Effect of Organic Amendments and EM on Rice Production in Myanmar

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Introduction

Although chemical-based, conventional farming practices have substantially increased crop yields, they have created numerous problems for mankind. The use of chemical fertilizers and pesticides have contributed significantly to the pollution of both surface and ground water. Moreover, residual pesticides that have been used for protection of crops from insects and diseases can have adverse effects on human and animal health. In addition, the increasing cost of agricultural chemicals such as fertilizers, insecticides and herbicides have continued to lower a farmer's net cash return. Excessive soil erosion caused by conventional farming systems has seriously reduced soil fertility and crop productivity. It is estimated that some 3 billion tons of top-soil are lost each year to soil erosion in United States alone (Parr and Hornick, 1991).

A growing worldwide concern for these problems has motivated administrators, researchers, environmentalists, and farmers to seek alternatives to chemical-based, conventional agriculture. Some of the developments in alternative agriculture systems include: 1) organic farming without the use of synthetic chemicals and 2) low-input farming systems which allow limited use of chemicals for achieving such goals as (a) maintaining or improving the natural resource base, (b) protecting the environment, (c) ensuring profitability, (d) conserving energy, (e) increasing productivity, (f) improving food quality and safety, and (g) creating a more viable socioeconomic infrastructure for farms and rural communities.

In 1989, "The Organic Agriculture Association of Dietmen" was officially established in Japan with similar objectives. Moreover, interest in organic agriculture, low-input/sustainable agriculture, regenerative agriculture, alternative agriculture, and nature farming, which share some common goals, is increasing worldwide. Of the various emerging farming systems, Kyusei Nature Farming appears to be a promising method for overcoming problems of conventional chemical farming.

Kyusei Nature Farming, which uses Effective Microorganisms (EM), encompasses the following five requirements: 1) it must produce superior food for improving and maintaining human health, 2) it must bring economic and spiritual benefit to both producers and consumers, 3) it must be sustainable and be easily practiced by anyone, 4) it must conform to nature and protect the environment, and 5) it must produce enough food for an increasing world population.

In this farming technique, Effective Microorganisms (EM), such as photosynthetic bacteria, ray fungi, yeast, and filamentous fungi, are applied as mixed cultures to the soil to enhance the availability of soil nutrients, to increase humus formation, to suppress weeds, and to control plant diseases and pathogens.

Experiments conducted throughout Japan, from the northernmost island (Hokkaido) through the southernmost island (Okinawa) as well as in Taiwan, Thailand, the United States, and Brazil, have shown good prospects for the practical application of Kyusei Nature Farming.

At the First Steering Committee meeting of the Asia-Pacific Natural Agriculture Network (APNAN) held in Atami, Japan, in April 1990, it was agreed that members would conduct common experiments to study the effect of organic amendments and EM on crop production and soil properties under various regional conditions. APNAN member countries include Bangladesh, India, Indonesia, Japan, Korea, Malaysia, Myanmar, Pakistan, Philippines, Sri Lanka, Thailand and Taiwan. Accordingly, experiments conducted at the Institute of Agriculture, Yezin, Pyinmana, Myanmar from June to December 1990 are described in this report.

The primary objectives of Kyusei Nature Farming are: (a) to avoid or largely exclude the use of synthetic agricultural chemicals, especially fertilizers and pesticides; (b) to enhance the quality of the environment and protection of the natural resource base; (c) to improve the productivity and profitability of small farmers and the long-term sustainability of their farming systems; (d) to optimize the use of on-farm resources and minimize the dependence of farmers on off-farm resources and purchased inputs; and (e) to enhance the safety and nutritional quality of food. The principal objectives of this research were: 1) to study the effect of organic amendments and effective microorganisms on crop production and soil characteristics; 2) to study the feasibility and adaptability of Kyusei Nature Farming with EM under the specific agroecological conditions of the Union of Myanmar; and 3) to develop an agricultural system which will be economically and environmentally beneficial for the local farmers.

Materials and Methods

The experiments described here were conducted at the Institute of Agriculture, Yezin, 140 kilo-meters north of Yangon in the Union of Myanmar. The area has two distinct seasons. A dry season extends from October to April, followed by a wet season. During the dry season, a cold period occurs in the months of December through February, followed by warm weather. The details of the monthly weather reports for 1990 are given in Table 1.

Table 1. Record of Rainfall and Temperature in 1990 for Yezin.

Month	Rainfall (mm)		Maximum Temperature (^{o}C) Mean	Minimum Temperature (^{o}C) Mean
	Total	Mean		
January	Nil	Nil	30.9	13.2
February	Nil	Nil	33.0	16.6
March	Nil	Nil	34.8	20.1
April	30.5	1.0	36.9	22.6
May	275.0	8.9	32.8	24.5
June	280.2	9.3	31.1	24.7
July	362.8	11.7	29.9	24.3
August	231.4	7.5	31.1	24.6
September	442.8	14.8	30.9	24.5
October	18.1	0.6	32.9	23.9
November	107.6	3.6	31.3	22.1
December	Nil	Nil	31.1	16.6

Total rainfall from January to December 1990 -1748.4 mm

The soil type was a black Vertisol, which generally contains about 40 percent clay and is plastic and sticky when wet and very hard when dry. Analytical data for the soil are shown in Table 2.

The test crop was paddy rice. The variety is locally known as "Manawthuka"; its original name is

"Mashuri M". It supposedly originated in Malaysia and is a semidwarf type with a plant height of less than 100 cm. This variety also has a drooping panicle axis.

A split-plot design was selected for the experiment. The main plot treatments had 2 levels of EM. These were designated as E1 (with EM) and E2 (without EM). The subplot treatments included: T1, control; T2, recommended fertilizer; T3, organic matter (OM-1); and T4, organic matter (OM-2). The experiment was replicated four times to minimize the standard error.

For main plot treatment 1 (E1), suspensions of stock cultures of effective microorganisms designated EM 4 and EM 5 were diluted 1:1000 with distilled water and applied five times at a rate of 5000 ml of diluted suspension per hectare. The applications were as follows: (a) incorporated into the soil 2 weeks before transplanting; (b) incorporated into the soil 1 week before transplanting; (c) sprayed onto the soil and plants 1 week after transplanting; (d) sprayed onto the soil and plants 2 weeks after transplanting; and (e) sprayed onto the soil and plants 4 weeks after transplanting.

Table 2. Soil Properties for Three Experimental Conditions

Soil Properties	Experimental Condition		
	Pot	Microplot	Field
pH	5.80	6.80	5.30
Organic Carbon (%)	0.98	1.22	0.78
Total Nitrogen (%)	0.07	0.12	0.08
Cation Exchange Capacity (meq/100g)	8.70	9.80	10.10
Available P_2O_5 (kg/hectare)	14.00	34.90	36.90
Exchangeable K (meq/100g)	0.30	0.20	0.20
Exchangeable Ca (meq/100g)	5.90	7.70	5.40
Exchangeable Mg (meq/100g)	2.10	2.20	2.20

For subplot treatment 1 (T1), no fertilizer and no organic matter were added. For subplot treatment 2 (T2), urea fertilizer at the rate of 40 kg N per hectare was applied in split dosage; two-thirds of the total N was added as a basal treatment prior to transplanting, and the remaining one-third was applied at the panicle initiation stage. Triple superphosphate fertilizer at the rate of 30 kg P_2O_5 per hectare was applied as a basal treatment in a single dose. For subplot treatment 3 (T3), rice straw (OM-1) (C:N ratio of 72:l) was applied at a rate of 10 tons per hectare as one of the organic amendments. For subplot treatment 4 (T4), 60-day old green manure, *Sesbania rostrata* (OM-2), was added at a rate of 10 tons (fresh weight) per hectare. *S. rostrata* at this stage of growth has a C:N ratio of 12:1 . *S. rostrata* is a stem-nodulating legume that originated in West Africa which can grow well in standing water.

The experiment was conducted simultaneously under three conditions including: pots in the screen house, microplots in cement tanks, and field plots at the University Farm.

Rice seeds were sown on June 11, 1990, for the pot and microplot experiments, and on July 11, l990, for the field trial. Transplanting of seedlings occurred one month later and harvests were on November 2, November 1, and December 1, 1990, respectively.

Pot Experiment

Thirty-two glazed earthenware pots having a diameter of 23 cm and a height of 30 cm were used.

The holes at the bottom of each pot were carefully sealed before filling with 5 kg of soil. Three 30-day old rice seedlings were transplanted into each pot.

Microplot Experiment

Thirty-two cement tanks were used, each with a surface area of one square miter and a height of 25 cm. Rice seedlings were transplanted with a spacing of 20 cm between rows and 15 cm between hills. Three seedlings were planted into each hill.

Field Experiment

A field experiment was conducted at the University Farm. To prevent possible lateral movement of EM microorganisms after flooding, brick walls were constructed 2 feet below and 1 foot above the soil surface between the main blocks of the treated and untreated plots.

Plot size was 6 by 3 meters. The distance between the subplots was 5 meters, and the subplots were separated by double mud bunds to minimize lateral movement of plant nutrients from one subplot to another. Rice seedlings were transplanted at a spacing of 20 cm between rows and 15 cm between hills.

Results and Discussion

Various yield components were determined including plant height, number of panicles per hill, number of filled grains per hill, grain yield, straw yield, biomass yield, and percentage of un-filled grains. The variances between the treatment means were statistically analyzed.

Pot Experiment

Plant Height. Analysis of variance indicated that there were significant differences between the plant heights at the 5 percent level. Table 3 shows that the height of the green manure treated plants was comparable to, or even slightly greater than, plants treated with the recommended fertilizer rate. Rice straw-treated plants were the shortest, possibly indicative of the extent of denitrification which is usually associated with the use of low nitrogen plant materials. The effect of the subplot treatments on plant height is in the order of green manure > fertilizer > control > rice straw.

Table 3. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Plant Height at Harvest (Pot Experiment).

Treatment	With EM (cm)	Without EM (cm)	Difference (cm)
Control	84.5	81.9	2.6
Fertilizer	82.9	85.4	-2.5
Rice Straw	80.3	79.7	0.6
Green Manure	82.0	87.6	-5.6

Number of Panicles per Hill. Statistical analysis showed that there were significant differences in the number of panicles per hill for the subplot treatment at the 1 percent level. Green manure treated plants had a higher number of panicles per hill than the other three treatments (Table 4), and this was significant at the 5 percent level by the Duncan's Multiple Range Test (DMRT). The effect of the subplot treatments on the number of panicles per hill is in the order of green manure > fertilizer > control = rice straw.

Number of Filled Grains Per Hill. Statistical analyses indicated that there were significant differences between the subplot treatments at the 1 percent level. Table 5 shows that the mean value of the number of filled grains per hill of the green manure-treated plots was higher than for the recommended fertilizer rate; this was significant at the 5 percent level by DMRT. The effect of the subplot treatments on the number of filled grains per hill is in the order of green manure > fertilizer > control = rice straw.

Grain Yield. Statistical analyses indicated that grain yield of the subplot treatments was significantly different at the 1 percent level. Treatment means for grain yield from the green manure treated plots is significantly higher than those of other subplot treatments at the 5 percent level by DMRT (Table 6). The subplot treatment effects on the grain yield are in the order of green manure > fertilizer > control = rice straw.

Straw Yield. Statistical analyses showed that straw yields per hill were significantly different for the subplot treatments at the 1 percent level. Table 7 shows that rice straw yield was highest for the green manure treatment, while the straw treatment gave the lowest straw yield suggesting that denitrification had occurred. The effect of the subplot treatments on straw yields are in the order of green manure > fertilizer > control > rice straw.

Effect of EM on Yield Components. Visual observation revealed that the rice plants treated with EM looked healthier and were greener when compared with untreated plants. The performance of EM-treated plants was visibly better especially in the vegetative stage. However, differences in plant growth between the main plot treatments were less pronounced at the later stage or reproductive stage. This may have resulted from the mineralization of nitrogen from organic materials through microbial activity. Some microbiologists believe that the positive effects, usually observed at the early stages of plant growth, were caused by the production of small amounts of highly active growth promoting substances and not by fixation of large amounts of nitrogen (Gray and Williams, 1971). A higher incidence of crop lodging was observed for the untreated plants while those plants treated with EM showed no sign of lodging up to the harvest stage.

Table 4. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Panicle Development (Pot Experiment).

Treatment	With EM	Without EM	Difference
Control	10.8	11.0	-0.2
Fertilizer	12.5	11.5	1.0
Rice Straw	10.8	10.8	0.0
Green Manure	13.5	13.3	0.2

Unit: panicles / hill.

Table 5. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Grain Filling (Pot Experiment).

Treatment	With EM	Without EM	Difference
Control	1214	1223	-9
Fertilizer	1299	1336	-37
Rice Straw	1137	1137	0
Green Manure	1478	1571	93

Unit: filled grains / hill.

Table 6. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Grain Yield (Pot Experiment).

Treatment	With EM	Without EM	Difference
Control	25.0	23.8	1.2
Fertilizer	26.0	26.7	-0.7
Rice Straw	22.7	22.5	0.2
Green Manure	29.4	31.0	-1.6

Unit: g / hill.

Table 7. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Straw Yield (Pot Experiment).

Treatment	With EM	Without EM	Difference
Control	27.2	24.9	2.3
Fertilizer	27.9	29.9	-2.0
Rice Straw	21.4	21.8	-0.4
Green Manure	32.4	31.3	1.1

Unit: g / hill.

Although visual observations and some of the experimental data show the superiority of crop performance for EM-treated plants, the differences between main plot treatment effects were too small to warrant any statistical significance. Moreover, since the experimental design had only two levels of main plot treatment replicated four times, there were only three error degrees of freedom which is insufficient for a reliable analysis of variance F test.

Experiences of other workers revealed that the effect of EM on crop yield was usually not evident in the first test crop (Higa, 1986, 1989, 1991; Lin, 1991; Panchaban, 1991). Generally crop yields tend to increase gradually as subsequent crops are grown (Higa, 1989; Arakawa, 1991).

Microplot Experiment

Results of the microplot study to determine the effect of chemical fertilizer, organic amendments, and EM on the height, grain and straw yields, and total biomass of rice are reported in Tables 8-13.

Results were similar to those of the pot experiments. Analyses of variance revealed that the differences between the effects of the subplot treatments on yield components of paddy rice were significant at the 5 percent level. The effect of green manure (*Sesbania rostrata*) on the yield components of paddy rice in the microplots was equal to or, in some cases, even better than those treated with the recommended level of chemical fertilizer.

With respect to the effect of EM on the growth and yield of rice, visual observations indicated that the EM-treated plants performed better than those without EM. EM-treated plants grew more vigorously, and the foliage was darker green in color. A higher incidence of crop lodging at the harvest stage was observed for plants which did not receive the EM, while plants treated with EM showed no sign of lodging throughout the experimental period.

The differences between crop performance of the EM-treated and untreated microplots were more easily visible at the early stage of growth (i.e., vegetative stage) than at the later stage (i.e., reproductive stage). The results show that the positive effects of EM treatment on all the yield components were consistent (Table 14). However the differences between the means of yield components were not statistically significant. Since other workers have reported that the effect of EM on crop yields tended to increase with time, there is a need to study the short- and long-term effects of EM on crop production.

Table 8. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Plant Height at 45 Days after Transplanting (Microplot Experiment).

Treatment	With EM	Without EM	Difference
Control	69.9a	69.9b	0.0
Fertilizer	73.2a	70.5b	2.7
Rice Straw	71.0a	66.3c	4.7
Green Manure	71.7a	75.0a	-3.3

Unit: cm.

Column means sharing a common letter are not significantly different at the 5% level by DMRT. Data are the means of 4 replications.

Table 9. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Plant Height at 60 Days after Transplanting (Microplot Experiment).

Treatment	With EM	Without EM	Difference
Control	80.2	79.8	0.4
Fertilizer	83.1	81.3	1.8
Rice Straw	80.8	77.5	3.3
Green Manure	84.0	86.4	-2.4

Unit: cm

Data are the means of 4 replications.

Table 10. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Plant Height at Harvest Stage (Microplot Experiment).

Treatment	With EM	Without EM	Difference
Control	107.4	106.3	1.1
Fertilizer	110.6	108.0	2.6
Rice Straw	109.4	105.4	4.0
Green Manure	110.5	112.7	-2.2

Unit:cm

Data are the means of 4 replications.

Table 11. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms

on Rice Grain Yield (Microplot Experiment).

Treatment	With EM	Without EM	Difference
Control	1154	1132	22
Fertilizer	1281	1196	85
Rice Straw	1183	1123	60
Green Manure	1249	1257	-8

Unit: g / m^2

Data are the means of 4 replications.

Table 12. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Straw Yield (Microplot Experiment).

Treatment	With EM	Without EM	Difference
Control	1343b	1351ab	-8
Fertilizer	1564a	1416ab	148
Rice Straw	1390ab	1243b	147
Green Manure	1338b	1541a	-203

Unit: g / m^2

Column means sharing a common letter are not significantly different at the 5% level by DMRT. Data are the means of 4 replicates.

Table 13. Effect of Chemical Fertilizer, Organic Amendments and Effective Microorganisms on Rice Biomass Yield (Microplot Experiment).

Treatment	With EM	Without EM	Difference
Control	2498ab	2483bc	15
Fertilizer	2845a	2612b	233
Rice Straw	2574b	2367c	207
Green Manure	2587b	2798a	-211

Unit: g / m^2

Column means sharing a common letter are not significantly different at the 5% level by DMRT. Data are the means of 4 replicates.

Table 14. Effect of Effective Microorganisms on Yield Components of Rice.

Yield Components	Average Value for 16 Observations		
	With EM	Without EM	Difference
POT EXPERIMENT			
Plant height (cm)	82.4	83.7	-1.3
Panicles/hill	11.9	11.6	0.3
Filled grains/hill	1282	1316	-34
Grain yield (g/hill)	25.8	26.0	-0.2
Straw yield (g/hill)	27.2	26.9	0.3
Biomass yield (g/hill)	53.0	53.0	0.0
Unfilled grains (%)	5.4	6.1	-0.7
MICROPLOT EXPERIMENT			
Plant height (cm)	109.5	108.1	1.4
Panicles/hill	11.9	11.7	0.2

Filled grains/hill	1201	1185	16
Grain yield (g/m^2)	1216	1177	39
Straw yield (g/m^2)	1409	1388	21
Biomass yield (g/m^2)	2626	2565	61
Unfilled grains (%)	6.3	7.0	-0.7
FIELD EXPERIMENT			
Plant height (cm)	95.5	94.6	0.9
Panicles/hill	10.9	10.5	0.4
Filled grains/hill	1425	1383	42
Grain yield (at harvest) (kg/10 m^2)	5.2	4.9	0.3
Straw yield (at harvest) (kg/10 m^2)	12.5	11.7	0.8
Biomass yield (at harvest) (kg/10 m^2)	17.7	16.6	1.1
Unfilled grains (%)	-	-	-

Field Experiment

Results from the field experiments were erratic because of uncontrollable factors such as (a) soil heterogeneity, (b) non-uniform soil moisture levels, and (c) bird and rodent problems. The experimental site has a serious soil heterogeneity problem. Levelling during the soil preparation stage to reduce the slope may have made the soil heterogeneity problem even more severe. Because of the slope factor and a poor irrigation system, attempts to maintain a uniform moisture level throughout the experimental site were not completely successful. Birds and rodents may have contributed to the erratic pattern of results. Nevertheless, the positive effects of the EM treatment on crop performance were easily visible, particularly at the vegetative stage. The mean of 16 observations also showed that the positive effects of EM on yield components of paddy rice were consistent (Table 14). As indicated earlier, further investigation is needed before reliable conclusions can be drawn for long-term effects of EM on crop yields.

Summary and Conclusions

Subplot treatments had significantly different effects on yield components of paddy rice. The effectiveness of the treatments on the yield components were in the order green manure > recommended fertilizer > control > rice straw. Application of green manure, *Sesbania rostrata*, at the rate of 10 tons per hectare was found to be equally as effective as the currently recommended chemical fertilizer rate which is 40 kg N and 30 kg P_2O_5 per hectare. The use of *Sesbania rostrata* appears to be a promising substitute for nitrogenous fertilizers.

Visual observations show that the use of effective microorganisms (EM) produced better crop growth of paddy rice, particularly at the vegetative stage. Although the effect of EM was positive in several observations, the differences between the yield components of EM-treated and un-treated plots were not statistically significant. These results represent the work of one season and, therefore, further investigation of both short-term and long-term effectiveness of EM on crop production is needed before any specific conclusions can be drawn.

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