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# BIOCONVERSION OF PADDY STRAW AND BIOFERTILIZER FOR SUSTAINABLE RICE BASED CROPPING SYSTEMS

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**ABSTRACT**:

*The recommended models was carried out on three different provinces of Mekong Delta viz., An Giang, Can Tho and Long An at different in 30 households to study the effects of composting paddy straw by Trichoderma sp combined with nitrogen fixing bacteria Gluconacetobacter diazotrophicus, Bradyrhizobium japonicum (for soybean) and Bradyrhizobium spp (for groundnut) and phosphate solubilizing bacteria (Pseudomonas syringae). Application of recommended models on rice – soybean/groundnut - rice enhanced yield components and grain yields of crops at three sites of different seasons excepting in Cantho site at 2007 Spring – Summer season as compared to conventional farmers' fertilizer model. The average input of fertilizer cost for three crops in three seasons were saved at an amount of VND 953,640 / ha equal to 45.74 % as compared to farmers' practice. In the recommended model, the gross input also got reduced VND 1,092,277 / ha equal to 14.48 %; rice, groundnut and soybean grain yield increased at 12.37 %, 19.71 % and 5.24 %; respectively. The total income increased as 12.28 %; the cost price were reduced to an extent of 27.94 %, 9.10 % for rice and leguminous crops, respectively led to the income increased to an amount of 2,773,586 VND/ha equal to 45.13 % as compared to farmers' practice model. Furthermore, the quality of the products such as lipid, protein, phosphorus, potassium contents as well as soil available nutrients and benefit microorganisms (fungi, bacteria and actinomycetes) enhanced significantly at the harvesting stage.*

*The total benefical microorganism population in soils of the recommended model increased $4.23*10^8$ CFU/g dry soil, $3.39*10^8$ CFU/g dry soil and $8.85*10^8$ CFU/g dry soil for An Giang, Can Tho and Long An, respectively in comparision to the conventional farmes practice model.*

**Key words**: composting rice straw, nitrogen fixing bacteria, phosphate solubilizing bacteria, Pseudomonas *syringae, Trichoderma* sp.

## INTRODUCTION

In Vietnam, rice is the most important crop in the Mekong Delta that growing areas occupied nearly 4 million ha per year. With the introduction of high yielding rice varieties and adoption of intensive rice cultivation, large quantities of rice residues such as straw, stubbles are available on farms.

However, most of rice straw was burnt or removed after harvesting without retuning. However, this rice straw cannot be applied or directly incorporated into soil. They are known to reduce the availability of important mineral nutrient to growing plants through immobilization into organic forms and produce phototoxic substances during their decomposition. Besides that, farming practice on rice-based cropping system, which involves heavy application of chemical fertilizers, may cause depletion of certain nutrients in soil and

certain others would generally accumulate in excess resulting in nutrient imbalance, which affects soil productivity and environmental pollution.

Among the means available to achieve sustainability in agricultural production, suitable cropping systems, organic manure and bio-fertilizer play an important and key role because they possesses many desirable soil properties and exerts beneficial effect on the soil physical, chemical and biological characteristics of the soil. The result of trials on rice crop studied by CLRRI indicated that rice straw treated by *Trichoderma* fungi inoculant then application of composted rice straw at 6 tons/ha or in combination with different farmer's doses of chemical fertilizer at 40, 60, 80% NPK improved significantly soil microorganisms, electron transport system activities and total protein (Luu Hong Man *et. al.*, 2003). The role of biological nitrogen fixation (BNF) in supplying plants with needed N, which can make agriculture more productive and sustainable without harming the environment, has to be efficiently harnessed. Plant growth is directly influenced by the available of reduced N, leading to the long accepted practice of manuring, fertilizer application, or rotational crop practices (Dang Kim Son, 1986; Gresshoff and Rao, 1987). Nitrogenous chemicals account for as much as 30% of the total fertilizer needed for agricultural crops, with the increasing cost of chemical fertilizers and concern about environmental pollution. Studies indicate that rhizosphere, roots, stems and leaves of even healthy plants harbour diverse microbial communities that include $N_2$ fixing bacteria as rhizobia and free living bacteria (*Azotobater, Azospirillum, Herbaspirillum*…) or *Gluconacetobacter diazotrophicus*, a promising diazotrophic endophyte (Muthukumarasamy *et al.* 2002). The long-term field experiment on soybean conducted at Can tho showed that the quality nutrient contents and uptake of soybean with reference to N, P and K and soil available P and K were significantly improved by application of composted paddy straw and inoculants viz. *Rhizobium fredii* and *Bradyrhizobium sp* (Tran Thi Ngoc Son *et al.*, 2003). After N, phosphorus (P) is the major plant growth-limiting nutrients despite being abundant in soils in both inorganic and organic forms. However, many soils throughout the world are P-deficient because the free phosphorus concentration (the form available to plants) even in fertile soil is not higher than 10 µM even at pH 6.5 where it is most soluble (Gyneshwar *et al.*, 2002). To circumvent the problem of P deficiency, chemical fertilizers are added to the soils but cost of chemical phosphatic fertilizers is high (Goldstein *et al*., 1993) and low efficiency (<0.1%)(Scheffer and Schachtschabel, 1992). Phosphorus biofertilizers in the form of microorganisms, especially phosphate-solubilizing bacteria in rhizosphere, can help in increasing the availability of accumulated phosphates for plant growth by solubilization (Richarson, 1994; Nautiyal *et al.*, 2000). In addition, the microorganisms involved in P solubilization as well as better scavenging of soluble P (P biofertilizer) can enhance plant growth by increasing the efficiency of BNF. It enhances the availability of other trace elements such as Fe, zinc (Zn), etc. and by production of plant growth promoting substances (Kucey *et al*, 1989). These bacteria also produced indole-3-acetic acid; a phytohormone is known to be involved in root initiation, cell division and cell enlargement, very commonly (Barazani and Friedman, 1999). These beneficial microorganisms, especially PGPR (Plant Growth Promoting Rhizobacteria), are grown in the simple, cheap media and they are mixed with the appropriate carriers to produce biofertilizers. However, the optimum organic and bio-fertilizer doses as well as their effectiveness for upland crops rotation with rice have not been studied in details so far. In this regard, an attempt has been made to study on "Bioconversion of paddy straw and biofertilizer application for sustainable rice based cropping systems" under financial support by the Swedish International Development Cooperation Agency (SIDA) and Ministry of Science and Technology Vietnam (MOST).

**General objective**

To study and apply the new technologies of the rice – upland crop (soybean and groundnut) - rice cropping patterns under different soil conditions of Mekong Delta in order to reduce production cost, environmental pollution, and to increase farmers' livelihood, sustainable agricultural development

**Specific objectives**

1. To evaluate the effect of composted rice straw manure and biofertilizers on rice-soybean/groundnut cropping patterns under different soil type conditions
2. To study the residual effect of composted rice straw manure and biofertilizers on soil fertility under rice-based cropping systems
3. To determine the effects of composted rice straw manure and biofertilizers to soil microbial population under rice based cropping condition
4. To assess the influence of organic and bio-fertilizer on soybean/groundnut under rice-based cropping system to reduce input cost and to increase economic efficiency

**MATERIALS AND METHODS**

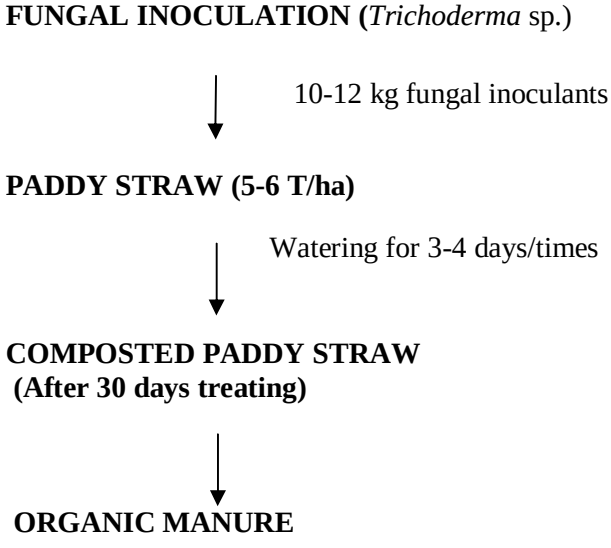
**Experiment sites**

Demonstrations were carried out at three provinces *viz.* (1) Phu Hoa village, Thoai Son district , An Giang province; (2) Truong Thanh village, Co Do district , Can tho city; (3) Tan My village, Duc Hoa district, Long An province. Two rices + one upland crop were commonly applied there.

**Timing**

1. In lightly acidic soil of An Giang province: Rice (2006 Summer-Fall) + Rice (2006-07 Winter-Spring) + Soybean (2007 Spring-Summer)
2. In alluvial soil of Can Tho province: Rice (2006 Summer-Fall) + Rice (2006-07 Winter - Spring) + Soybean (2007 Spring - Summer)
3. In unfertile sandy soil of Long An province: Rice (2006 Summer-Fall) + Rice (2006-07 Winter Spring) + Groundnut (2007 Spring-Summer)

**Paddy straw:** paddy straw collected from 2006-07 Winter Spring seasons from farmers' fileds. It was used to produce the composted paddy straw as local organic manure. The composted paddy straw treated by fungal inoculants as *Trichoderma* sp. was produced by Soil Microbiology Department of CLRRI. After 30 days of composting, it was used to apply for rice crops in recommended model during 2006 Summer-Fall and 2006-07 Winter Spring season. The general process of composting as given below:



**Biofertlizers**

4 Fungal inoculants (*Trichoderma* sp.) in powder formula produced by CLRRI's Soil Microbiology Department was applied to treat rice straw for decomposition as organic manure.

5 Bioferilizers for nitrogen fixation on rice, soybean and groundnut (*Gluconacetobacter diazotrophicus, Bradyrhizobium japonicum/Bradyrhizobium* sp.) that produced by CLRRI's Soil Microbiology Department and Biotechnology Research and Development Institute (BRDI), Can Tho University.

6 Bioferilizers for phosphate solubilizing bacteria on soybean and groundnut cultivation (*Pseudomonas syringae*) that produced by BRDI, Can Tho University.

**Methods of inoculant production**:

Fungal inoculant (Trichoderma sp.) in powder formula was applied to treat into rice straw heap with adequate moisture supplying for decomposition. It took around 21 - 24 days after inoculation (2 kg/ton of rice straw); decomposed rice straw was used as organic manure

*Bradyrhizobium japonicum* (USDA 110 strain) for soybean and *Bradyrhizobium* spp. (NC92 strain) for groundnut are grown in the G6 medium (Singleton *et al*, 2002), in 4 days on rotary shaker and population reaches $>10^9$ cells/ml, rhizobial liquid was mixed with sterile peat at 50% moisture. Rhizobial inoculant ($>10^9$ cells/g) was contained in plastic bags and stored at room temperature.

*Pseudomonas syringae* (P18 strain) was isolated from soybean rhizosphere soil and was determined high soluble phosphate and IAA. It was grown in sucrose apatite medium (Whitelaw et al, 1999) in 7 – 10 days and population reaches $>10^9$ cells/ml, pseudomonad liquid was mixed with the combination of sterile peat and bagasse at 50% moisture and the inoculant ($>10^9$ cells/g) was put in plastic bags and stored at room temperature

The *Gluconacetobacter diazotrophicus* strains isolated from roots and stems of sugar cane and determined high level of fixed nitrogen. They are grown in 10% sugar medium (Cavalcante and Dobereiner, 1988) in 4 days on rotary shaker and population reaches $>10^9$ cells/ml. Bacterial liquid was mixed with the mixture of sterile peat and bagasse at 50% moisture and contained in plastic bags and stored at room temperature ($>10^9$ cells/g)

**Experimental demonstration model layout**

Field demonstrations were conducted in alluvial soil, unfertile sandy soil and lightly acidic soil conditions with the rotational system (Rice – Legume – Rice). The model experiment was arranged in two treatments

*** For rice cropping**

1 Recommended model: 6 ton composted paddy straw by *Trichoderma* sp. fungus + 25 kg N+ 200 kg bio-fertilizers (100 kg/ha bio-phosphate fertilizer [*Pseudomonas syringae*] and 100 kg/ha nitrogen fixing bacteria inoculant [*Gluconacetobacter diazotrophicus*]) + 30 $K_2O$ kg/ha

2 Farmers' practices model: the fertilizer doses applied as farmers' practices

*** For upland cropping**

The demonstration model was continued in Spring-Summer 2007 in the same 30 farmers' fields that practiced of previous rice crops. At An Giang and Can Tho provinces soybean were sown and at Long An provinces was groundnut crop after rice. The model experiment was laid out in two treatments *viz*. recommended practice (RP) and farmers' practice (FP) as following:

1. Recommended model: 20 kg N + 2 liters /ha bio-phosphate fertilizer [*Pseudomonas syringae*] + 2 liters /ha nitrogen fixing bacteria inoculant [*Bradyrhizobium japonicum* inoculants for soybean / *Bradyrhizobium* spp. inoculants for groundnut] + 30 $K_2O$ kg/ha
2. Farmers' practices model: the fertilizer doses applied as farmers' practices
3. Model area: 1,000 $m^2$. Each kind of model was replicated for 10 times representated as

10 households. Total demonstration models were of 30 households from three different sites.

The composted paddy straw was incorporated into soil one day prior to sowing at rate of 6 ton/ha. Soybean plants was spaced at cm intervals in 40 cm rows and peanut plants at 20 cm intervals 20 cm rows and legume seeds was sown in the holes and covered with mixture of rhizobial inoculants and burnt-rice husk. Potassium fertilizer as Potassium chloride (60 %$K_2O$); Inorganic nitrogen fertilizer as urea (46% N); nitrogen fixing bacteria inoculant and phosphate solubilizing was broadcasted at before sowing

**Sample collection methods**

1 **Rice and leguminous crops sample**: Yield components and grain yield were obtained at the end of cropping season to evaluate the effects of compost and biofertilizers

2 Nutrient estimation in grain content for soybean and groundnut grain consisted of total N, $P_2O_5$, $K_2O$ and lipid content

**Soil samples:** Soil samples was taken at the beginning and at the end of the experiment to analyse soil pH, available N, available P, exchangeable K and organic matter and microbial population (bacteria, *Actinomycetes* and fungi) by standard methods

**Economic effeciency:** (i) materials (seeds, fertillizes, chemical plant protection), (ii) labour, (iii) input, (iv) income, (v) benefit recorded and evaluated.

The data obtained from the present investigation were subjected to statistical scrutiny and the results were interpreted statistically.

## RESULTS AND DISCUSSIONS

### Bioconversion of paddy straw

Soil Microbioly Department of CLRRI produced the composted paddy straw treated by fungal inoculants as Trichoderma sp. After 30 days of composting by this technique, it was used to apply for rice crops in recommended model during 2006 Summer-Fall and 2006-07 Winter Spring seasons. The 30 households from three provinces carried out to produce the composted padd straw as organic manure, which is treated by *Trichoderma* sp. The bioconversion of paddy straw took place progressively through the reduction in C:N ratio. After 4- 5 weeks, the C:N ratio recorded from 18.2 to 20.4. (Table 1). This is C:N ratio level was suitable to apply for rice (Fig.1)

**Table 1.** N content, Organic carbon and C:N ratio of paddy straw manure treated by *Trichoderma* sp. at various timing (mean value of 30 households)

| Treated timing (week) | N (%) | C (%) | C:N ratio |
|---|---|---|---|
| 1 | 0.98 | 38.7 | 39.4 |
| 2 | 1.45 | 35.1 | 24.0 |
| 3 | 1.46 | 35.6 | 24.4 |
| 4 | 1.67 | 34.2 | 20.4 |
| 5 | 1.82 | 33.2 | 18.2 |

*Source: Soil Microbiology Department of CLRRI*

**Fig. 1.** Composting process of paddy straw in household

a. Fungal inoculants *Trichoderma* sp.; b. Inoculation of *Trichoderma* sp. c. Watering; d. composted paddy straw

**Effect of paddy straw manure and bio-fertilizers on yield of crops at different seasons and locations:**

**In 2006 Summer-Fall season**: under recommended model, the average grain yield of rice obtained 3.77 to 4.63 T/ha. That was statistically significant difference as compared to farmers' practice (3.43 to 3.71 T/ha) at 0.01 level in case of An Giang (T value = 4.84**) and Long An (T value = 3.86**) and at 0.05 level (T value = 2.2*) in case of Can Tho. The increase in grain yield of rice due to recommended model was estimated about 9.91% to 14.28 % higher as compared to conventional practice of farmer (Fig.2)

**In 2006=07 Winter - Spring season**: under recommended model, the average grain yield of rice obtained 4.44 to 8.18 T/ha. That was statistically significant difference as compared to farmers' practice (3.79 to 4.91T/ha) at 0.01 level in case of An Giang (T value = 5.31**) and Long An (T value = 3.81**) and at 5% level in case of Can Tho (T value =2.34*). The increase in grain yield of rice due to recommended model was estimated about 17.15 to 35.43% (Fig.3)

**In 2007 Spring - Summer season**:

1. For soybean grain yield (at An Giang and Can Tho sites): yield from recommended model the gained from 1.77 to 2.50 T/ha, statistically significant difference as compared to farmers' practice (1.78 to 2.28 T/ha) at 1% level. T value is 2.91** in An Giang. There was no significant difference in in Can Tho (Fig. 4)
2. For groundnut grain yield (at Long An site): yield from recommended practice gained 3.62 T/ha, statistically significant difference as compared to farmers' practice (3.03 T/ha) at 1% level (T value = 9.13**). Grain yield of rice under recommended model was estimatedly increased 19.47 % (Fig. 4)

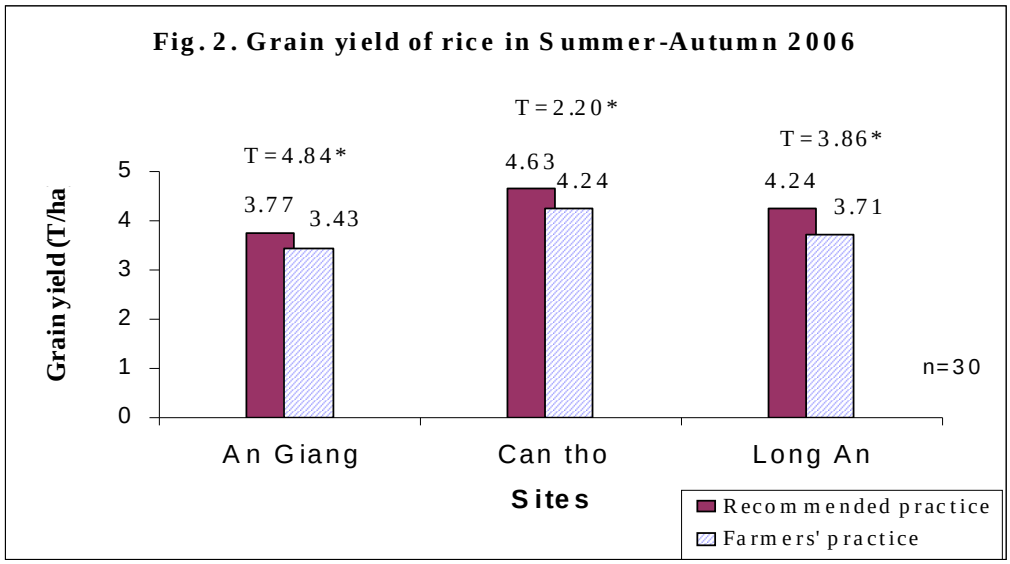



**Fig 2.** Grain yield of rice in 2006 Summer- Autunm

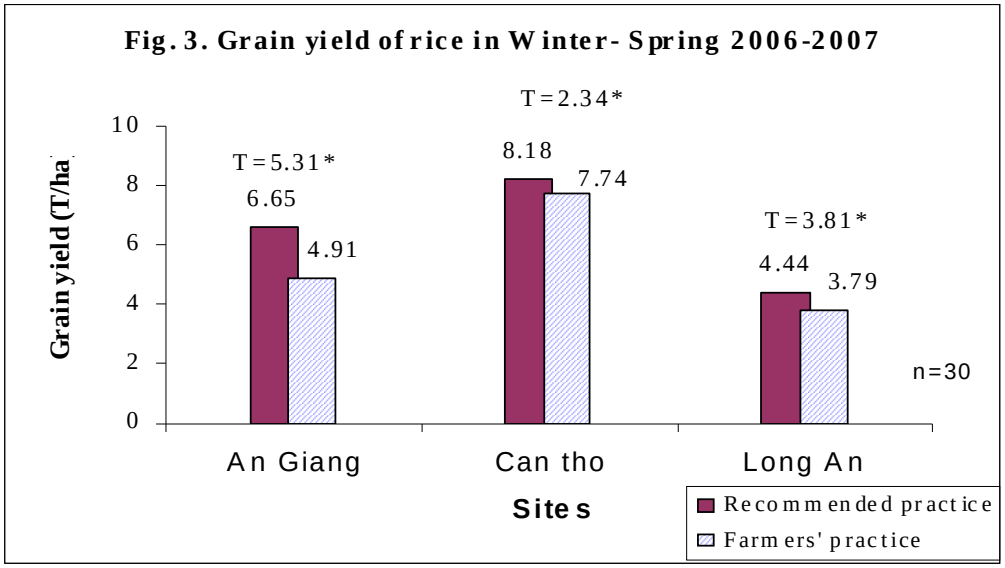



Fig 3. Grain yield of rice in 2006-07 Winter- Spring

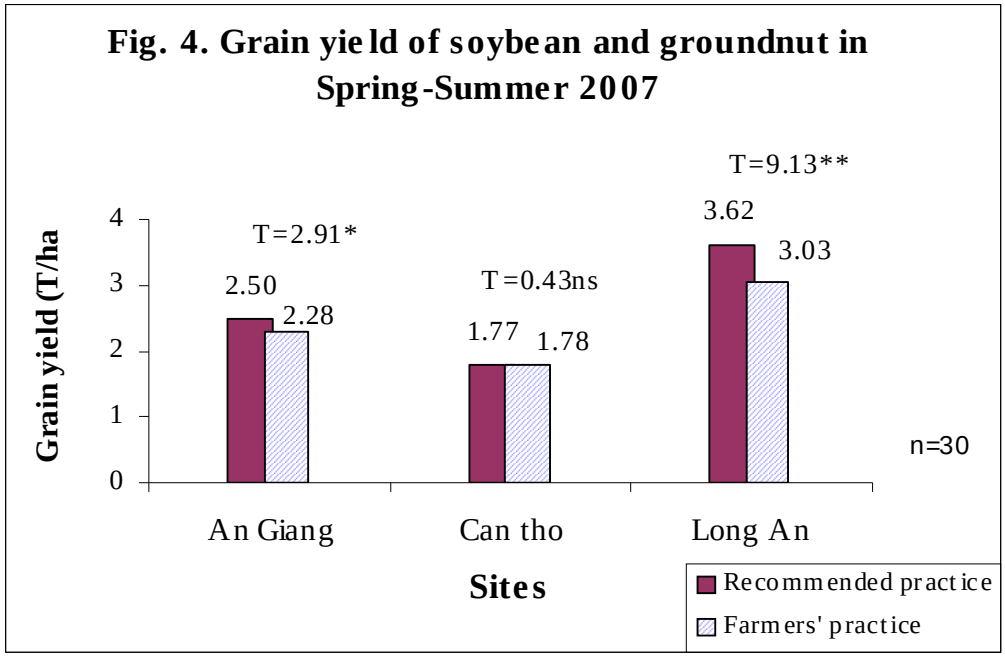



**Fig 4.** Grain yield of soybean and grodnut in 2007 Spring – Summer

**Effect of paddy straw manure and bio-fertilizers on microbial population at 3 different sites**

**Soil microbial population:** The obtained results recorded from two different methods of rice cultivation *viz.* farmers' practice and recommended model presented in the table 1 and figure 1. In An Giang province, average soil bacterial population under recommended model was significantly recorded higher than in farmers' practice (T value = 3.38*)

At Can tho site, the average soil microbial population under recommended model was significantly recorded higher than in farmers' practice (T value = 2.62*, 3.63*, 2.05* for fungi, Bacteria and Actinomycetes, respectively).

At Long An site, the average soil fungi and bacteria population under recommended model were significantly recorded higher than in farmers' practice (T value = 5.37**, 4.32* for fungi and bacteria, respectively).

Overall, the average microbial population under recommended model was increased 73.76, 105.9 and 76.26% in An Giang, Can Tho and Long An, respectively. This results is in line with the finding of Muthukumarasamy et al (2002), Luu Hong Man et al (2003)

**Table 2.** Average soil microbial population in three different sites at harvest stage (x $10^6$ CFU / 1 g of dried soil)

| Items | Fungi | Bacteria | Actinomycetes | Total |
|---|---|---|---|---|
| An Giang | | | | |
| Recommended model | 0.360 | 675.7 | 321.3 | 997.4 |
| Farmers' practice | 0.495 | 342.0 | 231.3 | 573.8 |
| Difference | -0.135 | 333.7 | 90.0 | 423.6 |
| T value | $-1.32^{ns}$ | 3.38* | $1.81^{ns}$ | 4.03** |
| Can Tho | | | | |
| Recommended model | 0.495 | 495.5 | 165.2 | 661.2 |
| Farmers' practice | 0.234 | 219 | 102 | 321.23 |
| Difference | 0.261 | 276.5 | 63.2 | 339.96 |
| T value | 2.62* | 3.63* | 2.05* | 3.95** |
| Long An | | | | |
| Recommended model | 1.394 | 1760.7 | 284.1 | 2046.2 |
| Farmers' practice | 0.33 | 849.1 | 311.5 | 1160.9 |
| Difference | 1.064 | 911.6 | -27.4 | 885.264 |
| T value | 5.37** | 4.32* | $-0.405^{ns}$ | 3.93** |

Source: Soil Microbiology Department, CLRRI

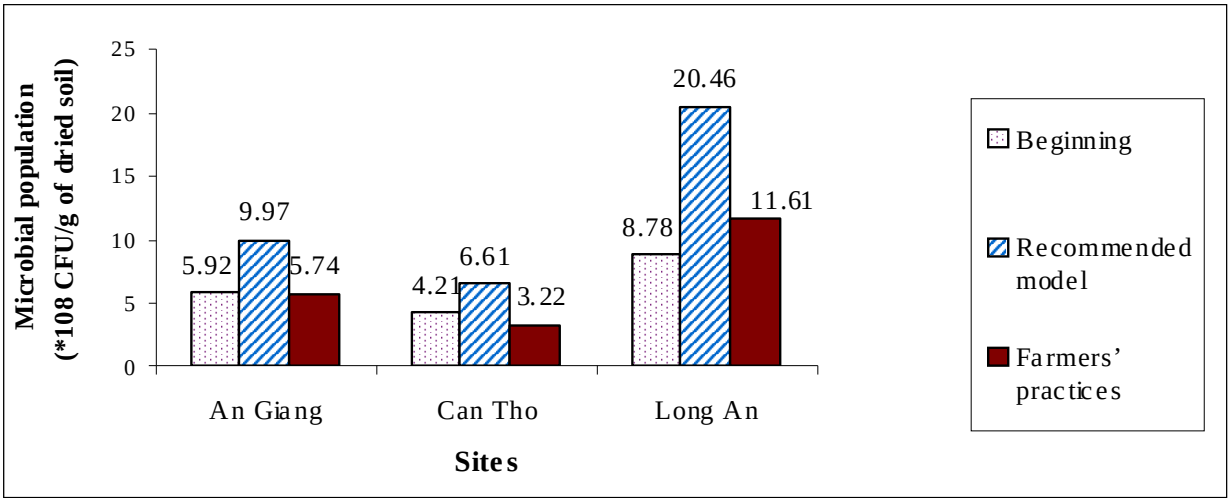



**Fig 5.** Total microbial population at harvest stage

**Effect of paddy straw manure and bio-fertilizers on soil physico-chemical properties and grain quality**

**Soil physico-chemical properties** (table 3)

Under recommeded model, soil properties were recorded higher in all parameters *viz*. pH, soil organic carbon, available N, P and K as compared to farmers' practice. The average increment in pH was to the tune of 0.211 units over control at An Giang site but not in Can tho and Long An sites. This could be ascribed to the fact that the decomposition of organic wastes released Ca and Mg nutrient, which could slightly increased soil pH (Tran thi Ngoc Son and Ramaswami, 1997)

**Organic carbon**: the higher average value was obtained under recommeded model as compared to farmers' practice in all three locations *viz.* An Giang , Can Tho and Long An at harvest stage. A

build up of organic carbon is due to application of composted paddy straw combined with biofertilizer + 25 kg N/ha of inorganic nitrogen. It was recorded from 0.034 to 0.176 % equally to 0.909 to 6.041 % as compared to farmers' practice model. This may be due to inorganic fertilizer supplying the needed energy and nutrient for the decomposition of complex organic reserves and rapid multiplication in the soil microbial population.

**Available nitrogen**: Marked differences were observed on soil available nitrogen due to different practices. The higher soil N value was observed under recommended model as compared to farmers' practice from 5.78 to 19.467 pppm. This was due to the inherent N content of the composted paddy straw incorporated and transformation during composting and after application into the soil nitrogen fixing bacteria *viz. Gluconacetobacter diazotrophicus, Bradyrhizobium japonicum.* This is in agreement with the previvious finding of Tran thi Ngoc Son et al. 2006.

**Available P**: was also found to be increased to an extent of 0.38 to 2.18 ppm under recommended model as compared to farmers' practice equal to an increment of 96.46%, 72.73% and 3.49 % in An Giang, Can Tho and Long An, respectively. Organic acids released during decomposition of organic influences the pH from stable complexes or chelates with cations responsible from P fixation as well as the phosphate solublizers *viz., Pseudomonas* and in turn, increased P availability application of biofertilizers significantly reduced the fixation of added as well as native P, making P more available to plant. This resut supports the findings of many workers (Tran thi Ngoc Son and Ramaswami, 1997; Gyaneshwar, *et al*., 2002)

**Available K**: was also found to be influenced by different cultural practices. It was obtained higher value to an extent of 4.6 to 7.0 ppm under recommended model as compared to farmers' practice. These increments were equal to 12.46%, 6.53% and 8.16 % in An Giang, Can Tho and Long An, respectively

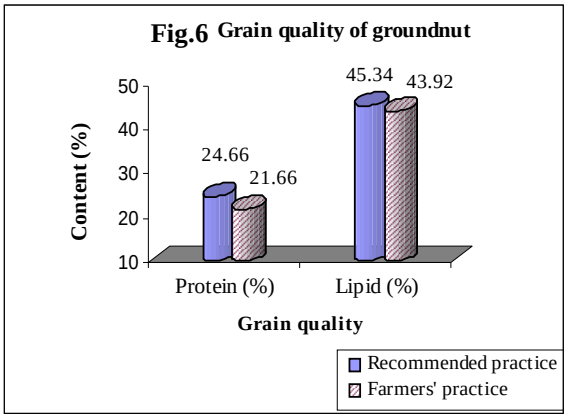
**Table 3.** Average soil nutrient availability of crops at 3 sites at harvest stage under different cultural practices

| Parameters | Locations | An Giang | Can Tho | Long An |
|---|---|---|---|---|
| **pH** | RM (1) | 4.938 | 5.07 | 5.88 |
| | FP (2) | 4.727 | 5.29 | 5.99 |
| | (1)-(2) | 0.211 | -0.22 | -0.11 |
| | % increase | 4.464 | -4.159 | -1.836 |
| **OC (%)** | RM (1) | 3.774 | 3.948 | 1.650 |
| | FP (2) | 3.740 | 3.772 | 1.556 |
| | (1)-(2) | 0.034 | 0.176 | 0.094 |
| | % increase | 0.909 | 4.666 | 6.041 |
| **N (ppm)** | RM (1) | 27.78 | 29.53 | 16.92 |
| | FP (2) | 16.84 | 10.063 | 11.14 |
| | (1)-(2) | 10.94 | 19.467 | 5.78 |
| | % increase | 64.96 | 193.5 | 51.89 |
| **P (ppm)** | RM (1) | 4.44 | 4.94 | 11.28 |
| | FP (2) | 2.26 | 2.86 | 10.90 |
| | (1)-(2) | 2.18 | 2.08 | 0.38 |
| | % increase | 96.46 | 72.73 | 3.49 |
| **K (ppm)** | RM (1) | 63.2 | 75.0 | 71.6 |
| | FP (2) | 56.2 | 70.4 | 66.2 |
| | (1)-(2) | 7.00 | 4.60 | 5.40 |
| | % increase | 12.46 | 6.53 | 8.16 |

Source: Soil Science Department, CLRRI, (1) Recommended model; (2) Farmer's practice

**Effect of paddy straw and biofertilizer grain quality and uptake**

1. Protein and lipid content in groundnut grain: The mean value of protein content in groundnut grain under recommended practice was recorded higher (due to the application of biofertilizer) than farmer practice. The protein content in grain in recommended model increased 13.85% as compared with farmers' practice. The mean value of lipid content in recommended model was higher 3.23% than farmers' practice (Fig. 6)
2. Treatmental influence on N uptake by soybean grain (Fig.7): N uptake by soybean grain was found to be influenced by the different treatments. At An Giang site, the mean value of N uptake (kg/ha) was recorded higher value (158 kg/ha) to an amount of 8.96% than farmers' practice (145 kg/ha). This is in accordance with the findings of many workers (Galal, 1997; Araujo and Teixeira, 2003, Tran thi Ngoc Son et al. 2004)



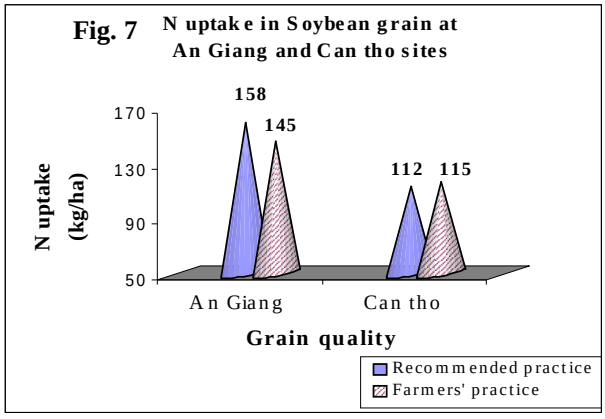




**Fig. 6 .** Grain quality of groundnut Fig. 7 . N uptake in soybean grain at An Giang and Can Tho sites

**Effect of paddy straw manure and bio-fertilizers on economic efficiency** (Table 4)

**In 2006 Summer-Fall:** Total average input cost under recommended model was recorded lower as VND 1,360,000; 1,147,000 and 1,313,000 / ha as compared to farmers' practice in An Giang, Can Tho and Long An, respectively.

The benefit: under recommended model, the average gross return recorded as VND 9,050,000 to 11,114,000 / ha while under farmers' practice, this one only ranged from VND 8,224,000 to 10,174,000 / ha.

**In 2006-07 Winter- Spring:** Total average input cost under recommended model was recorded as VND 1,232,000; 1,040,000 and 890,000 / ha as compared to farmers' practice in An Giang, Can Tho and Long An, respectively.

The benefit: under recommended model, the gross benefit recorded as VND 5,336,000 to 17,336,00 / ha while under farmers' practice, this one only ranged from VND 2,823,000 to 15,097,000 / ha.

**In 2007 Spring- summer:** Total average input cost under recommended model was recorded the lower value as VND 1,289,000; 1,100,000 and 459,000 / ha as compared to farmers' practice in An Giang, Can Tho and Long An, respectively.

The benefit: under recommended model, the gross benefit recorded as VND 3,895,000 to 15,433,00 / ha while under farmers' practice, this one only ranged from VND 2,855,000 to 9,980,000 / ha.

Generally, the increase by recommended practice obtained higher benefit as 36.1%, 36.42% and 54.64 % as compared to farmers' practice in An Giang, Can Tho and Long An, respectively. That implied that the practice is acceptable according to the economic opinion and regulation.

**Table 4**: Mean value of economic efficiency of crop production under different practice (x VND 1,000 /ha)

| Items | 2006 Summer- Fall | | 2006-07 Winter- Spring | | 2007 spring- summer | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | RM (1) | FP (2) | RM (1) | FP (2) | RM (1) | FP (2) | RM (1) | FP (2) | Benefit from 3 seasons |
| **An Giang** | | | | | | | | | |
| Input | 3,921 | 5,281 | 6,576 | 7,808 | 6,452 | 7,741 | 16,949 | 20,830 | -3,881 |
| Gross return | 9,050 | 8,224 | 16,303 | 13,461 | 16,986 | 15,477 | 42,339 | 37,162 | 5,177 |
| Benefit | 5,129 | 2,943 | 9,727 | 5,653 | 10,534 | 7,736 | 25,390 | 16,332 | 9,058 |
| **Can Tho** | | | | | | | | | |
| Input | 4,579 | 5,726 | 5,189 | 6,229 | 7,548 | 8,648 | 17,316 | 20,603 | -3,287 |
| Gross return | 11,114 | 10,174 | 22,525 | 21,326 | 11,443 | 11,503 | 45,082 | 43,003 | 2,079 |
| Benefit | 6,535 | 4,448 | 17,336 | 15,097 | 3,895 | 2,855 | 27,766 | 22,399 | 5,367 |
| **Long An** | | | | | | | | | |
| Input | 3,699 | 5,012 | 5,743 | 6,633 | 14,349 | 14,808 | 23,791 | 26,453 | -2,662 |
| Gross return | 10,048 | 8,790 | 11,079 | 9,456 | 29,782 | 24,788 | 50,909 | 43,034 | 7,875 |
| Benefit | 6,349 | 3,778 | 5,336 | 2,823 | 15,433 | 9,980 | 27,116 | 16,579 | 10,537 |

(1) Recommended model; (2) Farmer's practice;

## CONCLUSIONS

The illustrated data has proved clearly the effect of composted paddy straw by *Trichoderma* sp. and nitrogen fixing bacteria (*Gluconacetobacter diazotrophicus, Bradyrhizobium japonicum, Bradyrhizobium* spp.) and phosphate solubilizing bacteria (*Pseudomonas syringae*) under different soil type conditions of Mekong Delta on rice-based cropping systems in different seasons. The results showed that application of recommended models on rice – soybean/groundnut - rice enhanced yield components and grain yields of crops at three sites of different seasons excepting in Cantho site in 2007 Spring – Summer season in comparison to conventional farmers' fertilizer level. Moreover, this cultural practice not only saved 60 - 70 kg N and 60 kg $P_2O_{5\ kg}$/ha but also obtained higher economic efficiency in term of gross income. The quality of products not only obtained higher content in term of lipid, protein, phosphorus in crop grain but also the soil nutrients and benefit micro-organisms (fungi, *Azotobacter and Actinomycetes)*. It can be recommended to apply in larger scale areas to reduce cost production, environmental pollution; to increase farmers' livelihood and sustainable agricultural development.

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## REFERENCES

AgronomyAhmad F; I Ahmad and MS Khan. 2005. Indole Acetic Acid Production by the Indigenous Isolates of *Azotobacter* and Fluorescent *Pseudomonas* in the Presence and Absence of Tryptophan. Turk. J. Biol. 29, 29-34

Araujo AP and MG Teixeira. 2003. Nitrogen and phosphorus harvest indices of common bean cultivars: Implications for yield quantity and quality. Plant and Soil 257, 425-433

Cavalcante VA and J Dobereiner. 1988. A new acid-tolerant nitrogen-fixing bacterium associated with sugarcane. Plant Soil 108, 23-

31.

Dang kim Son 1986. Cropping systems in the floating rice of the Mekong Delta. Agricultural Publisher, Ha Noi

Galal YGM. 1997. Dual inoculation with strains of *Bradyrhizobium japonicum* and *Azospirillum brasilense* to improve growth and biological nitrogen fixation of soybean (*Glycine max* L.) Biol. Fertil. Soils 24, 317-322

Gresshoff PM and AN Rao. 1987. Agricultural Applications of Biotechnology, COSTED, Madras, 27-41.

Gyaneshwar P; G Naresh Kumar; LJ Paresh and PS Poole. 2002. Role of soil microorganisms in improving P nutrition of plants. Plant and Soil 245, 83-93

Luu Hong Man, Vu Tien Khang and Takeshi Watanabe .2003. Improvement of soil fertility by straw manure. Omon Rice 11:74-82. Agricultural Publishshing House , Cuulong Delta rice research institute, Omon, Cantho, Vietnam.

Molla AH; H Shamsuddin; MS Halim; M Morziah and AB Putch. 2001. Potential for enhancement of root growth and nodulation of soybean co-inoculated with *Azospirillum* and *Bradyrhizobium* in laboratory systems. Soil Biol. and Biochem. 33, 457-463

Munor-Rojas J and J Caballero-Mellado. 2003. Population Dynamics of *Gluconacetobacter diazotrophicus* in SugarCane Cultivars and Its Effect on Plant Growth. Microbial Ecology 46, 454-464

Muthukumarasamy R; G Revthi, S Seshadri and C Lakshminarasimhan. 2002. *Gluconacetobacter diazotrophicus* (syn. *Acetobacter diazotrophicus*), a promising diazotrophic endophyte in tropics. Current Science 83, 137-145

Patten C and BR Glick. 2002. Role of *Pseudomonas putida* Indoleacetic Acid in Development of the Host Plant Root System. Applied and Environmental Microbiology 68, 3795-3801

Rennie RJ. 1981. A single medium for the isolation of acetylene reducing (dinitrogen-fixing) bacteria from soils. Can. J. Microbiol. 12, 413-417.

Rodriguez H and R Fraga. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. Biotechnology Advances 17, 319-339

Singleton P, H Keyser and D Herridge. 2002. Development and Evaluation of Liquid Inoculant. In: Inoculants and Nitrogen Fixation of Legumes in Vietnam. D. Herridge (ed.) ACIAR Proceeding 109e, pp 67-74.

Tran Thi Ngoc Son and PP Ramaswami. 1997. Bioconversion of organic wastes for sustainable for agriculture. Omon Rice 5: 55-62

Tran thi Ngoc Son, Vu van Thu and Hiromi Kobayashi. 2003. Effect of organic and bio fertilizer application on rice -soybean -rice cropping systems Page 65-81. In the proceedings of the final workshop of JIRCAS Mekong Delta Project- "Development of new technologies and their practice for sustainable farming systems in the Mekong Delta", November 25-26, 2003

Tran Thi Ngoc Son, VV Thu, LH Man and R Yamada. 2004. Effect of long term application of organic and bio fertilizer on soil fertility under rice -soybean -rice cropping systems . Omon Rice 12:44-50

Vessey JK. 2003. Plant growth promoting rhizobacteria as biofertilizers. Plant and Soil 255, 571-586

Whitelaw MA, TJ Harden and KR Helyar. 1999. Phosphate solubilisation in solution culture by the soil fungus *Penicillium radicum*. Soil Biol. and Biochem. 31, 655-656

Nhằm mục đích tiết giảm lượng phân hóa học để giảm chi phí sản xuất, giảm ô nhiễm môi trường đất, nước cũng như gia tăng chất lượng nông sản, mô hình sử dụng phân rơm hữu cơ và phân sinh học đã

được thực hiện ở 3 tỉnh ở đồng bằng sông Cửu Long bao gồm An Giang, Cần Thơ và Long An tại ruộng của 30 hộ nông dân để nghiên cứu ảnh hưởng của phân rơm hữu cơ phân hủy bởi nấm *Trichoderma* sp. phối hợp với vi sinh vật cố định đạm *Gluconacetobacter diazotrophicus* và *Bradyrhizobium japonicum* (cho đậu nành) */Bradyrhizobium* sp. (cho đậu phộng) và vi sinh vật hòa tan lân (*Pseudomonas syringae*) trên 3 loại đất khác nhau (đất phù sa, đất phèn và đất cát bạc màu) ở đồng bằng sông Cửu Long trong hệ thống canh tác lúa và cây trồng cạn (đậu nành và đậu phộng) trong 2 năm 2006-2007: Vụ Lúa Hè Thu 2006 - Lúa Đông Xuân (2006 - 2007) - Đậu nành/đậu phộng Xuân hè 2007. Quy trình kỹ thuật khuyến cáo (QTKC) bao gồm sử dụng phân rơm hữu cơ phân hủy bằng nấm *Trichoderma* sp. phối hợp với phân vi sinh vật cố định đạm và hòa tan lân được bón kết hợp N hóa học ở mức 25 kg N/ha (cho cây lúa) và bón phân vi sinh vật cố định đạm và hòa tan lân với phân hóa học ở mức 20 kg N/ha (cho cây họ đậu) để so sánh với qui trình nông dân (QTND) theo tập quán canh tác tại địa phương. Kết quả sau 3 vụ canh tác cho thấy ở QTKC có sử dụng phân rơm hữu cơ và phân vi sinh làm gia tăng các thành phần năng suất và năng suất ở cả 3 loại cây trồng gồm lúa, đậu nành và đậu phộng tại 3 điểm mô hình ngoại trừ tại Cần Thơ vụ Xuân Hè 2007 khi so sánh với QTND.

Khi có sử dụng phân rơm hữu cơ phối hợp với phân cố định đạm và hòa tan lân sinh học theo QTKC, kết quả trung bình qua 3 vụ tại 3 tỉnh đã giảm được lượng phân bón là 65,73 kg N/ha, 71,91 kg $P_2O_5$/ha và 24,45 kg $K_2O$/ha tương đương giảm chi phí phân bón trung bình qua 03 vụ canh tác là 953.640 đ/ha [tương đương 45,74%] so với QTND do đó dẫn đến tổng chi phí đầu tư ở QTKC đã giảm 1.092.277 đ/ha [tương đương 14,48%]. Mặc dầu đầu tư ở QTKC thấp hơn QTND nhưng hầu hết các yếu tố cấu thành năng suất và năng suất của cây lúa và cây họ đậu ở QTKC đều đạt cao hơn. Năng suất lúa trong QTKC đã gia tăng 585 kg/ha tương đương 12,37%, năng suất đậu phộng tăng 597 kg/ha tương đương 19,71% và đậu nành tăng 106 kg/ha tương đương 5,24% so với QTND. Do trong QTKC tăng năng suất nên tổng thu nhập trung bình cao hơn 1.681.309 đ/ha [tương đương 12,28%] so với QTND và do giảm được một số chi phí về vật tư và lao động nên lợi nhuận trong QTKC cao hơn 2.773.586 đ/ha tương đương tăng 45,13%. Do tiết kiệm được chi phí phân bón và năng suất gia tăng nên giá thành 1 kg lúa ở QTKC chỉ ở mức 931 đ/kg thấp hơn 361 đ/kg [tương đương giảm 27,94%] so với QTND (1.292đ/kg) và giá thành 1 kg đậu ở QTKC là l.592 đ/kg thấp hơn 360 đ/kg, tương đương giảm 9,10% so với QTND ( 3.595 đ/kg). Hiệu quả đầu tư đồng vốn ở QTKC là 2,38 cao hơn 0,57 [tương đương tăng 31,29%] so với QTND chỉ đạt 1,81.

Ngoài ra, chất lượng nông sản như các thành phần dưỡng chất trong hạt bao gồm lipid, protein, phosphorus, kali cũng như các yếu tố dinh dưỡng đất và các vi sinh vật có lợi trong đất (nấm, vi khuẩn và xạ khuẩn) đều tăng lên một cách có ý nghĩa. Các yếu tố dinh dưỡng đất tại 3 tỉnh cũng cho thấy có sự đóng góp của phân rơm phân hủy phối hợp với phân cố định đạm và hòa tan lân sinh học đối với độ phì của đất thông qua các chỉ tiêu về chất hữu cơ, đạm hữu dụng, lân hữu dụng, kali hữu dụng ở QTKC đều tăng so với QTND tương ứng tại An Giang chất hữu cơ tăng 0,053%, đạm hữu dụng 10,94 ppm, lân hữu dụng 2,18 ppm, kali hữu dụng cao hơn là 7,00 ppm; tại Cần Thơ, chất hữu cơ tăng 0,177%, đạm hữu dụng 19,47 ppm, lân hữu dụng 2,08 ppm, kali hữu dụng cao hơn là 4,60 ppm và tại Long An chất hữu cơ tăng 0,085%, đạm hữu dụng 5,79 ppm, lân hữu dụng 0,38 ppm, kali hữu dụng cao hơn là 5,40 ppm. Tổng số vi sinh vật có ích trong đất bao gồm như nấm, vi khuẩn và xạ khuẩn ở QTKC đều tăng so với QTND, tại An Giang, tổng số vi sinh vật trong đất ở QTKC cao hơn $4,23*10^8$ CFU/g đất khô; tại Cần Thơ cao hơn $3,39*10^8$ CFU/g đất khô và tại Long An cao hơn $8,85*10^8$ CFU/g đất khô so với làm theo tập quán canh tác của nông dân. Trên cơ sơ kết quả nghiên cứu đạt được các nông dân thực hiện mô hình và nông dân các vùng phụ cận đều mong muốn triển khai mô hình khuyến cáo ở một diên tích lớn hơn để giảm chi phí sản xuất, giảm ô nhiễm môi trường, cải thiện đời sống nông dân và góp phần sản xuất theo hướng nông nghiệp bền vững.

***Từ khóa:*** *Trichoderma* sp., *Pseudomonas syringae,* phân rơm hữu cơ, vi khuẩn cố định đạm, vi khuẩn hòa tan lân, hiệu quả kinh tế, đậu phộng, đậu nành, lúa, năng suất.