Yields of Rice and Maize as Affected by Effective Microorganisms

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Abstract

The growth and yield of EM treatment of seed, seedling nursery bed, field and all above combinations in paddy rice and maize were investigated. EM cultures were applied 2 to 6 times at dose of 20 l per ha. The yield of rice and maize increased by 7.2 to 7.4% in seed treatment, 7.1 to 7.4% in seedling nursery bed treatment, 4.2 to 13% in field treatment, 9.5 to 14.9% in combination treatment, and 9.0 to 30% on continuous application of EM than each control. Application of EM increases the number of beneficial microorganisms, available nutrients and content of organic matter in soil, and it enhanced the neutralization of soil.

Introduction

It is suggested that Effective Microorganisms (EM) increase the numbers of beneficial microorganisms in soil, thus maintaining the natural ecosystem of the cultivated land and diminishing the risk of environmental pollution with improved crop productivity and quality (Higa, 1991).

EM is known to solubilize and make available the nutrients required by crop plants and suppress the infestation of harmful microorganisms and improve soil texture by increasing the humus content (Higa, 1991).

This paper presents the results from our research conducted from 1994 to 1997 on effect of EM in rice and maize crops.

Materials and Methods

EM_1 was used throughout the experiments and was made using molasses. For seed treatment, seeds were immersed for 24 hours under dark in a EM solution diluted 1000 times.

For nursery seedbed treatment and main field application, EM was applied by spraying at the rate of 20 L/ha after diluting 1000 times. For combined treatment of EM and Bokashi, 1.5 L of EM_1 and molasses were dissolved in 150 L of water and mixed with one ton of Bokashi. The resultants were fermented for 10 days under anaerobic conditions before use. Bokashi was made from rice bran, bean cake and fish meal. For combined application of EM and farmyard manure, 2 L of EM_1 and molasses were dissolved in 200 L of water and mixed with one ton of farmyard manure for fermenting for 15 days under anaerobic conditions. The fermented Bokashi or farmyard manures were evenly applied to field and ploughed between April 20 and 30 each year.

Experiments were conducted based on completely randomized design with 4 replications. Plot size was 10 m^2. The yield of each treatment was estimated by harvesting and weighing all plants in the plots. The data obtained were subjected to analysis of variance and mean separation. The number of microorganisms was counted by the dilution plate method. The pH of soil was measured as eluted by IN KCI solution. The content of soluble nitrogen was assayed by the alkaline hydrolysis method, the soluble phosphorus content by the calorimatric method using molybdenum blue, and the soluble potassium content by the flame spectrophotometric method.

Results and Discussion

Effect of EM on the Yield of Rice and Maize

Out of 11 experiments conducted in rice (Table 1), 6 experiments (55 percent) showed positive response to EM treatment. When Bokashi fermented with EM was applied, 7 experiments (70 percent) showed positive effect.

Table 1. Effect of EM Treatment on Rice Yield (Kg/ha)

Location	Manuring System	Control	EM[2)]	EM+B[3)]	Increase [1)] EM	Increase [1)] EM+B
1	$N_{80}P_{60}K_{40}$	6,173	6,214	6,206	41	33
	$N_{80}P_{30}K_{25}$	6,350	6,280	6,150	-70	-200
	$N_{100}P_{30}K_{25}$ +20t FM[4]	6,020	6,450		430*	
2	$N_{60}P_{20}K_{o}$+20t FM	6,360	7,592	8,262	1,232*	1,902*
	$N_{120}P_{40}K_{o}$	7,800	8,212	8,375	412	575*
	$N_{50}P_{50}K_{50}$ + 20t FM	6.937	7,631	7,934	694*	997*
	$N_{160}P_{80}K_{0}$	8,154	8,714	9,216	560*	1,062*
	$N_{160}P_{80}K_{0}$	8,944	9,266	9,570	322	626*
	$N_{80}P_{40}K_{50}$	7,672	7,875	8,028	203	356
	$N_{60}P_{60}K_{50}$ + 20tFM	6,846	7,534	8,046	688*	1,200*
	$N_{80}P_{60}K_{40}$ +20t FM	4,780	5,250	5,490	470*	710*
	Mean	6,912	7,365	7,728	453	816
	Index	100.0*	106.6	111.8		

1) Increase over control, 2) EM treatment, 3) Combined treatment of EM+Bokashi, 4) Farmyard manure
*Significant at 0.05 level.

In maize (Table 2), significant effect of EM treatment was found in two (25 percent) of 8 experiments conducted. However, combined treatment of EM and Bokashi showed significant effect in all 3 experiments.

Table 2. Effect of EM treatment on Maize Yield(kg/ha)

Manuring System	Control	EM[2)]	EM+B[3)]	Increase [1)] EM	Increase [1)] EM+B
$N_{80}P_{80}K_{40}$	7,077	7,371	7,812	294	735 *
$N_{160}P_{0}K_{60}$	9,168	9,370	9,796	202	628 *
$N_{160}P_{0}K_{0}$	9,244	9,306	--	62	--
$N_{80}P_{0}K_{0}$	10,116	10,407	--	291	--
$N_{40}P_{0}K_{0}$	10,006	10,438	--	432	--
$N_{100}P_{70}K_{50}$ + 20t FM[4)]	6,450	6,930	--	480 *	--
$N_{80}P_{60}K_{50}$	4,809	5,154	--	345	--
$N_{60}P_{60}K_{50}$ + 20t FM	6,804	7,447	7,680	643 *	876 *
Mean	7,959	8,303	8,429	344	766
Index	100.0	104.3	105.9		

1) Increase over control, 2) EM treatment, 3) Combined treatment of EM+Bokashi, 4) Farmyard manure
*Significant at 0.05 level.

As shown in Tables 1 and 2, significant effects of EM treatment were obtained only in plots with 20 ton/ha of farmyard manure or 1 ton/ha of Bokashi. Without application of manure or Bokashi, positive effects of EM were not found. According to this result, it appears that a sufficient amount of organic matter as the carbon source should be provided for the positive effect of EM which consists of active microorganisms.

Effect of EM on the Number of Effective Microorganisms in Soil

EM treatment increased the number of aerobic bacteria, nitrogen-fixing bacteria, and Actinomycetes 10.5, 17.8, 49.6, and 1.7 times over control, respectively (Table 3).

Table 3. Effect of EM on the Number of EM in Soil

Plot	AB[1)] ($X10^7$)	AAB[2)] ($x10^6$)	Act[3)] ($x10^5$)	Nit[4)] ($x10^4$)	FF[5)] ($x10^4$)
Control	1.1	1.3	1.5	1.1	5.3
EM+Bokashi	11.6	23.1	2.6	54.6	6.0

[1)]Aerobic bacteria, [2)] Anaerobic bacteria, [3)] Actinomycetes, [4)] Nitrogen fixers, [5)] Filamentous fungi

However, there was a slight increase (1.1 times over control) of the number of filamentous fungi where major pathogens occur.

The increase of the number of effective microorganisms might be ascribed to the fact that EM itself contains large number of effective microorganisms and biologically active substances excreted by them stimulated by the growth of effective microorganisms. Thus, EM treatment might create a soil environment favourable for effective microorganisms, and accelerate the solubilization of nutrients in the soil. (Higa, 1991).

Effect of EM Treatment on the Content of Nutrients in Soil

EM treatment increased the content of soluble nutrients in soil. The contents of soluble nitrogen, phosphorous and potassium increased 4.4, 3.6 and 2.8 mg/100g soil, respectively (Table 4). pH of the soil treated with EM was 0.1 higher than control.

The increase of soluble N, P and K contents might be attributed to activity of nitrogen fixers and organic acids excreted by different organisms of the EM.

Table 4. Effect of EM Treatment on the Content of Soluble Nutrients in Soil

		Content of soluble Nutrients (mg/100g soil)		
Treatment	pH (KCl)	N	P_2O_5	K_20
Control	5.1	8.3	12.3	20.0
EM+Bokashi	5.2	12.7	15.9	22.8

Plant Growth Stimulation by EM Treatment

When rice seeds were treated with EM after diluted 1,000 times, root development was promoted and dry matter weight remarkably increased (Table 5). After cutting rice shoots 1cm long and dipping in the 100 time-diluted solution of EM for 48 hours under dark, the shoot length was 2.3 mm longer than control (dipped in water). Such promotion might be due to biologically active substances in EM.

Table 5. Growth Promotion by EM Treatment

Treatment **	No. of Roots per Plant	Length of Roots (cm/plant)	DW of Roots (mg/root)	Length of Shoot (mm)
Control	7.6	17.2	48.8	11.5
EM treatment	13.7	20.8	62.3	13.8

** 100 plants measured

Effect of Combination of Different Treatments of EM

EM should be applied to soil several times in order to increase the density of EM in soil. This may be achieved by combination of different treatments like seed treatment, nursery seedbed treatment and main field application.

According to our results (Table 6), such combined treatments enabled to increase the density of EM in each cultural operation. Thus, growth of crop plants was improved as a whole, resulting in yield increase.

Table 6. Effect of Combination of EM Treatments on Rice and Maize Yield (kg/ha)

Treatment	Rice (Pyongyang No. 21)			Maize (Hwasong No.1)		
	Yield	**Increase**	**%**	**Yield**	**Increase**	**%**
Control	4.780	--	100	6,804	--	100
EM combined treatment **	5.250	470*	109.8	7,447	643*	109.5
EM combined treatment+Bokashi**	5,490	710*	114.9	7,680	876*	112.9

* Significant at 0.05 level
** Total amount of EM used for treatment 125 l/ha

Effect of Continuous Application of EM

Continuous application to the same soil of EM increases the density of EM in soil with its effect improved.

Effect of EM on rice yield was higher in the third year than that in the first year of application (Table 7).

Table 7. Effect of Continuous Application of EM on Rice Yield

Year	Treatment	Yield (Kg/ha)	Increase Kg	Increase (%)
Year 1 (1994)	$N_{60}P_{60}K_{50}$ + 20 tons of farmyard manures	6,250	--	100
	$N_{60}P_{60}K_{50}$ EM treatment (6 times 20 L/ha each)	6,810	560*	109.0
	$N_{60}P_{60}K_{50}$ EM treatment (6 times 20 L/ha each) + 1 ton of Bokashi	7,072	822*	113.1
Year 3 (1996)	$N_{60}P_{60}K_{50}$ + 20 tons of farmyard manures	6,846	--	100
	$N_{60}P_{60}K_{50}$ EM treatment (6 times 20 L/ha each)	7,534	688*	110.0
	$N_{60}P_{60}K_{50}$ EM treatment (6 times 20 L/ha each) + 1 ton of Bokashi	8,046	1,200	117.5

* Significant at 0.05 level

Application of a Large Dose of Organic Fertilizers as a Source of Nutrition for EMs

Availability of source of energy is a limiting factor for rapid propagation of microorganisms of EM. Significant EM effects were obtained when EM was applied together with farmyard manures or Bokashi (Table 8). However, sole application of EM seldom generated significant yield increase over control.

Table 8. Effect of Rice Yield of the Farmyard Manures and Bokashi Fermented with EM

Treatment	Yield (Kg/ha)	Increase (Kg)	Increase (%)
Control ($N_{50}P_{50}K_{40}$)	6,926	--	100
$N_{50}P_{50}K_{40}$ + EM treatment (5 times 20 l/ha each)	7,631	705	110.2
$N_{50}P_{50}K_{40}$+ EM treatment (5 times 20 l/ha each) + 2.5 tons of the fermented farmyard manures	8,341	1,415	120.4
$N_{50}P_{50}K_{40}$+ EM treatment (5 times 20 l/ha each) + 1 ton of the fermented Bokashi	7,933	1,007	114.5
$N_{50}P_{50}K_{40}$+ EM treatment (5 times 20 l/ha each)			

These results showed that EM is effective when available carbon or energy source is sufficient.

Effect of EM and Dose of Chemical Fertilizers

EM was more effective in lower doses than in higher doses of chemical fertilizers (Table 9, 10).

Table 9. Effect of EM on Rice Yield in Different Dose of Nitrogen Fertilizer

Treatment	Yield (Kg/ha)	Increase (Kg)	(%)
Control ($N_{160}P_{60}$ + 20 tons of FM)	8,944	---	100
$N_{160}P_{60}$+ 20 tons of FM + EM treatment (6 times 20 l each)	9,266	322	103.6
$N_{160}P_{60}$+ 20 tons of FM+ EM treatment (6 times 20 l each) + 1 ton/ha Bokashi	9,570	626*	107.0
Control ($N_{160}P_{60}$ + 20 tons of FM)	8,154	---	100
$N_{120}P_{60}$+ 20 tons of FM + EM treatment (6 times 20 l each)	8,714	560*	106.9
$N_{160}P_{60}$+ 20 tons of FM+ EM treatment (6 times 20 l each) + 1 ton/ha Bokashi	9,216	1.062*	113.0

* Significant at 0.05 level

Table 10. Effect of EM on Maize Yield in Different Doses of Nitrogen Fertilizers

Treatment	Yield (Kg/ha)	Increase (Kg)	(%)
No + 10 tons of FM	10,116	--	100
No + 10 tons of FM + EM treatment (4 times, 20 l each)	10,407	291	102.9
N_{40} + 10 tons of FM	10,006	--	100
N_{40} + 10 tons of FM + EM treatment (4 times, 20 l each)	10,439	433	104.3

Conclusions

Significant effects of EM in terms of yield were obtained in the soils applied with farmyard manure or Bokashi. Otherwise, EM treatment rarely improved crop yields. Effect of EM might be due to the enhanced number of beneficial microorganisms, the increased contents of soluble nutrients, and action of physiological active substances.

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