**Nature Farming in Taiwan: Effects of Organic Amendments and EM on Rice Production**

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## Introduction

Regular additions of organic amendments to soil, including crop residues, animal manures, green manures, night soil, and composted organic wastes, can markedly improve soil productivity, fertility, and tilth. Also, such amendments can significantly increase the numbers of beneficial soil microorganisms (Higa and Wididana, 199l). With effective microorganisms (EM) arable land is revitalized, thus enhancing plant health and improving the growth and yield of paddy rice (Lin, 199l). This report describes the results of a study on the effect of organic amendments and EM on the yield and quality of paddy rice and on soil chemical properties.

## Materials and Methods

Eight bud pieces per bundle of paddy rice, variety Tai-Nung No. 69 (Yang, 1985) were planted on February 16, 1991, in a 2000 $m^2$ field of black soil; the crop was harvested on June 30. Before planting, the following treatments were applied to the soil of various plots.

1) Organic 1: soybean residues at 200 kg per 1000 $m^2$
2) Organic 2: clam shells at 100 kg per 1000 $m^2$
3) Cut straw without EM at 900 kg per 1000 $m^2$
4) Cut straw with EM at 900 kg per 1000 $m^2$
5) Rice bran (chaff and powder) without EM at 100 kg per 1000 $m^2$
6) Rice bran (chaff and powder) with EM at 100 kg per 1000 $m^2$
7) Fish meal (powdered bone and viscera) at 100 kg per 1000 $m^2$
8) EM 2 (diluted 1:500), EM 3 (1:1000), EM 4 (1:1000)
9) EM 5 (diluted 1:500 and 1:1000)

The EM solutions contain mixtures of 80 species from 10 genera of co-existing microorganisms, including photosynthetic bacteria, ray fungi, yeasts, and Lactobacillus spp. They were maintained at pH 8.5 with a population of about 109 per g (Higa, 1990a). The EM 5 is a mixture of EM 2, EM 3, and EM 4 with molasses, 5 % vinegar, and 15% alcohol (1:10 each) (Kazihada. l990).

The experimental field was divided into 8 plots according to organic amendments and EM application. The experimental plots were designated as T1, T2, T3, and T4, with and without EM solutions being sprayed onto the plots. Straw at 0.5 kg per $m^2$ was added to the plots before planting.

The treatments without EM were:

T1: no fertilizers or pesticides used; straw added, but no soybean residues or clam shells. This was designated as the control treatment.

T2: fertilizers and pesticides used; straw and rice bran added but no soybean residues or clam shells.

T3: straw and rice bran added, also soybean residues and clam shells.

T4: straw and rice bran added, also clam shells.

Straw was applied to all treatments as the basic organic fertilizer.

The treatments with EM were similar except that the straw and rice bran were treated with EM. Fish meal was applied when EM solutions were sprayed onto the plots. For T2, chemical fertilizer was added on March 9 and April 20, 1991; pesticides were sprayed on March 30 and April 20. For T3 and T4, EM 4 was sprayed on March 9, March 30, April 20 and May 9, 1991. EM 5 was sprayed on March 30 and April 20 for disease control.

## Results and Discussion

Fanners have used organic amendments to provide plant nutrients to crops for centuries. Crops grown in organic farming systems have been adapted to conditions of slow release of nutrients from organic materials. However, the advantages of using these materials arose from their ability to sustain son productivity without degrading the ecosystem (Sangakkara et al., 1990),

Results reported in Table 1 show that effective microorganisms enhanced the benefits of organic amendments such as soybean residues or EM-treated straws as sources of nutrients for paddy rice. The number of rice buds in each bundle increased significantly from the original eight (Table 1). While there was a significant difference in the numbers of buds for the T2 treatment (with and without EM) there were no significant differences in bud numbers for other treatments, although in most cases the reported values were higher with EM (Table 1). According to the methods of Frank and Bauer (1989), the main stems, leaves and all tillers of spring wheat grown in the field with 2 nitrogen and 2 water levels were separated and analyzed for water soluble carbohydrates (WSC), and the content of N and P. The levels of WSC were higher in the stems than in leaves for all treatments. WSC levels in the stems increased rapidly as plants developed, while the concentrations in leaf tissue changed only slightly during the growth period. The N and P content of leaves and stems decreased for all treatments as plants developed morphologically. Leaf tissue had higher N levels than stems, but stems had higher P levels. The tissue analyses suggest that WSC concentrations in stems are an important factor in determining total tiller number and survival. Future studies will determine whether this is the case for paddy rice.

There were no significant differences in the length of straw and length of ear grains whether plots were treated with EM or not (Table 1). However, for the weight of straw, there were significant differences between the plots treated with EM and those not treated (Table 1). For rice yield the total weight of whole grain rice and white rice was greater for the EM-treated plots than those without EM regardless of the organic amendment. There was no clear relationship with the application of organic amendments to the soil. It was apparent that EM treatment increased the yield of paddy rice; however these yields did not differ very much from conventional paddies in which chemical fertilizers and pesticides were used. In many cases, the yields of EM-treated paddies were greater than those of conventional-farmed paddies 1 to 2 years after EM treatment was started (Higa. 1990b).

**Table 1: Effects of Organic Amendments and EM on the Yield and Quality of Paddy Rice.**

| Yield Quality of Parameters | T1 Control | | T2 Chemical/ Organic | | T3 Organic | | T4 Organic | |
|---|---|---|---|---|---|---|---|---|
| | No EM | EM | No EM | EM | No EM | EM | No EM | EM |
| Average number of Buds | 18.0 | 19.7 | 29.2 | 21.8 | 28.5 | 29.9 | 23.1 | 24.3 |
| Average length of ear grain (cm) | 14.8 | 15.8 | 16.7 | 17.3 | 18.0 | 20.2 | 17.1 | 17.4 |
| Average length of whole straw (cm) | 74.9 | 79.5 | 80.9 | 75.5 | 79.3 | 82.6 | 77.9 | 81.2 |
| Gross weight of straws (kg/m$^2$) | 0.89 | 1.35 | 0.98 | 1.62 | 1.11 | 1.95 | 1.00 | 1.94 |
| Gross weight of whole rice (kg/m$^2$) | 0.78 | 0.84 | 1.01 | 1.03 | 1.11 | 1.42 | 1.08 | 1.33 |
| Net weight of white rice (kg/m$^2$) | 0.35 | 0.44 | 0.67 | 0.65 | 0.88 | 1.15 | 0.85 | 1.01 |

An interesting result in this study was that, with the exception of T2, the number of buds in each bundle was almost the same for both EM-treated and untreated plots; however, the weight of straw was greater in the plots treated with EM than for the untreated plots. To explain this apparent inconsistency, a nutrient analysis was conducted on the straw (Table 2). The straws were ashed and analyzed accordingly. In most cases the EM-treated rice was found to have a higher content of salt, total nitrogen, and exchangeable potassium, calcium, and ferrous iron, but not available phosphoric acid or exchangeable magnesium. There was no obvious relationship with organic matter, or exchangeable zinc and manganese between the EM-treated plots and the untreated plots.

**Table 2: Effect of EM on the Nutrient Content of Rice Straw from Different Treatments.**

| Nutrient Content | EM Treated | T1 Control | T2 Chemical/Organic | T3 Organic | T4 Organic |
|---|---|---|---|---|---|
| pH value | - | 10.8 | 10.9 | 10.9 | 10.8 |
| | + | 10.9 | 11.1 | 10.8 | 10.9 |
| Salt value (mmhos/cm) | - | 1.46 | 1.01 | 4.45 | 1.76 |
| | + | 1.63 | 5.23 | 5.11 | 4.25 |
| Organic matter (%) | - | 2.50 | 2.50 | 5.25 | 6.40 |
| | + | 4.30 | 2.80 | 2.45 | 5.25 |
| Total nitrogen (%) | - | 0.17 | 0.22 | 0.29 | 0.22 |
| | + | 0.32 | 0.20 | 0.41 | 0.25 |
| Available $P_2O_5$ (%) | - | 0.02 | 0.04 | 0.03 | 0.05 |
| | + | 0.02 | 0.02 | 0.03 | 0.02 |
| Exchangeable K (%) | - | 10.0 | 8.6 | 8.5 | 8.0 |
| | + | 8.1 | 12.5 | 10.0 | 8.6 |
| Exchangeable Ca (%) | - | 0.97 | 1.21 | 1.54 | 1.13 |
| | + | 1.27 | 2.24 | 1.90 | 1.43 |
| Exchangeable Mg (%) | - | 0.59 | 0.70 | 0.67 | 0.70 |
| | + | 0.40 | 0.67 | 0.56 | 0.71 |
| Exchangeable Zn (ppm) | - | 153 | 334 | 438 | 345 |
| | + | 267 | 478 | 228 | 228 |
| Exchangeable Fe (ppm) | - | 590 | 4,934 | 3,127 | 1,200 |
| | + | 1,203 | 967 | 11,147 | 2,554 |
| Exchangeable Mn (ppm) | - | 1,689 | 4,713 | 4,350 | 4,215 |
| | + | 1,423 | 4,478 | 4,393 | 2,367 |

Soil samples were taken from the plots for chemical analyses at the time of harvest (Table 3). The content of exchangeable K of straw ranged from 8.1 kg/ha to 12.5 kg/ha which provides an adequate potassium supplement. Straw was applied (900 kg/ 1000 $m^2$) to all treatments as the basic organic fertilizer (Table 2). However, exchangeable K values between 100 to 200 kg/ha are necessary for optimum yields of paddy rice. Nevertheless, the soil had a low content of other nutrients, i.e., nitrogen (optimum value, 3.0%) and phosphoric acid (optimum value, 1000 to 3000 kg/ha). Also the organic matter content was considered to be low. Thus, according to the present understanding of the nutritional requirements for optimum yields, this soil was highly infertile for growing crops (Higa, 1990c). The pH and calcium content were already near the optimum for T4 from the application of clam shells (100 kg per 1000 $m^2$) as a soil conditioner. While there were some significant differences in the nutrient content of the soil as affected by EM and the organic amendments, results were generally inconclusive. Nevertheless, extensive studies have shown that effective microorganisms (EM) can be particularly effective in making nutrients available to plants and suppressing plant pathogens (Higa, 1989).

**Table 3: Effect of EM on the Chemical Properties of Soil from Different Treatments.**

| Property | EM Treated | T1 Control | T2 Chemical/Organic | T3 Organic | T4 Organic |
|---|---|---|---|---|---|
| pH value | - | 4.1 | 4.3 | 4.9 | 6.1 |
| | + | 4.7 | 4.9 | 5.1 | 6.3 |
| Salt value (mmhos/cm) | - | 0.11 | 0.07 | 0.14 | 0.11 |
| | + | 0.06 | 0.06 | 0.17 | 0.10 |
| Organic matter (%) | - | 1.70 | 1.70 | 2.80 | 2.45 |
| | + | 1.80 | 2.40 | 2.65 | 2.00 |
| Total nitrogen (%) | - | 0.04 | 0.11 | 0.13 | 0.09 |
| | + | 0.12 | 0.09 | 0.14 | 0.10 |
| Available $P_2O_5$ (kg/ha) | - | 403 | 437 | 795 | 594 |
| | + | 456 | 458 | 739 | 611 |
| Exchangeable K (kg/ha) | - | 125 | 158 | 150 | 137 |
| | + | 141 | 111 | 171 | 165 |
| Exchangeable Ca (kg/ha) | - | 876 | 1,011 | 919 | 3,774 |
| | + | 663 | 1,043 | 1,190 | 3,750 |
| Exchangeable Mg (kg/ha) | - | 99 | 97 | 249 | 319 |
| | + | 64 | 84 | 230 | 470 |
| Exchangeable Zn (ppm) | - | 1.0 | 2.5 | 6.5 | 6.0 |
| | + | 1.0 | 1.5 | 7.0 | 7.0 |
| Exchangeable Fe (ppm) | - | 266 | 308 | 322 | 301 |
| | + | 271 | 321 | 318 | 304 |
| Exchangeable Mn (ppm) | - | 1.0 | 4.5 | 31 | 4.0 |
| | + | 2.0 | 3.0 | 41 | 13.0 |

In conventional theory, organic materials added to soil undergo decomposition by microorganisms, and minerals (nutrients) are released to become available for uptake by plants. In organic energy theory, organic amendments are fermented by species of *Lactobacillus*, and other lactic acid producing microorganisms. This, in turn, releases amino acids and polysaccharides as soluble organic compounds that are absorbed intact by plants to be utilized beneficially in various metabolic pathways. Kinjo (1990) found that the amount of amino acids produced after incubation of organic matter with EM for five days was significantly higher than the control. The absorption of amino acids, sugars, and other organic compounds by plant roots has been demonstrated in plant tissue culture (Higa, 1989). Reganold (1988) found that when Naff silt loam soil was farmed organically it developed a significantly higher organic matter content, cation exchange capacity, total nitrogen, extractable potassium, water content, pH, polysaccharide content, enzyme levels, and microbial biomass than when farmed conventionally. In the long-run, organic farming was more effective in maintaining soil tilth and productivity and in reducing soil erosion compared with conventional farming methods.

## Conclusions

It was found that the presence of sufficient organic matter in the soil (T3) was important to support the growth and activity of effective microorganisms, and for improving soil physical properties and increasing the yield of rice. In order to examine the beneficial effects of EM-treated organic matter as soil conditioners for crops, this study was conducted using straw, rice bran and soybean residues. The results show that the yield and quality of paddy rice were significantly increased, especially for T3 (soybean residue plus clam shells). A high priority for future research is to demonstrate the economic advantage (i.e., economic value) of using organic amendments as soil conditioners and biofertilizers to reduce the farmer's planting costs. Also a high priority is the production of Super EM for maintaining grass on golf courses and for controlling water quality and infectious diseases in fish ponds.

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