Kyusei Nature Farming in Japan: Effect of EM on the Growth and Yield of Spinach

S. Imai and T. Higa
International Nature Farming Research Center, Atami, Japan and
University of the Ryukyus, Okinawa, Japan

Introduction

A major concern in the conversion from conventional farming methods to Kyusei Nature Farming has been the amount of time needed to develop a good quality soil that would provide for economically stable production. Using mainly composted organic materials as biofertilizers and soil conditioners, it has usually taken several years to attain a suitable level of soil tilth, fertility, and productivity that typifies Kyusei Nature Farming systems. Moreover, during the first few years of the conversion from conventional farming to Kyusei Nature Farming it is not unusual for crop yields to decline temporarily. Thus, it has been necessary for farmers to exercise considerable patience and understanding during the conversion process.

The observed decline in crop yields can often be attributed to the fact that soils, where conventional farming is practiced, have become disease-inducing or putrefactive soils from long-term use of pesticides and chemical fertilizers. Consequently, it takes time to establish a disease-suppressive or zymogenic soil. Until this conversion process is complete, it is virtually impossible to exceed crop yields that were obtained with conventional farming methods.

This paper reports results of pot and field experiments to determine the effects of compost, effective microorganisms (EM), and chemical fertilizer on the growth and yield of spinach in two different soils. One soil had been farmed according to Kyusei Nature Farming methods, while the other had been farmed conventionally.

Methods and Materials

In the pot experiment, the two soils were removed from the field for treatment. One soil was taken from an area where Kyusei Nature Farming (without EM) had been practiced for six years and the pots were designated as Series A. A second soil was obtained from a nearby area where conventional farming was practiced and the pots were designated as Series B.

Fully decomposed compost was prepared from sawdust, rice bran, and waste vegetable materials and applied to appropriate pots (0.1 m^2 soil surface exposed) at a rate of 10 m^3/10 ares (1 are = 0.01 hectare; the abbreviation for are is "a"). Compost amended pots also received crushed crab shells at a rate of 60 kg/10 a, and crushed oyster shells at the same rate. These amendments comprised about 10 percent of the total soil volume.

Chemical fertilizer was applied to designated pots to provide N, P, and K at rates of 20, 12, and l5 kg/10 a, respectively. Dolomite was also applied to the fertilizer-amended pots at a rate of 100 kg/10 a. Both compost and chemical fertilizer were applied to the appropriate pots on September 24, 1987. When EM was applied in combination with either compost or chemical fertilizer, one liter of EM 4 was diluted with water at 1:500 (EM: water) and sprayed over these amendments prior to mixing with the soil.

Spinach was planted (20 seeds/pot) on October 1, 1987 and thinned to 10 plants/pot on October 30. Harvesting of the spinach started on December 3 and continued for some time. This procedure was followed because of variable growth among treatments. Thus, pots were harvested when the crop reached the proper stage of growth.

Pots which received EM 4 as a soil amendment at planting also received a mixture of EM 2 (1:1000 dilution) and EM 3 (1:2000 dilution) that was foliarly applied to the spinach plants on October l, 15, 29 and November 12.

Populations of microorganisms in the rhizosphere soil of spinach roots for each treatment were assessed by the College of Agriculture, University of the Ryukyus, Okinawa, Japan. A summary of the various treatments applied in the pot study is as follows:

Series A: Soil from Kyusei Nature Farming Area
Treatment 1 - Compost only
Treatment 2 - Compost + EM
Series B: Soil from Conventional Farming Area
Treatment 3 - Compost only
Treatment 4 - Compost + EM
Treatment 5 - Chemical fertilizer only
Treatment 6 - Chemical fertilizer + EM
These treatments are also summarized in Table 1. All treatments were replicated three times.

Table 1. Designation of Treatments Applied to Two Different Soils in a Pot Experiment to Determine the Effect of Compost, EM, and Chemical Fertilizer on the Growth and Yield of Spinach.

Soils	Treatments			
	Compost Only	Compost + EM	Fertilizer Only	Fertilizer + EM
Series A: (soil from Kyusei Nature Farming Area)	1	2	-	-
Series B: (soil from Conventional Farming Area)	3	4	5	6

Results and Discussion

Pot Experiment

The populations of microorganisms in the root surface-rhizosphere soil of spinach plants as affected by the various treatments after 11 weeks of growth are reported in Table 2. The number of aerobic bacteria was higher in both of the compost-amended soils when EM was used as an inoculant, compared with compost applied without EM. However, when EM was applied with chemical fertilizer, the number of aerobic bacteria was actually lower than when only fertilizer was applied. This suggests that chemical fertilizer may have created an unfavorable environment for this particular group of microorganisms.

Table 2. Populations of Microorganisms in the Rhizosphere of Spinach Plants Grown in Pot Cultures of Two Different Soils Treated with Compost, EM, and Chemical Fertilizer.*

Microorganisms	Series A		Series B			
	Compost only	Compost + EM	Compost only	Compost + EM	Fert. only	Fert. + EM
Aerobic bacteria (x 10^7)	8.53	11.3	6.21	8.45	13.3	8.13
Mold fungi (x 10^5)	1.26	7.85	1.36	10.8	0.38	0.82
Actinomycetes (x 10^6)	3.64	2.85	2.27	1.69	1.05	1.64
Lactic acid bacteria (x 10^3)	1.19	1.43	0.15	13.8	1.50	2.98
Fusarium spp. (x 10^3)	1.86	5.71	15.1	5.76	30.0	14.2
Fusarium occupancy (%)	1.48	0.73	11.1	0.53	80.0	17.3

* Data are expressed as numbers of microorganisms per gram of soil (dry weight basis). Microbial counts were made on December 25, 1988 after 11 weeks of growth.
Soil in Series A was taken from Kyusei Nature Farming area.
Soil in Series B was taken from conventional farming area.

The rhizosphere fungal populations were significantly higher for both the nature-farmed soil and conventionally- farmed soil when EM was used as an inoculant after the application of compost or chemical fertilizer. The numbers of mold fungi were markedly depressed by the application of chemical fertilizer, with or without EM.

The number of actinomycetes was higher in both compost- amended soils, and were slightly lower when EM was applied. The lowest number of actinomycetes was found in the conventionally-farmed soil and they increased marginally from treatment with EM.

The populations of lactic acid bacteria were higher for all treatments that included EM, and were particularly high for the conventionally- farmed soil when amended with compost + EM. Populations were slightly higher when the conventionally- farmed soil was treated with chemical fertilizer + EM compared with fertilizer alone.

The number of *Fusarium* spp. (a group of known soil-borne plant pathogenic fungi) was increased when the compost-amended, nature-farmed soil was treated with EM. However, the presence of EM appeared to significantly suppress the number of *Fusarium* spp. in the rhizosphere of spinach plants grown in the compost-amended, conventionally- farmed soil. The highest population of *Fusarium* spp. was found in the rhizosphere of the fertilizer-amended, conventionally- farmed soil. However, the population of this particular plant pathogen was significantly reduced by treatment with EM.

A most interesting observation reported in Table 2 is that of *Fusarium* spp. occupancy. The data show the dramatic reduction in the presence of this plant pathogenic fungus in the rhizosphere of both soils due to the application of EM. The percent reduction of *Fusarium* spp. by EM in the compost-amended, nature- farmed and conventionally -farmed soils was approximately 50 and 95 percent, respectively. The reduction in *Fusarium* spp. in the fertilizer- amended, conventionally-farmed soil from EM treatment was near 80 percent. These results indicate that EM can significantly enhance the transformation of a disease-inducing soil to a disease-suppressive soil.

The yields of spinach grown in pot cultures of the two soils that were treated with compost, EM, and chemical fertilizer are reported in Table 3. The highest total yield and average weight per plant was obtained with the fertilizer-amended soil that had been farmed conventionally. When EM was applied with the chemical fertilizer treatment the result was a small decline in the total yield and average plant weight.

The next highest yield was obtained from adding compost and EM to the soil that had been farmed according to nature farming methods. This indicates that considerably higher crop yields can be expected by utilizing EM in Kyusei Nature Farming practices which previously depended only on compost as a biofertilizer and soil conditioner.

While the highest spinach yield resulted from the fertilizer only treatment (Table 3, Series B) it is important to note that these pot cultures had the highest *Fusarium* spp. occupancy (Table 2). Consequently, after chemical fertilizer was applied, the conventionally -farmed soil reached a high potential for becoming a disease-inducing soil. If the treatment was repeated and spinach planted again, there is a high probability that severe crop injury from *Fusarium* could occur. One alternative is to follow spinach with a crop that is not subject to *Fusarium* injury. Perhaps a better alternative, even when chemical fertilizer is used, is to apply EM which greatly reduces the soil inoculum density and disease incidence of *Fusarium* spp. as reported in Table 2.

Table 3. Yield of Spinach Grown in Pot Cultures of Two Different Soils Treated With Compost EM and Chemical Fertilizer.*

Yield Parameters	Series A		Series B			
	Compost only	Compost + EM	Compost only	Compost + EM	Fert. only	Fert + EM
Number of plants	30	28	30	30	30	30
Total fresh weight (g)	135	345	37	92	436	402
Average weight/plant (g)	4.5	12.3	1.2	3.1	14.5	13.4
Relative yield (%)	100	273	27	69	322	298

* Spinach was harvested in December 1988 after 10 to 11 weeks of growth. Yield is reported as fresh weight.
Soil in Series A was taken from Kyusei Nature Farming area.
Soil in Series B was taken from conventional farming area.
Relative yield is expressed as the percent of that obtained from compost- amended, nature farming soil designated as 100 percent.

The lowest yield and plant weight (Table 3) resulted from the application of compost only to the soil that had been farmed conventionally. However, when EM was included there was a substantial increase in the yield parameters, although the values were still low compared with the other treatments. This seems to reflect the frequently reported observation that crop yields generally decline during the initial conversion from conventional farming to Kyusei Nature Farming.

In comparing the compost only treatments for the two soils (Table 3) it is apparent that the yield values were considerably higher for the soil that was farmed according to Kyusei Nature Farming methods. The most likely explanation is that the regular additions of compost over time have increased the reserve of total plant nutrients which provides a slow but continuous release of available nutrients through microbiological interactions. On the other hand, conventionally- farmed soils receive mainly chemical fertilizers that provide readily available nutrients to the plant. However, a substantial amount of the fertilizer nutrients are lost through leaching, runoff, and volatilization and the soil soon reaches a condition of deficiency.

Conventionally- farmed soils often contain low levels of organic matter compared with those subject to Kyusei Nature Farming. Soil organic matter is important for the storage, retention and supply of available nutrients for plant growth; it is the site of most microbiologically- mediated processes and absolutely vital to facilitate the conversion of a disease-inducing soil to a disease-suppressive soil.

Field Experiment

A field experiment was conducted on the farm of Mr. Hatanaka in Nara Prefecture; he has been practicing Kyusei Nature Farming for spinach production since 1982. Table 4 shows his spinach yields from 1982, when he began the conversion from conventional farming to Kyusei Nature Farming, through 1987, the year he started using EM.

In Type 1 cultivation, where spinach is planted in the fall and harvested in the winter, Mr. Hatanaka experienced significantly lower spinach yields for several years following the conversion from conventional farming to Kyusei Nature Farming. From 1984 to 1986 the spinach yields generally increased, but did not reach the 2500 kg/10 a level that was expected for conventional farming. EM was first used in 1987 and resulted in a dramatic yield increase of 3065 kg/10 a.

In Type 2 cultivation, spinach is planted in the spring and harvested in the early summer. The expected yield for conventional agriculture with this type of cultivation is 2000 kg/10 a. As shown in Table 4, spinach yield declined considerably in 1983, the first year of conversion from conventional farming to Kyusei Nature Farming, and was reduced to zero in 1984. Yields recovered substantially in 1985 and 1986 but were still below the expected conventional farming average of 2000 kg/10 a. With the first use of EM in 1987, there was a serious decline in spinach yields that were attributed mainly to bad weather. While Mr. Hatanaka's yield was only 500 kg/10 a, the poor growing season resulted in a spinach shortage in the marketplace. Consequently, his crop was of good quality and he was able to sell it at higher prices.

Table 4. Yield of Spinach from Two Types of Cultivation on the Hatanaka Farm in Nara Prefecture From 1982 to 1988.

Type of Cultivation*	Yield of Spinach (kg/10 a)						
	1982	1983	1984	1985	1986	1987	1988
1. Fall plant/winter harvest	1800	1400	1750	2190	2075	3065	
2. Spring plant/summer harvest	-	650	-	1200	1460	500	1600

*Type 1 cultivation: Conversion to Kyusei Nature Farming from conventional farming began in 1982. The expected spinach yield for conventional farming is 2500 kg/10 a. EM was first used on the 1987 crop.

Type 2 cultivation: Conversion to Kyusei Nature Farming from conventional farming began in 1983. The expected spinach yield for conventional farming is 2000 kg/10 a, EM was first used on the 1987 crop.

There is a greater risk associated with the Type 2 cultivation of spinach because the crop is harvested during the warm, humid weather of early summer when insects and diseases are prevalent and pesticides must be used frequently. Also, weeds are a problem during this time which often necessitates the use of herbicides.

The introduction of EM technology as an additional practice for Kyusei Nature Farming systems has enabled Mr. Hatanaka to achieve a stable production of spinach in both Type 1 and Type 2 cultivations. To further enhance his profitability, Mr. Hatanaka planted onion seeds in November 1988 in a small area where spinach was yet to be harvested. The area was not plowed or tilled in any way and did not receive chemical fertilizer. He did, however, apply EM to the new planting of onions on a regular basis. While early growth of the onions was shown, later development increased markedly after the remaining spinach was harvested and the weather became warmer.

As a result of this multiple cropping venture, Mr. Hatanaka harvested more than 25,000 bunches of onions (200-grams each) between March and early September. This outstanding yield was equivalent to more than 5000 kg/10 a, or about twice the expected yield from conventional farming. It also demonstrates that maximum and optimum crop yields of superior quality can be achieved through the practice of Kyusei Nature Farming, accompanied by the proper and timely use of EM technology. Moreover, using EM with Kyusei Nature Farming enhances the probability that such a combination can exceed the yield and quality of crops obtained from conventional farming.

Throughout this study, Mr. Hatanaka has gained knowledge and confidence in Kyusei Nature Farming, and he has continued to increase the amount of land that he devotes to it. He now provides advice and instructions on the application Kyusei Nature Farming principles and EM technology to other farmers in the Prefecture. Consequently, the number of farmers who have successfully adopted this system has increased significantly.