Effect of Organic Amendments and EM on Crop Production in Pakistan

T. Hussain, G. Jilani, M. Yaseen and M. A. Abbas
University of Agriculture, Faisalabad, Pakistan

Abstract

Trials were conducted to evaluate the technology of effective microorganisms (EM) under the agroecological conditions of Pakistan. In the first trial, EM and a fungus inoculum (FI) were compared with a fertilizer treatment on wheat. Fertilizer was significantly superior to microorganisms and organic materials in terms of crop growth and yield. EM application had a small positive effect on the crop. In another experiment involving a rice-wheat rotation, EM had less effect on the growth and yield of both crops, In this study, EM increased the efficiency of organic amendments, i. e., green manure (GM) and farmyard manure (FYM) because of their decomposing ability and, thus, more nutrients were released from these organic materials. Still, EM application could not compete with the conventional fertilizers for rice and wheat production, However, crop response to EM is greater with successive applications. In a third experiment, EM was applied as a microbial inoculant to enhance the composting of certain organic wastes and residues. A comparison of the N content in these materials after a period of composting showed that EM accelerated organic matter mineralization as indicated by the higher N content in the EM-treated organic materials. These studies have shown that EM technology has a high potential for increasing the yield and quality of crops in Pakistan.

Introduction

With the adoption of modern technology for intensive cropping, there is increased demand on the soil to provide plant nutrients. The native fertility of agricultural soils in Pakistan is inherently low and cannot sustain high crop yields. This has necessitated the widespread use of chemical fertilizers. For example, the agricultural soils in the wheat growing area of Punjab contain less than 1 percent organic matter (Azam, 1988). Soil productivity can be enhanced through the utilization of chemical fertilizers as well as organic materials (Azad and Yousaf, 1982). Although chemical fertilizers are very effective in increasing yield, they may cause some problems such as deterioration of soil structure, pollution of surface and groundwater, and a very high investment which may make the system unsustainable. Because of these fundamental problems some agricultural scientists have begun to examine alternative low-input technologies.

Nature farming may be a way of solving one or more of these problems. Research is aimed at the development of a production system that utilizes the natural ecosystem to ensure pollution-free food products, energy conservation, reduced production costs, best use of local resources, and revitalization of agriculture in rural areas. Mokichi Okada of Japan initially advocated this farming method in 1935 which he called "Kyusei Nature Farming." In 1983, Dr. Teruo Higa began to develop the technology of effective microorganisms (EM) as an added dimension to Kyusei Nature Farming. EM consists of mixed cultures of compatible and beneficial microorganisms including photosynthetic bacteria, ray fungi, filamentous fungi and yeasts. When added to soil, EM cultures can accelerate the decomposition of crop residues and manures, thereby enhancing the availability of nutrients to plants. The results of preliminary studies on EM reported by Arakawa (1991) showed that the effect of EM was significant. Yields of peanuts and carrots were far better with the addition of EM than with chemical-based, conventional agriculture. This led to extensive field experiments on EM in 1986 in different agroclimatic zones through-out Japan.

In the subarctic zone, EM was effective in the large scale production of wheat, potatoes, soybeans, adjuki beans, onions and carrots. In the temperate zone, trials indicated that EM was advantageous in paddy fields and orchards and for the production of many other crops. The increased crop production due to EM is attributed to increased fertility and the reduction of disease and insect infestation of soils and crops. Direct effects as a result of the increased activity of nitrogen-fixing bacteria and VA-mycorrhizal fungi were also observed.

In the present studies, EM was applied to rice and wheat after amending soil with organic matter as green manure (GM) to determine its effect on crop yields. In another study, different waste materials, namely rice straw, wheat straw, farm yard manure, poultry manure, and city waste (refuse) were composted after inoculation with EM, so that maximum nutrient concentrations could be available to the crop within a short period of time.

Materials and Methods

These studies examined the possible re-placement of chemical fertilizers with organic and biological amendments to enhance sustainable crop production. Three studies were conducted to determine the benefits of EM on crop production. The first two studies were conducted in the field. The soil was a Typic Camborthids soil series with a sandy clay loam texture which had pH, 7.85; ECe, 1.65 dS m^{-1}; CEC, 8.5 $cmol^{(+)}kg^{-1}$, organic matter, 0.55 percent; total N, 0.04 percent. The third study, to determine the effect of EM on the composting of organic materials, was conducted in cemented pits. The details of these studies are as follows.

Effect of EM and Organic Amendments on Wheat Production

In this field study, various organic materials and microbial inoculants were applied to a wheat crop and their effectiveness was compared. The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications. The individual plot size was 4 x 4 m (16 m^2). The experiment was conducted with the following treatments:

1) Control
2) Wheat straw at 200 kg ha^{-1} + urea at 12.5 kg ha^{-1}
3) T2 + Fungus Inoculum (FI) at 10kg ha^{-1}
4) Effective Microorganisms (EM) sprayed on the crop (four applications with dilutions of EM:Water of 1:1000, 1:2000, 1:3000 and 1:10,000, respectively.
5) EM applied to soil at a dilution of 1:1000
6) EM + farmyard manure (FYM) at 20 t ha^{-1}
7) FYM at 20 t ha^{-1}
8) EM + wheat straw at 200 kg ha^{-1}
9) EM + rice straw at 200 kg ha^{-1}
10) Recommended fertilizers at 115 kg N ha^{-1} + 70 kg P_2O_5 ha^{-1}

The crop was sown in November 1989 in rows 30 cm apart, At harvest, data on the growth and yield of wheat were recorded, and the plant samples were analyzed for N, P, and K.

Effect of EM and Organic Amendments on Rice and Wheat Production

This field experiment was initiated in 1990 with rice. The field had similar characteristics to the one used for the wheat experiment. It was laid out in a split-plot design with three replications; individual plot size was 4 x 4 m (16 m^2). The treatments were as follows:

a) Main-plots:

T1 = No EM applied to the crop
T2 = EM applied to the crop

b) Sub-plots:

T1 = Control
T2 = Recommended NPK fertilizers
T3 = Green manure (GM) at 20 t ha^{-1}
T4 = Decomposed FYM at 20 t ha^{-1}

For the rice crop, EM 4 was applied weekly (after transplanting) for eight weeks at a dilution of l:1000 for first two-week period, 1:2000 for the second two-week period, 1:3000 for third two-week period and 1:10,000 for the fourth two-week period. After rice harvest, wheat was sown in the same plots and subjected to the same treatments with the exception that EM 4 was applied after irrigation only four times at dilutions of 1:1000, 1:2000, 1:3000 and 1:10,000, respectively. The rice and wheat fertilizer treatments were 120 kg N, 90 kg P_2O_5, and 60 kg K_2O per hectare. Growth and yield parameters were recorded for both crops.

Beginning in 1990, this experiment will continue for a total of 5 years with a rice-wheat rotation in the same permanent plots.

Effect of EM on the Nitrogen Content of Organic Materials After Composting

This trial was conducted in cemented pits of 2 x 1 x 1.5 m (L x W x D) beginning in the summer of 1991; the objective was to decompose different organic materials in the shortest possible time to enhance the availability of plant nutrients. The treatments were as follows in a split-plot design:

a) Main-plots: EM treatments
  - T1 = No EM applied
  - T2 = EM applied

b) Sub-plots:
  - T1 = Farmyard manure (FYM)
  - T2 = Poultry manure (PM)
  - T3 = Wheat straw
  - T4 = Rice straw
  - T5 = City waste

The organic materials were analyzed for their total carbon and nitrogen contents before filling the pits. EM 4 was then applied to the designated treatments at a 1:1000 dilution, and the materials were well mixed. Three samples from each pit were collected for analysis at two-week intervals for two months. Temperature of the decomposing materials was also recorded at appropriate intervals. The samples were analyzed for total organic C and N at each sampling.

Results and Discussion

Effect of EM and Organic Amendments on Wheat Production

Growth and Yield of Wheat. Data on plant height, number of tillers, and grain and straw yield of wheat are shown in Table 1. The highest values for all parameters resulted from the N+P fertilizer treatment and were highly significant. The next highest values, i.e., the FYM+EM and FYM treatments, were not significantly different. These were followed by wheat straw+fungus inoculum (FI) treatments which were not significantly higher than the EM+straw treatments, but the differences were highly significant compared to the control. Akhtar (1990) also found that addition of *Arachniotus* sp. (FI) along with chaffed wheat straw significantly increased the yield of wheat grain, sugarcane, cotton, mung pulses, chickpeas, fenugreek, tomato and potato crops. The fungal microbes significantly increased the yield of wheat over that of the control. Results for wheat straw and rice straw were statistically similar. Application of EM to the soil gave somewhat better results than EM sprayed on the standing crop. Effective microorganisms (EM) when applied alone was less effective than when applied with either wheat or rice straw. It was observed that wheat straw at 200 kg ha^{-1} caused a small increase in the growth and yield of wheat. In this experiment, the EM application did not increase the yield significantly, which may reflect the lack of full establishment of EM cultures in soil during the first year. Higa and Wididana (1991) also observed that the growth and production of tomatoes were not significantly different between EM and non-EM treatments during the first year.

Table 1. Effect of EM and Fertilizer Application on the Growth and Yield of Wheat.

Treatment	Plant Height (cm)	Tillers (no. m^{-2})	Yield (t ha^{-1})	
			Grain	Straw
Control	77.7e	179f	1.09e	1.92f
Wheat straw	78.7de	188ef	1.37de	2.23ef
Wheat straw + FI	81.3c	208d	1.92c	2.66cd
EM sprayed on crop	79.9cde	188ef	1.52cde	2.31def
EM applied to soil	80.0b	196def	1.58cd	2.44de
EM + FYM	84.0b	282b	2.59b	3.21b
FYM	82.0bc	238c	2.57b	2.94bc
EM + wheat straw	81.0cd	205de	1.79cd	2.51de
EM + rice straw	81.0cd	201de	1.78cd	2.45de
N + P fertilizers	102.0a	349a	4.36a	7.29a

Treatment means in a column sharing the same letters are not significantly different at the 5% Probability level.

Nutrient Uptake by Wheat. Tables 2, 3 and 4 show, respectively, the N, P, and K uptake by wheat as affected by the various treatments. Significantly higher N, P and K uptake was observed in wheat grain and straw from the fertilizer treatment. The EM+FYM treatment and FYM alone were significantly different from each other except for N uptake by straw; the EM+FYM treatment was also superior to FYM alone in P and K uptake by grain and straw. The remaining treatments were superior to the control but were not significantly different from one another. The N, P, and K uptake associated with the organic/biological treatments were low compared to the fertilizer treatment.

Table 2. Nitrogen Uptake by Wheat as Affected by EM and Fertilizer Application.

Treatment	Nitrogen Uptake (kg ha^{-1})		
	Grain	Straw	Total
Control	19.9g	6.4e	26.3
Wheat straw	26.8f	8.2de	35.0
Wheat straw + FI	40.0d	10.6bcd	50.6
EM sprayed on crop	34.4de	10.4bcd	44.8
EM applied to soil	30.8ef	9.0cde	39.8
EM + FYM	61.5b	11.8bc	73.3
FYM	55.5c	12.4b	67.9
EM + wheat straw	35.9de	9.9bcd	45.8
EM + rice straw	37.2d	9.2cde	46.4
N + P fertilizers	102.0a	39.4a	141.4

Treatment means in a column sharing the same letters are not significantly different at the 5% Probability level.

Table 3. Phosphorus Uptake by Wheat as Affected by EM and Fertilizer Application

Treatment	Phosphorus Uptake (kg ha^{-1})		
	Grain	Straw	Total
Control	2.6d	4.5d	7.2
Wheat straw	3.8d	6.2cd	10.0
Wheat straw + FI	5.2c	7.2c	12.4
EM sprayed on crop	4.6cd	7.0c	11.6
EM applied to soil	4.4cd	6.8c	11.2
EM + FYM	8.8b	9.7b	18.5
FYM	8.1b	9.3b	17.4
EM + wheat straw	5.3c	7.4c	12.7
EM + rice straw	4.7cd	6.4c	11.1
N + P fertilizers	12.1a	20.2a	32.3

Treatment means in a column sharing the same letters are not significantly different at the 5% Probability level.

Table 4. Potassium Uptake by Wheat as Affected by EM and Fertilizer Application

Treatment	Potassium Uptake (kg ha^{-1})		
	Grain	Straw	Total
Control	3.4h	28.1f	31.5
Wheat straw	4.5g	36.0e	40.5
Wheat straw + FI	6.5d	43.1d	49.6
EM sprayed on crop	5.4f	39.6de	45.0
EM applied to soil	5.4f	37.5e	42.9
EM + FYM	10.6b	54.7b	65.3
FYM	9.1c	48.8c	57.9
EM + wheat straw	5.8ef	40.8de	46.6
EM + rice straw	5.9e	39.5de	45.4
N + P fertilizers	13.9a	123.2a	137.1

Treatment means in a column sharing the same letters are not significantly different at the 5% Probability level.

Effect of EM and Organic Amendments on Rice and Wheat Production

Growth and Yield of Rice. A study of the effect of organic amendments and EM on crop production in a rice-wheat rotation was initiated in 1990. Harvest data on the growth and yield of rice are presented in Tables 5 and 6. Plant height was greater with application of EM than without. Among the other treatments, NPK fertilizer resulted in maximum plant height both with and without EM application. Green manure was better than FYM, both of which were superior to the control. The number of tillers was affected by the various treatments in the same manner as plant height; maximum number of tillers occurred with the fertilizer treatment (Table 5).

Paddy rice and straw yield data presented in Table 6 showed that the EM application gave slightly better yields; this might have been the result of the initial use of EM, i.e., the associated microorganisms in EM may not yet have become fully established in the soil (Higa and Wididana, 1991). Similar results were obtained by Lee (1991) who found that EM application resulted in a slight increase in growth and yield of rice; however, yields for the control and compost treatments were only 70 to 80 percent of those with the fertilizer treatment. In the present study, maximum paddy rice and straw yields were obtained with the fertilizer treatment and were followed by the green manure and farmyard manure treatments.

Table 5. Effect of EM and Organic Amendments on Plant Height and Number of Tillers of Rice.

Treatment	Plant Height (cm)		Tillers (no. m^{-2})	
	No EM	EM	No EM	EM
Control	81	84	143	167
NPK fertilizer	97	102	276	298
Green manure (GM)	88	97	206	220
Farmyard manure (FYM)	83	92	187	201

Table 6. Effect of EM and Organic Amendments on Grain and Straw Yield of Paddy Rice.

Treatment	Grain Yield (t ha^{-1})		Straw Yield (t ha^{-1})	
	No EM	EM	No EM	EM
Control	2.11	2.48	3.46	4.08
NPK fertilizer	5.04	5.19	8.22	8.46
Green manure (GM)	4.10	4.36	5.77	6.33
Farmyard manure (FYM)	3.93	4.06	5.65	5.96

In a similar-type of microplot experiment conducted in Myanmar, the resulting grain and straw yields were in the order of green manure > fertilizer > control > straw (Myint, 1991). The effect of

EM was positive; however, the differences between the yield components in EM-treated and untreated plots were not significant. A similar study conducted in Taiwan by Lin (199l) revealed that organic matter gave higher yields than the fertilizer treatment. He reported that the principal disadvantage of using organic matter is the low content of plant nutrients and their slow rate of release. Consequently, large amounts of most organic amendments are required to sustain the growth and yield of crops. He also reported that EM significantly increased the growth and yield of rice.

Growth and Yield of Wheat. After the initial rice crop, a following wheat crop was grown in the same plots with same treatments. Observations on growth and yield were recorded at the harvest stage, and similar results were obtained as for rice. Plant height and number of tillers (Table 7) showed maximum values with the fertilizer treatment and were followed by green manure and farmyard manure treatments; these treatments were superior to the control. It was observed that EM increased plant height and the number of tillers in the green manure and farmyard manure treatments over the control, but the response was reversed for the fertilizer treatment.

Grain and straw yield of wheat were also affected in a similar manner, in which EM did not enhance these parameters in the fertilizer treatment (Table 8). These results are in agreement with those of Lin (199l) for rice where EM did not affect yields obtained with chemical fertilizers. In the present study, the effect of EM application was more pronounced for the second crop (wheat) than for the first crop (rice). This supports the idea that the effectiveness of EM increases with successive applications and time. In this study the overall effectiveness of the treatments were in the order: fertilizer > green manure > farmyard manure > control. While EM was found to be slightly beneficial to the growth and yield of crops, the differences were not always statistically significant.

Table 7. Effect of EM and Organic Amendments on Plant Height and Number of Tillers of Wheat.

Treatment	Plant Height (cm)		Tillers (no. m^{-2})	
	No EM	EM	No EM	EM
Control	78	85	299	315
NPK fertilizer	96	87	347	328
Green manure (GM)	86	87	317	333
Farmyard manure (FYM)	83	86	263	323

Table 8. Effect of EM and Organic Amendments on Grain and Straw Yield of Wheat.

Treatment	Grain Yield (t ha^{-1})		Straw Yield (t ha^{-1})	
	No EM	EM	No EM	EM
Control	1.63	1.93	2.10	2.43
NPK fertilizer	3.69	3.41	4.84	4.69
Green manure (GM)	2.72	3.44	4.18	4.43
Farmyard manure (FYM)	2.04	2.82	2.42	3.93

Effect of EM on the Nitrogen Content of Organic Materials After Composting

In this study five organic materials were subjected to composting in duplicate pits. The original percentage N analysis for these materials is shown in Table 9. In one set EM was not applied (control), whereas the other set was subjected to EM treatment. After 15 and 45 days of composting, samples from each treatment were analyzed for their N content (Table 9). At both sampling times, it was noted that EM enhanced the decomposition and mineralization of all organic materials resulting in higher N percentages compared with their respective controls. Among the various organic wastes and residues, poultry manure was found to have the highest percentage of N after composting, both with and without EM application. On the other hand, wheat and rice straw were the least decomposed which may have resulted from their inability to retain sufficient moisture to support active microbial decomposition. City waste was moderately decomposed; it contained a variety of materials some of which were difficult to decompose. The results indicate that composts can be made safely and beneficially in considerably less time with the addition of EM.

Table 9. Effect of EM on the Nitrogen Content of Organic Materials Initially and After 15 and 45 Days of Composting with and without EM.

Organic Material	Nitrogen Content (%)				
	Initially	After 15 Days		After 45 Days	
	No EM	No EM	EM	No EM	EM
Farmyard manure	0.42	0.49	0.70	0.70	0.84
Poultry manure	0.56	0.84	1.19	0.98	1.26
Wheat straw	0.35	0.42	0.49	0.49	0.56
Rice straw	0.28	0.28	0.35	0.42	0.49
City waste	0.35	0.49	0.56	0.56	0.63

References

Akhtar, C.M. 1990. A microbial approach to boost the crop yields. p.51-74. In Proc. National Seminar on Economic Revival of Small Farmers. University of Agriculture, Faisalabad, Pakistan.

Arakawa, Y. 1991. Kyusei Nature Farming in Japan. p. 20-23. In J.F. Parr, S.B. Hornick and C.E. Whitman (ed.) Proceedings of First International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C. USA.

Azad, M.I. and M.Y. Yousaf. 1982. Recycling of organic matter to improve the soil productivity. Pakistan J. Agric. Res. 22(2):15-18.

Azam, F. 1988. Studies on organic matter fractions of some agricultural soils of Pakistan. Sarhad J. Agi. 4(3):364-369.

Higa, T. and G.N. Wididana. 1991. Changes in the soil microflora induced by effective microorganisms. p. 153-162. In J.F. Parr, S.B. Hornick, and C.E. Whitman (ed.) Proceedings of First International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C. USA.

Lee, K.H. 1991, Studies on effective microorganisms application. APNAN 2nd Steering Committee Meeting held January 25-27, 1991 in Kuala Lumpur, Malaysia.

Lin, D.L. 1991. Effects of organic amendments and effective microorganisms on rice production. APNAN 2nd Steering Committee Meeting held January 25-27, 1991 in Kuala Lumpur, Malaysia.

Myint, C.C. 1991. The effect of organic amendments and effective microorganisms on crop production. APNAN 2nd Steering Committee Meeting held January 25-27, 1991 in Kuala Lumpur, Malaysia.