Omonrice 10: 79-86 (2002)

Improvement of soil fertility by rice straw manure

Luu Hong Man[1], Vu Tien Khang
Takeshi Watanabe[2]

ABSTRACT

*Rice straw manure (**RSM**) was produced by treating with fungal inoculant (Trichoderma sp) through a long-term experiment on "Improvement of soil fertility by rice straw manure". The results of five continuous seasons showed that a complete application of **RSM** increased yield over control 5.91 % in wet season (**WS**) and 6.86% in dry season (**DS**). While, complete application of chemical fertilizer (**NPK**) increased yield over control 29.31% in WS and 37.73% in DS. Treatments in which **RSM** combined with different doses of chemical fertilizer yielded over control from 14.67 – 28.71 % in WS and from 26.94 -37.02% in DS. The microbial population and their function in soil indicated that a complete application of chemical fertilizer and control treatment had lower microbial population in soil as compared to complete application of **RSM** or in combination with different doses of chemical fertilizer. A possitive correlation between soil microorganisms and ETS activities and between soil microorganisms and total protein content in soil were also recorded.*

Key words: RSM, NPK fertilizer, soil improverment, soil microorganisms

INTRODUCTION

Rice is the most important crop in Mekong Delta. With the introduction of high yielding rice varieties and adoption of intensive rice cultivation, large quantities of rice residues as straw, rice stubles are available on farms. However, most of rice straw was burnt or removed after harvesting. These rice straw can not be applied or plouged directly into the soil because of their wide C:N ratio. They are 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 alleviate such problems, the rice straw materials, under intensive decomposition in heaps or pits with adequate moisture and suitable microbial inoculants could be used as organic manure (Gaur et al. 1990) in rice field.

During the 2000's wet season ,2000-2001's dry season, 2000's wet season; the Cuu Long Delta Rice Research Institute (CLRRI) has collaborated to Japan International Research Center for Agricultural Sciences (JIRCAS) to start a long-term experiment in which rice straw was decomposed by suitable fungal inoculant 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 and inorganic fertilizer alone or in combination on rice yield and (2) their effects to microbial communities in rice soil condition.

MATERIALS AND METHODS

Fungal inoculant (*Trichoderma* sp.) in powder formula was produced by CLRRI's Microbiology Department was applied to treat into rice straw heap with adequte moisture suppling for decomposition. It took 30-45 days after inoculation, decomposed rice straw was used as organic manure.

The experiment stated in 2000's wet season. Germinated seeds of rice varietie

[1] Cuu Long Delta Rice Research Institute, Omon, Vietnam
[2] Japan International Research Center for Agricultural Sciences, JIRCAS, Japan

"IR64" (110-day growth duration) was broadcasted in the plot (30 m^2) with 200kg/ha seed rate. The experiment including seven treatments was conducted in randomized complete block design with three replications:

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

T2: 100% rice straw manure (6 t/ha)

T3: 100% rice straw manure (6 t/ha) + 20% NPK (16N- 6P_2O_5 -6K_2O kg/ha)

T4: 100% rice straw manure (6 t/ha) + 40% NPK (32N- 12P_2O_5 -12 K_2O kg/ha)

T5: 100% rice straw manure (6 t/ha) + 60% NPK (48N- 18P_2O_5 -18 K_2O kg/ha)

T6: 100% rice straw manure (6 t/ha) + 80% NPK (64N- 24P_2O_5 -24 K_2O kg/ha)

T7: 100% inorganic fertilizer (wet season: 80N- 30P_2O_5 -30 K_2O kg/ha and dry season: 100N- 30P_2O_5 -30 K_2O kg/ha)

Rice straw manure (6t/ha) was basal application. Total phosphorus fertilizer (P_2O_5) was basal application. Nitrogen (N) was applied in three splits: 1/3 was applied at 10 days after sowing (DAS), then 1/3 at 20 DAS and 1/3 at 30 DAS. Potassium fertilizer (K_2O) was applied in two slipts: 1/2 was applied at 10DAS and 1/2 at 30 DAS. The standard grower's practice at recommended rate in dry season will be applied as (100N- 40P_2O_5 -30 K_2Okg/ha)

Soils microbial population were estimated at the time of before sowing and at harvesting time. Total protein content (mg/ kg of dried soil) in soil (Herbert et al. 1971) and electron transport system (ETS) activities (n mol INTF per min-g dry weight of soil) or dehydrogenase (Chendrayan et al. 1980) were estimated at harvesting time. Soils were sampled at 10 days before harvesting to analyze the nutrient in soil.

Microbial population was estimated by plate counting method ,with the media (Subba Rao 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 recorded by Chlorophyll meter (SPAD-502) at 50 DAS, disease- insect incidence during growth cycle and yield and yield components were recorded. The data under this study was statistically analysed for a randomized complete block design by IRRISTAT for windows progame.

RESULTS AND DISCUSSION

1. Effect of rice srtaw manure and inorganic fertilizer in combination or alone application on rice yield

IR 64 is one of the most popular varieties in the Mekong Delta actually due to its high - yielding, short duration, moderate resistance to brown planthopper, and some major diseases, good eating quality.

The SPAD meter (SPAD-502) test can be a useful tool for Nitrogen management in rice. The optimum SPAD value for high yielding varieties ranges from 32-36 for direct seeded in dry season and 29-32 for direct seeded in wet season (Huan et al. 1998, 2000).

The result in Wet season (Table 1) showed that SPAD value in treatments T4, T5,T6 and T7 ranged from 30.9 to 35.2 (2000 WS), from 30.2 to 33.1 (2001 WS), and from 32.0 to 33.8 (2002 WS); the other treatments T1, T2 and T3 obtained SPAD value from 27.0 - 30.0. While, in Dry season, the result also indicated that SPAD value in treatments T4, T5, T6 and T7 ranged from 35.1 to 38.3 (2001 DS) and from 31.2 to 34.4 (2002 DS). Otherwise, treatments T1, T2 and T3 had SPAD value from 27.8 to 31.2 (2001 DS) and from 25.9 to 29.8 (2002 DS). The result also showed that the treatment T7 statistically gave highest SPAD value as compared to the other treatments in first season (2000 WS). However, non-significant diferrence in term of SPAD value among treatments T4, T5 T6 and T7 was observed in continuous seasons.

Table 1. Effect of rice straw manure and chemical fertilizer on SPAD value at 50 days after sowing

Treatment	2000 WS	2001 DS	2001 WS	2002 DS	2002 WS
T1. Control	27.0	27.8	27.2	25.9	27.7
T2. RSM (6t/ha)	27.4	28.2	27.5	26.5	27.9
T3. RSM + 20 %NPK	28.6	31.2	28.5	29.8	30.0
T4. RSM + 40% NPK	30.9	35.1	30.2	31.2	32.0
T5. RSM+ 60%NPK	30.8	36.4	32.2	33.4	32.6
T6. RSM+80% NPK	31.7	36.4	32.9	33.6	33.1
T7. NPK (DS:100:30:30) (WS: 80:30:30)	35.2	38.3	33.1	34.4	33.8
CV (%)	4.71	3.30	2.80	3.00	2.80
LSD (5%)	2.53	1.94	1.51	1.63	1.55

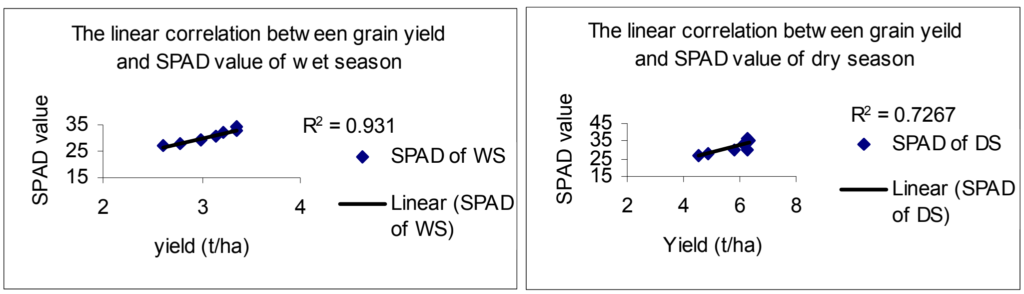

Fig 1. The correlation between SPAD index and grain yield.

There were possitive correlation between SPAD value and grain yield R^2 = 0.931 and R^2 = 0.7267 in wet season and dry season, respectively.

The result on yield (table 2) indicated that in 2000's wet season (WS), there were non-significant differences in terms of grain yield among treatments T1, T2, T3; among treatments T3, T4, T5 and among treatments T5, T6, T7. However, T7 statistically gained much higher yield than treatments T1, T2, T3, T4.

In 2000's dry season (DS), there were non-significant differences in grain yield among treatments T3, T4, T5, T6 and T7. However, these treatments performed higher yield than treatments T1 and T2.

In 2001's WS, treatment T6 obtained the highest yield and significantly differed from T1, T2 and T3. However, T6 grain yield was not different from T4, T5 and T7. There were non-significant differences in grain yield between treatment T1 and T2, but these treatments was significant lower in grain yield as compare with treatment T3.

In 2002's DS, Maxium grain yield was obtained in treatment T5 and significantly differed from T1, T2 and T3. However, T5 grain yield was not different from T4, T6 and T7. There were non-significant differences in grain yield between treatment T1 and T2, but these treatments was significant lower in grain yield as compare with treatment T3.

In 2002's WS, treatment T6 obtained the highest yield and significantly differed from T1, T2 and T3. However, T6 grain yield was not different from T4, T5 and T7. There were non-significant differences in grain yield between treatment T2 and T3, but these treatments was significant higher in grain yield as compare with treatment T1.

Table 2. Effect of rice straw manure and chemical fertilizer on rice yield of IR64.

Treatment	2000 WS	2001DS	2001 WS	2002 DS	2002 WS
T1. Control	2.19	4.32	2.67	4.78	2.98
T2. RSM (6t/ha)	2.23	4.60	2.91	5.13	3.20
T3. RSM + 20 %NPK	2.51	5.50	3.24	6.05	3.22
T4. RSM + 40% NPK	2.66	5.84	3.53	6.46	3.26
T5. RSM+ 60%NPK	2.71	5.94	3.63	6.76	3.33
T6. RSM+80% NPK	2.90	5.92	3.71	6.55	3.42
T7.NPK (DS:100:30:30) (WS: 80:30:30)	3.07	5.89	3.60	6.65	3.37
CV (%)	8.20	5.50	4.00	5.10	3.3
LSD (5%)	0.37	0.52	0.24	0.55	0.19

The above results also indicated that grain yield of IR64 was increased by the continuous application of rice straw manure. Especially, from second season to the continuous seasons, the grain yield of treatment T4 in which rice straw manue combined with 40% NPK was not significantly differed from treatment T7 in which complete application of chemical fertilizer (NPK). Continuous application of organic manure alone overyielded 9,9 % than control (Padalia 1975). Otherwise, application organic manure in combination with inorganic fertilizer over overyielded 11-12% than control (Tan 1992). In this experiment (table 4), we also recorded that the treatment which completed application of rice straw manure overyielded 5.91% and 6.86 % than control in WS and DS, respectively.

The treatment in which complete application of chemical fertilizer (NPK) overyielded 29.31% and 37.73 % than control in WS and DS, respectively.

The treatment in which rice straw manure combined with different doses of chemical fertilizer (NPK) overyielded 14.67-28.71% and 26.94-37.02 % than control in WS and DS, respectively.

Table 3. Effect of rice straw manure and chemical fertilizer on percentage of rice yield

Treatment	Percentage of grain yield over control						
	WS 2000	DS 2001	WS 2001	DS 2002	WS 2002	Average of three W.S	Average of two D.S
T1. Control	-	-	-	-	-	-	-
T2. RSM (6t/ha)	1.82	6.40	8.61	7.32	7.30	5.91	6.86
T3. RSM + 20 %NPK	14.61	27.31	21.34	26.56	8.05	14.67	26.94
T4. RSM + 40% NPK	23.46	35.18	32.20	35.14	9.39	21.68	35.16
T5. RSM+ 60%NPK	23.74	37.50	35.95	41.42	11.74	23.81	39.46
T6. RSM+80% NPK	32.42	37.01	38.95	37.02	14.76	28.71	37.02
T7. NPK (DS:100:30:30) (WS: 80:30:30)	40.02	36.34	34.83	39.12	13.08	29.31	37.73

2. Microbial communities under rice soil conditions:

Essential factors of sustainable agriculture are maintenance of viable, diverse population and functioning microbial communities in the soils. Soil organisms are one of the most sensitive biological markers and the most useful agents for classifying disturbed or contaminated systems. The use of microorganisms and their functioning in terms of total numbers of microorganisms, total respiration rates, and enzyme activities (ETS activities, alkaline phosphatase, sulphatase, asparaginase...) for examination of environmental stresses and declining biological diversity needs to be investigated (OTA 1987; Parkinson and Coleman 1991).

The continuous application of organics will energise 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 only estimated the microbial population, total protein content and electron transport system (ETS) activities or dehydrogenase in soil. The result (table 4) showed treatments in wet season obtained higher in microbial population than treaments in dry season. In genaral, the result on average number of WS and DS also indicated that plots in which rice straw manure was incorporated, obtained higher in microbial population as compared to plots in which rice straw manure was not applied (T1 and T7). This observation was similarly recorded in terms of ETS activities and total soil protein (mg/ kg of dried soil). During five continuous seasons; the result also indicated that the lowest value of ETS activities (μ mol INTF per min-g soil) obtained in complete application of chemical fertilizer treatment (T7). in contrast to this the plot in which complete application of rice straw manure was found to be higher in value of ETS activities than treatment T7. While. among treatments in which rice straw manure in combination with different doses of chemical fertilizer only treatment T6 and treatment T4 exhibited highest value of ETS activities in WS and DS respectively.

Table 4. Effect of rice straw manure and chemical fertilizer on microbial population of soil.

Treatment	WS 2000	DS 2001	WS 2001	DS 2002	WS 2002	Average of three W.S	Average of two D.S
T1. Control	7.84	6.48	7.73	7.20	7.04	7.54	6.84
T2. RSM (6t/ha)	8.71	6.90	8.14	7.32	7.08	7.98	7.11
T3. RSM + 20 %NPK	8.77	6.78	7.92	7.76	7.04	7.91	7.27
T4. RSM + 40% NPK	8.73	6.70	8.22	7.51	7.28	8.08	7.11
T5. RSM+ 60%NPK	8.74	6.95	8.30	7.08	7.23	8.09	7.02
T6. RSM+80% NPK	8.57	7.04	7.98	7.66	7.23	7.93	7.35
T7. NPK (DS:100:30:30) (WS: 80:30:30)	7.93	6.78	7.70	7.04	7.00	7.54	6.91
* Before sowing	8.71						
Average	**8.47**	**6.80**	**8.00**	**7.38**	**7.13**	**7.86**	**7.08**
Sd	**0.34**	**0.18**	**0.22**	**0.28**	**0.11**	**0.23**	**0.18**

Note:* sd of microbial population in wet season was not calculate to treatment of before sowing.

Table 5. Effect of rice straw manure and chemical fertilizer on ETS activities* of soil

Treatment	WS 2000	DS 2001	WS 2001	DS 2002	WS 2002	Average of three W.S	Average of two D.S
T1. Control	33.3	67.0	59.4	75.6	47.8	46.85	71.30
T2. RSM (6t/ha)	53.2	79.0	60.4	94.7	51.9	55.17	86.85
T3. RSM + 20 %NPK	33.2	75.0	87.1	105.4	53.8	58.03	90.20
T4. RSM + 40% NPK	33.1	80.6	61.5	126.9	60.9	51.83	103.75
T5. RSM+ 60%NPK	46.8	87.8	98.2	87.2	48.9	64.63	87.50
T6. RSM+80% NPK	33.4	70.4	86.9	104.6	74.6	64.97	87.50
T7. NPK (WS:80-30-30) (DS: 100-30-30)	33.1	61.5	58.4	73.4	46.6	45.97	67.45
Average	**38.0**	**74.4**	**73.1**	**95.4**	**54.9**	**55.35**	**84.94**
Sd	**8.8**	**8.9**	**16.9**	**18.8**	**9.8**	**7.86**	**12.19**

Note: * ETS activities = n mol INTF per min-g dry weight of soil
INTF: Iodonitrophenyl Formazan

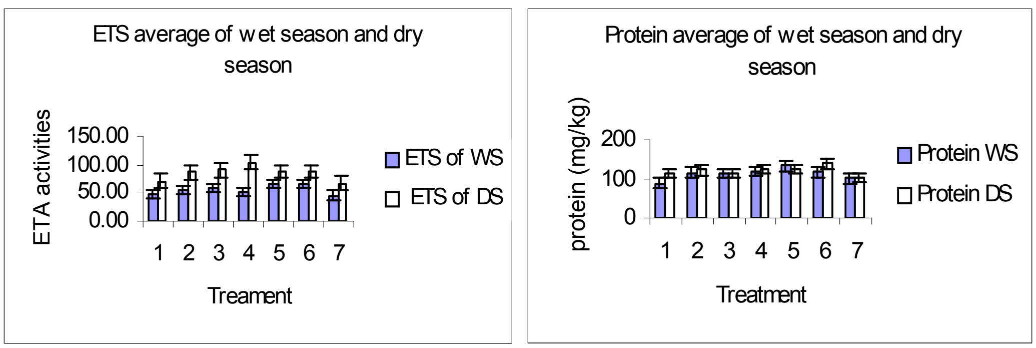

Fig 2. Average value of ETS activities and total protein content in soil.

Table 6. Effect of rice straw manure and chemical fertilizer on total protein* of soil

Treatment	WS 2000	DS 2001	WS 2001	DS 2002	WS 2002	Average of three W.S	Average of two D.S
T1. Control	76.6	118.6	100.6	104.5	88.7	88.63	111.55
T2. RSM (6t/ha)	93.3	130.5	132.2	114.2	119.3	114.93	122.35
T3. RSM + 20 %NPK	78.7	115.1	141.5	111.9	122.5	114.23	113.50
T4. RSM + 40% NPK	90.5	129.9	149.1	121.6	115.0	118.20	125.75
T5. RSM+ 60%NPK	86.0	137.6	195.1	113.3	116.3	132.47	125.45
T6. RSM+80% NPK	79.7	129.8	139.3	146.1	132.7	117.23	137.95
T7. NPK (WS:80-30-30) (DS: 100-30-30)	73.2	95.5	124.9	108.7	104.1	100.73	102.10
Average	**82.6**	**122.4**	**140.3**	**117.1**	**114.0**	**112.35**	**119.81**
Sd	**7.50**	**14.0**	**28.7**	**13.7**	**14.1**	**13.97**	**11.64**

- Total protein content = mg/ kg of dried soil

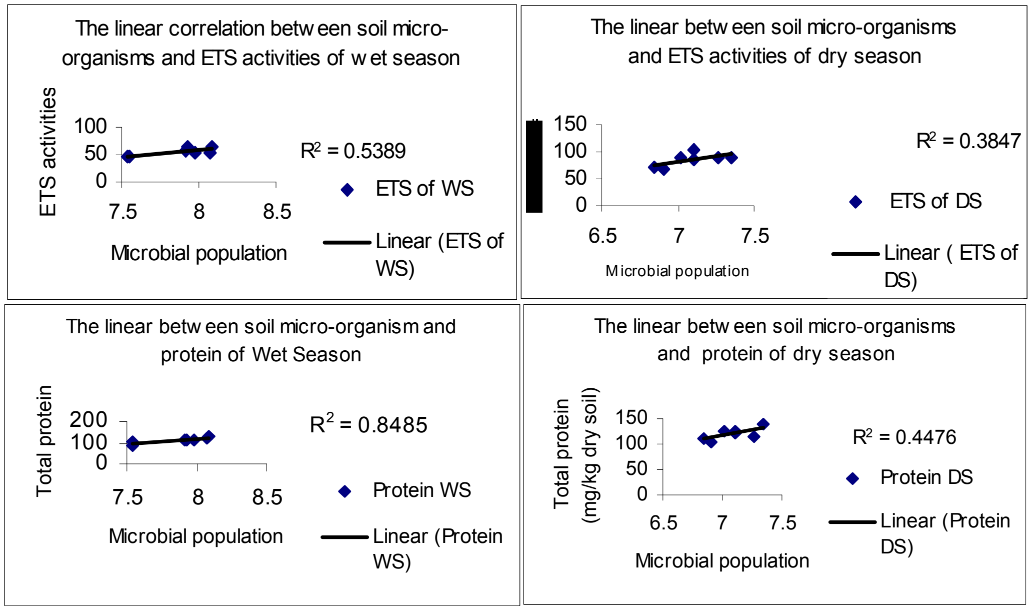

Fig 3. The linear correlation between soil micro-organisms and ETS activities; the linear correlation between soil micro-organisms and total soil protein.

Nutrient cycle in soils is catalysed by enzymes that are produced by organisms living in soil. Enzymes being associated with soil organisms may locate intracellular in cytoplasm. such as ETS activities. Other enzymes or attached the outer surfaces of living cells. "Abiotic" enzymes have dissociated from living biomass either by excretion or after the death of their producer cells. The later ones become usually immobilized by absortion to the internal or external surfaces of clay, or by forming complexes with humic colloids through copo-limerization, entrapment or adsortion (Boyd and Mortland 1990) and abiotic enzymes at low level are required to induce depolymerization enzymes by soil microbial community (Burns 1982).

The results in this long-term experiment (Fig .3) showed that there were positive correlation between soil micro-organisms and ETS activities R^2 = 0.5389 and R^2 = 0.3847 in WS and DS, respectively; positive correlation between soil micro-organisms and total protein content in soil R^2 = 0.8485 and R^2 = 0.4476 in WS and DS, respectively.

CONCLUSION

The primary result in this long-term experiment could be concluded as following:

1. Application of rice straw manure increased yield over control 5.91% and 6.86% in wet season and dry season, respectively.
2. Application of chemical fertilizer yielded over control 29.31% and 37.73% in wet season and dry season, respectively.
3. Rice straw manure combined with different doses of organic fertilizer yielded over control from 14.67 – 28.71% and from 26.94 - 37.02% in wet season and dry season, respectively.
4. There were possitive correlation between SPAD value and grain yield.
5. Complete application of chemical fertilizer treatment and control treatment were lower microbial population in soil as compared to complete application of rice

straw manure and treatments in which rice straw manure combined with different doses of chemical fertilizer.

6. A positive correlation between soil micro organisms and ETS activities and between soil micro organisms and total protein content in soil was noticed.

REFERENCES

Boy SA and MM Mortland. 1990. Enzyme interaction with clays and clay organic matter complexes. In: JM Bollag & G Stotzky (eds.) Soil Biochem. 6, 1-28.

Burn RG. 1982. Enzyme activity in soil: Location and possible role in microbial activities. Soil Biocheme. 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. Optimun fertilizer nitrogen rate for high yielding rice based on growth diagonics in wet seeded culture of rice. Proceedings of the 2000 annual workshop of JIRCAS Mekong Delta project; Nov 14-17, 2000. 60-67.

International Rice Research Institute (IRRI). 1991. IRRISTAT User's manual. Version 91.1. IRRI, 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 US. 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.

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. OMON RICE (2): 64-68.

SUMMARY IN VIETNAMESE

Rơm rạ sau thu hoạch được xử lý bằng chế phẩm sinh học (*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 5 vụ lúa liên tục, kết qủa ghi nhận được như sau: Bón hoàn toàn phân hữu cơ rơm rạ cho năng suất cao hơn đối chứng 5.91% trong vụ Hè -Thu (HT) và 6.86% trong vụ Đông -Xuân (ĐX). Trong khi đó, bón hoàn toàn phân hóa học (NPK) cho năng suất cao hơn đối chứng 29.31% trong vụ HT và 37.73% trong vụ Đ-X. Những nghiệm thức nơi mà phân hữu cơ rơm rạ được bón kết hợp với các mức phân hoá học (NPK) cho năng suất cao hơn đối chứng từ 14.67% đến 28.71% trong vụ HT và từ 26.94% đến 37.02% trong vụ ĐX. Kết quả cũng cho thấy ở nghiệm thức đối chứng và nghiệm thức 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 nghiệm thức bón hoàn toàn phân hữu cơ rơm rạ hay so với những nghiệm thức sử dụng phân hữu cơ rơm rạ 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.
