table 5). Compared with T1, grain yield in T2 was 19.26 % and 5.18 % higher in wet season and dry season, respectively. While, solo application of chemical fertilizer (T7) increased the yield over the T1 56.68 % in wet season and 23.97 % 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 47.14 to 63.56 % and 26.68 to 30.17 % higher than T1 in wet season and in dry season, respectively.

In 2003 dry season, grain yields were lower than other dry seasons because of 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 T6 and especially T7 was more severely damaged by the disease (Table 6).

In 2005 dry season, grain discoloration at T6 and T7 was more severe than other treatments (Table

6). 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 lower than other treatments although the difference was not significant (Table 7 and 8). As rice straw content much silica, replicated removal of rice straw at T1 and T7 might lead decrease of available Si in soil. It is reported that rice plant is more susceptible to fungal attack when N concentration was high and Si was low (Tisdale *et al.* 1985). We may decrease the risk of several diseases by decreasing chemical fertilizer input with RSM application.

These results shows that we can decrease chemical fertilizer input 20 to 60 % from the present recommended application rate by using RSM without decreasing rice yield in wet season. While, chemical fertilizer input 40 % from the present recommended application rate by using RSM obtained higher yield than treatment in which 100% chemical fertilizer application.

Table 4: Effect of RSM and chemical fertilizer on rice yield of IR64 (2001-2005 WS) and OM2517 (2006-2007 WS).

Treatment	Wet Season									Grain yield over control (%)
	2000	2001	2002	2003	2004	2005	2006	2007	Average	
T1	2.19	2.67	2.98	1.81	3.04	1.59	1.56	1.45	2.16 d	-
T2	2.23	2.90	3.20	1.83	3.69	2.36	2.47	1.94	2.58 c	19.26
T3	2.51	3.24	3.22	3.40	4.17	3.05	3.56	2.29	3.18c b	47.14
T4	2.66	3.53	3.26	3.63	4.46	3.51	3.74	2.49	3.41 ab	57.78
T5	2.71	3.62	3.33	3.47	4.66	3.63	4.37	3.18	3.62 a	67.61
T6	2.90	3.70	3.42	3.47	4.27	3.56	3.81	3.15	3.54 a	63.56
T7	3.07	3.60	3.37	3.15	4.04	3.36	3.83	2.67	3.39 ab	56.68
CV	8.20	4.00	3.30	13.10	5.95	12.64	13.48	11.0	10.4	
LSD 5%	0.37	0.24	0.19	0.68	0.42	0.68	0.80	0.48		

Means in a column followed by the same letter are not significantly different at $p < 0.01$, based on LSD test.

Table5: Effect of RSM and chemical fertilizer on rice yield of IR64 (2001-2005 DS) and OM2517 (2006-2007 DS)

Treatment	Dry season							Grain yield over control (%)
	2001	2002	2003	2005	2006	2007	Average	
T1	4.32	4.78	3.49	3.84	4.86	4.56	4.30 a	-
T2	4.62	5.13	3.84	4.01	4.88	4.73	4.53 a	5.18
T3	5.50	6.05	4.36	5.12	6.05	5.66	5.46 bc	26.65
T4	5.84	6.46	4.89	5.24	6.03	6.16	5.77 d	33.93
T5	5.94	6.76	4.49	5.39	6.12	5.79	5.75 cd	33.42
T6	5.92	6.55	4.30	4.90	5.86	6.11	5.60 bcd	30.17
T7	5.89	6.65	3.55	4.89	5.86	5.16	5.30 c	23.97
CV	5.50	5.10	9.00	7.90	6.99	10.4	5.0	
LSD 5%	0.52	0.55	0.65	0.67	0.71	1.01	-	

Means in a column followed by the same letter are not significantly different at $p < 0.01$, based on LSD test

Table 6. Rice Blast disease of 2003 dry season and grain discoloration of 2005 dry season

Treatment	Leaf blast disease (%) *	Neck blast disease (%)**	Grain discoloration (%)
T1	1.48	1.38	34.60
T2	2.94	0.90	35.70
T3	12.54	1.42	40.03
T4	14.87	1.54	46.10
T5	30.70	2.66	44.97
T6	38.27	3.60	59.02
T7	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.

Table 7. N and SiO₂ concentration in straw and grain in 2005 dry season

Treatment	N (%)		SiO ₂ (%)	
	Straw*	Grain*	Straw**	Grain *
T1	0.57a	1.16a	8.97	4.27a
T2	0.58a	1.14a	9.54	4.39a
T3	0.59a	1.18a	9.17	3.59b
T4	0.67a	1.23a	9.19	3.50b
T5	0.69a	1.29ab	9.64	3.51b
T6	0.94b	1.40 bc	9.47	3.40b
T7	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

Table 8: Si O₂ (%) 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

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 sensor to detect degradation or contamination of arable soil. Populations or activities of soil microorganisms such as soil respiration and enzyme activities (ETS activities, Alkaline Phosphatase, Sulphatase, Asparaginase and so on) are indicators to monitor environmental stresses and declining of biological diversity (OTA 1987; Parkinson and Coleman 1991).

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, total protein content and electron transport system (ETS) activities or dehydrogenase in soil. Microbial population in wet season was higher than that in dry season in general (Tables 8 and 9). Microbial population in soil where RSM was applied was higher than that in soil without RSM application. Same tendency was found in ETS activities and soil protein content (Tables 10, 11, 12 and 13).

There were positive correlation between soil micro-organisms and ETS activities $R^2 = 0.8575$ and $R^2 = 0.7029$ in WS and DS, respectively (Figure 2). There were also positive correlation between soil micro-organisms and total protein content in soil $R^2 = 0.9067$ and $R^2 = 0.7005$ in WS and DS, respectively.

Table 9: Effect of RSM chemical fertilizer on microbial population of soil in \log_{10} of C.F.U / g dry soil (Wet Season)

Treatment	Wet Season								
	2000	2001	2002	2003	2004	2005	2006	2007	Average
T1	7.84	7.73	7.04	5.79	7.70	6.14	7.55	7.49	7.16
T2	8.71	8.14	7.08	5.94	7.87	6.32	7.72	8.26	7.51
T3	8.77	7.92	7.04	6.20	7.94	6.38	7.44	7.78	7.43
T4	8.73	8.22	7.28	6.03	7.85	6.25	7.82	8.48	7.58
T5	8.74	8.30	7.23	6.06	8.14	6.27	7.50	8.38	7.58
T6	8.57	7.98	7.23	6.26	7.97	6.26	7.65	7.76	7.46
T7	7.93	7.70	7.00	5.93	7.83	6.24	7.34	7.96	7.24
TB	8.47	8.00	7.13	6.03	7.90	6.27	7.57	8.02	7.42
Sd	0.34	0.22	0.11	0.16	0.12	0.06	0.17	0.37	0.16

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

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

Treatment	Dry Season							Average
	2001	2002	2003	2005	2006	2007		
T1	6.48	7.20	6.43	7.19	6.70	7.43	6.91	
T2	6.90	7.32	6.82	7.28	7.23	7.78	7.22	
T3	6.78	7.76	6.78	7.24	7.18	7.96	7.28	
T4	6.70	7.51	7.14	7.40	7.04	8.94	7.46	
T5	6.95	7.08	6.78	7.41	7.15	8.08	7.24	
T6	7.04	7.66	7.11	7.32	7.08	7.96	7.36	
T7	6.78	7.04	6.76	7.26	7.00	7.48	7.05	
TB	6.8	7.38	6.83	7.30	7.05	7.95	7.22	
Sd	0.18	0.28	0.24	0.08	0.17	0.5	0.19	

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

Table 11: Effect of RSM chemical fertilizer on ETS activities* of soil (Wet Season)

Treatment	Wet Season								
	2000	2001	2002	2003	2004	2005	2006	2007	Average
T1	33.3	59.4	47.8	61.7	59.6	57.1	52.9	24.8	49.58
T2	53.2	60.4	51.9	84.7	76.1	83.0	58.6	34.8	62.83
T3	33.2	87.1	53.8	85.0	77.1	79.6	66.8	27.8	63.80
T4	33.1	61.5	60.9	98.2	84.3	76.5	67.2	22.6	63.04
T5	46.8	98.2	48.9	100.1	87.8	64.9	77.8	24.7	68.65
T6	33.4	86.9	74.6	102.4	62.6	61.2	74.6	31.3	65.87
T7	33.1	58.4	46.6	83.8	61.7	60.4	58.4	21.8	53.03
TB	38.01	73.13	54.93	87.99	72.74	68.96	65.2	26.1	61.0
Sd	8.8	16.9	9.8	14.0	10.6	10.4	9.07	4.8	7.0

*ETS activities = nmol INTF per min –g dry weight of soil
INTF: iodonitrophenyl formazan

Table12: Effect of RSM chemical fertilizer on ETS activities* of soil (Dry season)

Treatment	Dry Season						
	2001	2002	2003	2005	2006	2007	Average
T1	67.0	75.6	52.5	75.5	69.5	84.8	72.98
T2	79.0	94.7	67.6	93.8	90.1	97.8	85.00
T3	75.0	105.4	75.9	111.3	106.5	106.1	96.70
T4	80.6	126.9	97.7	79.8	70.8	112.2	94.67
T5	87.8	87.2	73.0	78.6	79.0	118.0	87.27
T6	70.4	104.6	79.7	87.3	71.5	88.9	83.73
T7	61.5	73.4	62.7	73.2	66.8	81.4	69.83
TB	74.4	95.4	72.7	85.7	79.2	98.5	84.3
Sd	8.9	18.8	14.2	13.3	14.4	14.2	10.1

* ETS activities = nmol INTF per min –g dry weight of soil
INTF: iodonitrophenyl formazan

Table 13: Effect of RSM chemical fertilizer on total Protein* of soil (Wet Season)

Treatment	Wet Season								
	2000	2001	2002	2003	2004	2005	2006	2007	Average
T1	76.6	100.6	88.7	83.9	80.9	79.90	71.5	54.4	79.6
T2	93.3	132.2	119.3	98.2	96.1	91.5	94.8	59.5	98.1
T3	78.7	141.5	122.5	102.8	98.4	90.4	97.0	62.7	99.3
T4	90.5	149.1	115.0	114.6	87.9	120.6	84.6	54.7	102.1
T5	86.0	195.1	116.3	105.2	86.3	98.34	105.4	70.6	107.9
T6	79.7	139.3	132.7	124.8	86.2	90.11	94.3	55.2	100.3
T7	73.2	124.9	104.1	96.8	84.5	88.85	93.3	49.6	89.4
TB	82.6	140.3	114.0	103.7	88.6	94.2	91.6	58.1	96.7
Sd	7.5	28.7	14.1	13.1	5.8	12.8	10.8	11.8	9.3

* Total protein content = mg/ kg dried soil

Table 14: Effect of RSM chemical fertilizer on total Protein* of soil (Dry Season)

Treatment	Dry Season						
	2001	2002	2003	2005	2006	2007	Average
T1	118.6	104.5	77.3	85.9	78.9	93.6	93.13
T2	130.5	114.2	87.3	124.8	118.7	99.4	112.48
T3	115.1	111.9	94.1	94.9	90.7	142.4	108.18
T4	129.9	121.6	90.1	118.2	106.4	106.8	112.17
T5	137.6	113.3	89.6	125.2	113.1	103.9	113.78
T6	129.8	146.1	112.1	129.5	104.4	99.7	120.27
T7	95.5	108.7	86.5	73.9	78.9	95.6	89.85
TB	122.4	117.1	91.0	107.5	98.7	105.9	107.1
Sd	14.0	13.7	10.6	22.2	16.1	16.7	11.3

Total protein content = mg/ kg dried soil

CONCLUSIONS

The results of eleven seasons experiment leads following conclusions

1. In wet season, chemical fertilizer input can be decreased 20 to 80 % from the present recommended application rate by using RSM without decreasing rice yield or we may expect higher yield with that treatment.
2. In dry season, chemical fertilizer input can be decreased 60 % from the present recommended application rate by using RSM gave higher yield than treatment in which 100% chemical fertilizer application.
3. Rice grown in field where chemical fertilizer was applied at recommended level was damaged by leaf blast disease, neck blast disease and grain discoloration more severely than rice grown where less chemical fertilizer was applied.
4. Replicated removal of rice straw may cause the decrease of available silica in soil.
5. There was positive correlation between SPAD value and grain yield.
6. Microbial population in soil where RSM was applied was higher than that in soil without RSM application.
7. There were positive correlations between soil micro organisms and ETS activities, and between soil microorganisms and total protein content in soil.

REFERENCES

- Boy SA and MM Mortland. 1990. Enzyme interaction with clays and clay organic matter complexes. In: J. M. Bollag & G. Stotzky (eds.) *Soil Biochem.* 6, 1-28.
- Burn RG. 1982. Enzyme activity in soil: Location and possible role in microbial activities. *Soil Biochem.* 14, 423-427.
- Chendrayan K, TK Adhyya and N Sethunathan. 1980. Dehydrogenase and invertase activities of flooded soils. *Soil Biol. Biochem.* 12: 271-273.
- Elliot L, VL Cochran and RI Papendick. 1981. Wheat residues and nitrogen placement effects on wheat growth in green house. *Soil. Sci.* 131: 48-52.
- Gaur AC, S Neelakantan and KS Dargan. 1990. *Organic manures.* I.C.A.R. Newdlhi. India.
- Herbert D, PJ Phipps and RE Strange. 1971. III. Chemical analysis of microbial cells. In Norris/Ribbon (eds.). *Methods Microbiol.* 5B: 249-252.
- Huan TTN, TQ Khuong, Tadao Kon and PS Tan. 1998. *OMON RICE.* (6): 53-58.
- Huan TTN, PS Tan and Hiroyuki Hiraoka. 2000. Optimum fertilizer nitrogen rate for high yielding rice based on growth diagnosis in wet seeded culture of rice.
- JIRCAS. 2000. Proceedings of the 2000 annual workshop of JIRCAS Mekong Delta project; Nov 14-17, 2000. 60-67.
- IRRI. 1991. International Rice Research Institute (IRRI). *IRRISTAT User's manual.* Version 91.1. IRRI, 1991. 367 p.
- Martin JP, RL Branson and WM Jarrell. 1978. Decomposition of organic material used in planting mixes and some effects on soil properties and plant growth. *Agrochimica.* 22: 248-261.
- Office of Technology Assessment of U.S. Congress (OTA). 1987. *Technologies to maintain biological diversity.* OTA-F330. Washington D.C..U. S Government printing office: 331p.
- Padalia CR. 1975. Effect of N, P & K fertilizer with and without farmyard manure on high yielding variety of rice. *Oryza* 12(10): 53-58.
- Parkinson D and DC Coleman. 1991. Microbial communities. activity nad biomass. *Agric. Ecosyst. Environ.* 34: 3-33.
- Samuel L Tisdale; Werner L. Nelson; James D. Beaton. 1985. *Soil fertility and fertilizers. "Micronutrients and other beneficial elements in soils and fertilizers"*. Macmillan Pub.Co. New york. 398 p.

- Subba Rao NS. 1977. Soil microorganisms and plant growth. Oxford & IBH publishing Co.PVT.LTD. pp. 192 - 207.
- Tan PS. 1992. Organic manure for high yielding rice. OMONRICE (2): 64-68.

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

Rơm rạ sau thu hoạch được xử lý bằng chế phẩm sinh học (nấm *Trichoderma sp*) để tạo thành nguồn phân hữu cơ, và thông qua thí nghiệm dài hạn nhằm “cải thiện độ phì của đất từ nguồn phân hữu cơ rơm rạ”. Qua 14 vụ lúa liên tục (8 vụ Hè Thu và 6 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 19,26 % trong vụ Hè Thu (**HT**) và 5,18% trong vụ Đông Xuân (**ĐX**). Trong khi đó, bón hoàn toàn phân hóa học (NPK) cho năng suất cao hơn đối chứng 56,68% trong vụ **HT** và 23,97 % trong vụ **ĐX**. Những thí nghiệm thực nơi mà phân hữu cơ rơm rạ được bón kết hợp với các mức phân hóa học (NPK) cho năng suất cao hơn đối chứng từ 47,14 % đến 67,61% trong vụ **HT** và từ 26,65% đến 33,93% 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 20% đến 60 % mà không làm giảm năng suất so với lượng phân hóa học theo mức khuyến cáo. Trong khi đó, bón lót phân hữu cơ và bón kết hợp với 40% phân hoá học cho năng suất cao hơn bón hoàn toàn phân hóa học (100% NPK) trong vụ Đông Xuân. Những thí nghiệm bón phân hóa học cao như thí nghiệm T6 (Rơm hữu cơ + 80% NPK) và T7 (100% NPK) biểu hiện phần trăm bệnh cháy lá, bệnh thối cổ gié và lem lép hạt cao hơn so với các thí nghiệm khác. Kết quả cũng cho thấy ở thí nghiệm đối chứng và thí nghiệm bón hoàn toàn phân hóa học có mật số vi sinh vật, tổng số protein, và chỉ số ETS hoạt động trong đất thấp hơn so với thí nghiệm bón hoàn toàn phân rơm rạ hữu cơ hay so với các thí nghiệm áp dụng phân rơm rạ hữu cơ được bón kết hợp với các mức phân hóa học khác nhau. Kết quả này cũng ghi nhận được sự tương quan giữa mật số vi sinh vật với chỉ số ETS hoạt động và sự tương quan giữa mật số vi sinh vật với tổng số protein trong đất.