Effect of Organic Amendments and EM on Crop Production in Bangladesh

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Abstract
A series of four experiments, including one pot experiment, with four treatments (control, fertilizer, cow dung, and rice straw) with and without effective microorganisms (EM) were conducted in Bangladesh. The crops were string bean, rice, red pepper (grown in pots), and Indian spinach. In most cases, the amendments significantly influenced yield. EM increased yield of string bean (146percent) and red pepper (up to 98 percent) except when red pepper was grown on soil amended with rice straw. Rice yields were consistently but non-significantly increased (17percent) as a result of EM application. EM slightly but negatively influenced the yield of Indian spinach.

Introduction
With the domestication of plants, crops were grown without chemical fertilizers and pesticides for centuries. With an increasing demand for food, feed, and fiber there was a need for increased crop production. It had been long observed that the application of organic wastes and residues increased crop yields. Therefore, the use of organic amendments as soil conditioners and biofertilizers in crop production was begun and is still an important component of farming systems worldwide. With further demand for increased crop yields per unit area, the use of synthetic chemicals in agriculture was established and has created a new era for the agricultural revolution. However, the use and misuse of agricultural chemicals has caused considerable harm to the environment, and has raised the concern of people and governments throughout the world. Thus, in response to environmental conditions, many countries are examining the merits of organic fanning. Chemical fertilizers, especially nitrogen, is applied at much higher rates than is actually required by the crop because of anticipated losses through leaching, surface run-off, volatilization, and denitrification. Overuse of fertilizers not only pollutes farmland, and surface and ground water, but the entire ecosystem and can cause adverse effects on human and animal health

Professor Teruo Higa, a horticulturist at the University of Ryukyus, Okinawa, Japan has developed a technology whereby mixtures of co-existing, beneficial microorganisms belonging to 10 genera and 80 species are applied to plants and soil. These microorganisms are reported to improve the availability of soil nutrients, and the growth, yield and health of crops. He has termed this mixture of co-existing microorganisms as Effective Microorganisms (EM). It has been reported that if EM is used for a few consecutive years it can significantly reduce the need for chemical fertilizers and also the use of insecticides and herbicides. EM can improve conditions in the plant rhizosphere as demonstrated in studies conducted in Thailand.

Draft power for plowing land in Bangladesh causes serious problems which may be at least partly overcome if the use of EM can improve soil physical properties as has been reported in Thailand. The draft requirement for plowing the land in many cases can be reduced.

Because of various socioeconomic, environmental and educational limitations in the poorer sections of Bangladesh, farmers can not afford to buy agrichemicals and, hence, productivity of their fanning systems is very poor. Because EM is inexpensive and easy to apply, this technology would be more easily adopted by fanners in Bangladesh than high-input technologies.

No research with EM has been done in Bangladesh. Therefore, as a part of the centrally-designed research program of the Asia Pacific Natural Agriculture Network (APNAN) that was founded in 1989, this study was undertaken to test the efficacy of EM to increase the production and productivity of rice and three horticultural crops in Bangladesh.

Materials and Methods
A series of four experiments were conducted in this investigation. The crops used in the experiments were string bean (*Vigna sesquipedalis* (L.) *Fruw*), rice (*Oryza sativa*), red pepper

(*Capsicum fructescens* L.), and Indian spinach (*Basella alba*). The field experiment with rice was conducted at the Bangladesh Rice Research Institute, Joydebpur, Gazipur; the other experiments were conducted at the Institute of Postgraduate Studies in Agriculture (IPSA), Salna, Gazipur, Bangladesh. Weather and climatic data for this location are reported in Appendix Table1.

Treatments

Factor A. Effective microorganisms (EM) were present or absent in each of the experiments,

Factor B. Amendments were used as follows:

T1 control

T2 recommended chemical fertilizer application

T3 cow dung at 10 t/ha

T4 rice straw at 10 t/ha

In the rice experiment, cow dung and rice straw were applied at 6 t/ha. In the pot experiment with red pepper an additional treatment of cow dung at 20 t/ha was used. With these exceptions, all treatments were the same for all four experiments.

Design

For all experiments a split-plot design was used, as was recommended by the APNAN Steering Committee, with EM as the main plot factor. The treatments were replicated three times.

Recommended Fertilizers for Crops

Fertilizers applied to the crops were as follows:

string bean - 21:44:28 (N:P:K)
rice - 80:25:35:20:5 (N:P:K:S:Zn)
red pepper - 42:39:35 (N:P:K)
Indian spinach - 62:44:4 1 (N:P:K)

Application of Organic Amendments and EM

Rock phosphate at a rate of 200 kg/ha was applied to each plot after plowing. Two weeks before planting the crops, cow dung, rice straw, and the recommended rate of chemical fertilizer were spread on the plots according to treatment. The plots were then sprayed with Super EM 4 (1:1000 dilution EM:water) at 1liter/m^2 and plowed down. The crops were subsequently sprayed 5 times at 10-day intervals with 1liter/m^2 of diluted EM 2, EM 3 and EM 4, in the absence of direct sunlight.

Planting of Crops

String bean and Indian spinach seeds were sown on April 7, 1991 in polyethylene pots and 15-day old seedlings were transplanted into the field at a spacing of 74 x 60 cm for string bean and 100 x 50 cm for Indian spinach. The plot size was 6 x 3 m. String bean plants were supported by bamboo branches of 2 meters in height.

Seeds of a local variety of red pepper were sown on March 3, 1991 and transplanted into earthen pots measuring 30 cm in diameter on April 11, 1991.

Rice seedlings of the cultivar BR-1 were transplanted at 28 days on May 23, 1991 with a spacing of 25 x 20 cm.

Management of Crops

Weeding, irrigation, and spraying of pesticides, occurred as necessity arose. It should be mentioned here that no crop remained free from weeds and diseases as a result of the EM application.

Harvesting of Crops

String beans were harvested from June 19 to August 20; Indian spinach from May 15 to August 6; rice on August 24; and red peppers from July 25 to August 20, 1991.

Results and Discussion

The results of this series of experiments are presented and discussed by crop. Only in pertinent cases are the main effects of organic amendments and effective microorganisms (EM) and their interactions presented and discussed separately in order to elucidate the combined effects and individual treatment effects.

String Bean

Effective Microorganisms. Effective microorganisms (EM) significantly influenced the number and weight of nodules, number of fruits, shoot weight and pod yield, but the weight of roots was not much affected (Table 1). Shoot and root weights were lower in plots receiving EM than those where EM was not applied. This is in agreement with Higa (1990) who stated that because of the production of a less dense shoot system in the EM-treated plants, the possibility for intercepting light is greater and would lead to a higher photosynthetic rate and ultimately to greater yields. Visual observations revealed that the foliage of EM-treated plants was less dense, with a darker green color than the plants without EM. Application of EM significantly increased the number and weight of nodules, number of fruits and yield. Hoque and Sattar (1989) reported that increased nodulation in pulse legumes resulted in yield increases up to 70 percent. The yields in this experiment were increased by 130 percent from the application of EM.

Table 1: Effect of EM on Yield and Yield Contributing Characters of String Bean.

Treatment	Shoot Weight/ Plant (kg)	Root Weight/ Plant (g)	Nodules/ Plant (no.)	Weight of Nodules/ Plant (g)	Fruits/ Plant (no.)	Yield (t/ha)	Yield Increase (%)
EM	0.76b	70.2b	224.3a	11.7a	19.4a	10.8a	130
No EM	0.98a	82.8a	119.1b	3.5b	8.5b	4.7b	-
LSD (5%)	0.03	0.8	1.7	0.1	0.3	0.2	

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

Organic and Fertilizer Amendments. All of the parameters recorded were highly influenced by the use of organic amendments (Table 2). There was, however, no difference in shoot weight between the control and rice straw treatments. Application of the recommended fertilizer and cow dung produced statistically equal shoot weights which were greater than the control or rice straw. Root weights differed greatly as a result of the amendment treatments with the control plots producing the least, and the fertilizer plots producing the most. The amendments were statistically different from each other with respect to nodule number and nodule weight. Cow dung was superior to all other treatments followed by the recommended chemical fertilizer rate, rice straw, and control. The trend for the production of numbers of fruit was the same except that there were no statistical differences between the recommended fertilizer and cow dung and between the recommended fertilizer and rice straw. The highest yields were obtained with cow dung (8.5 t/ha), followed by fertilizer (8.1 t/ha), rice straw (7.7 t/ha) and the control (6.7 t/ha).

Table 2: Effect of Amendments on Yield and Yield Contributing Characters of String Bean.

Treatment	Shoot Weight/ Plant (kg)	Root Weight/ Plant (g)	Nodules/ Plant (no.)	Weight of Nodules/ Plant (g)	Fruits/ Plant (no.)	Yield (t/ha)	Yield Increase (%)
Control	0.75b	65.9d	71.2d	3.1d	12.0c	6.7d	-
Fertilizer	0.96a	84.5a	200.0b	9.3b	14.5ab	8.1b	20.9
Cow dung	0.94a	82.9b	244.2a	10.1a	15.3a	8.5a	26.4
Rice straw	0.82b	72.8c	172.5c	7.8c	13.9b	7.7c	14.9
LSD (1%)	0.07	1.4	7.7	0.6	0.8	0.4	

Treatment means in a column sharing the same letters are not significantly different at the 1% level of probability

Interaction Between EM and Organic Amendments. The organic amendment treatments and EM were highly interactive in the yield and yield contributing characters of string bean (Table 3). Except for shoot weight there were clear statistical differences in all the parameters between EM and non-EM plots. Shoot and root weights with all amendments were lower in the EM plots compared with the non-EM plots. But the EM-treated plots significantly exceeded the non-EM plots with respect to number and weight of nodules, and the yield and numbers of fruit. This was the case for all of the organic amendments. With respect to these parameters, the highest yields were produced with cow dung and EM (12.1 t/ha), followed by fertilizer and EM (11.4 t/ha), rice straw and EM (10.4 t4la), and the control and EM (9.4 t/ha). The increased yields in the EM plots over those of non-EM plots were 146 percent with cow dung, 138 percent with the fertilizer, 131 percent with the control and 105 percent wit rice straw. The results of this experiment are in agreement with Sangakkara (1991) in which the application of EM increased the potential nitrogen-fixing capacity of legumes through greater nodulation.

Table 3: Effect of EM and Organic Amendments on the Yield and Yield Contributing Characters of String Bean.

Treatment	Shoot Weight/ Plant (kg)	Root Weight/ Plant (g)	Nodules/ Plant (no.)	Weight of Nodules/ Plant (g)	Fruits/ Plant (no.)	Yield (t/ha)	Yield Increase (%)
Control							
EM	0.61b	57.9f	112.7g	5.4d	16.9c	9.4d	131
No EM	0.89ab	74.0d	29.7h	0.8g	7.3e	4.1f	-
Fertilizer							
EM	0.81ab	82.0c	254.7b	14.3b	20.4a	11.4b	138
No EM	1.12a	87.0b	145.4e	4.4e	8.6de	4.8e	-
Cow dung							
EM	0.91ab	75.3d	312.0a	15.0a	21.7a	12.1a	146
No EM	0.97ab	90.4a	174.3d	5.3d	8.8d	4.9e	-
Rice straw							
EM	0.70ab	65.5e	218.0c	12.0c	18.7b	10.4c	105
No EM	0.94ab	80.0c	127.0f	3.5f	9.1d	5.0e	-
LSD (1%)	0.44	2.2	4.2	0.4	1.4	0.5	

Treatment means in a column sharing the same letters are not significantly different at the 1% level of probability

Yield increases of this leguminous crop as a result of the application of EM may be interpreted in terms of greater nitrogen availability in the soil that resulted from greater nodulation. In addition, the availability of other essential nutrients may have been higher because of the faster decomposition of organic matter due to EM. Since root nodule activity depends on enzyme activity which, in turn, depends on the growth and activity of soil microorganisms (Higa, 1990), the EM-treated plants may have had more active root systems leading to higher yields.

Rice

Effective Microorganisms. The analysis of variance showed that there were no statistical differences between EM and non-EM plots in any of the parameters studied (Table 4). Nonetheless, EM applications slightly increased plant height (1.5 percent), number of panicles (8.4 percent), number of tillers (7.8 percent), and yield (8.7 percent) over the non-EM plots. The number of non-effective tillers in the non-EM plots were slightly increased (4.8 percent) over the EM plots.

Table 4: Effect of EM on the Yield and Yield Contributing Characters of Rice.

Treatment	Plant Height (cm)	Panicles/m^2 (no.)	Tillers/m^2 (no.)	Non-Effective Tillers/m^2 (no.)	Yield (t/ha)	Yield Increase (%)
EM	69	324	345	21	3.9	8.5
No EM	68	299	321	22	3.6	-
	NS	NS	NS	NS	NS	

Organic and Fertilizer Amendments. There were no statistical differences among the amendments with respect to plant height, number of non-effective tillers and grain yield (Table 5).

The number of tillers and panicles were significantly higher in plots with fertilizer and cow dung than in the control plots. Yield was increased over the control plots by 13.8, 3.5 and 12.2 percent from the application of fertilizer, cow dung, and rice straw, respectively.

Table 5: Effect of Amendments on the Yield and Yield Contributing Characters of Rice.

Treatment	Plant Height (cm)	Panicles/m^2 (no.)	Tillers/m^2 (no.)	Non-Effective Tillers/m^2 (no.)	Yield (t/ha)	Yield Increase (%)
Control	67	275b	296b	21	3.4	-
Fertilizer	69	335a	356a	22	4.0	13.8
Cow dung	68	337a	357a	20	3.6	3.5
Rice straw	70	298ab	322b	23	3.8	12.2
LSD(5%)	NS	42	33	NS	NS	

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

Interaction Between EM and Organic Amendments. Except for the number of non-effective tillers, the interaction between EM and amendments were non-significant (Table 6). For all the organic amendments, the EM plots consistently produced slightly higher grain yields than the non-EM plots as reported for the control (16.7 percent), fertilizer (8.9 percent), cow dung (2.3 percent), and rice straw (9.3 percent).

Table 6: Effect of EM and Amendments on the Yield and Yield Contributing Characters of Rice.

Treatment	Plant Height (cm)	Panicles/m^2 (no.)	Tillers/m^2 (no.)	Non-Effective Tillers/m^2 (no.)	Yield (t/ha)	Yield Increase (%)
Control						
EM	68	283	302	18bc	3.7	16.7
No EM	66	267	290	23b	3.2	-
Fertilizer						
EM	70	365	394	30a	4.2	8.9
No EM	68	305	318	13cd	3.8	-
Cow dung						
EM	69	352	373	21b	3.6	2.3
No EM	67	323	341	18bc	3.5	-
Rice straw						
EM	71	296	309	12d	4.0	9.3
No EM	69	300	334	34a	3.7	-
LSD(5%)	NS	NS	NS	5.5	NS	

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

The slight but consistent increase in grain yield as a result of the application of EM was the result of a slight increase in the number of tillers and panicles per unit area.

The influence of EM may or may not be seen in the first year of an experiment. According to Harakawa and Higa (1991), crop yields due to EM gradually increased in subsequent years. Therefore, the non-significant increase in yield with EM in the first year of the rice experiment might have been expected. There are reports (Lin, 1991) that EM in the presence of added organic matter increased rice yields. Such increased yields may have resulted from the production of highly active growth promoting substances released by the microbial inoculants (Gray and Williams, 1971) and/or the increased fertility resulting from enhanced microbial metabolism (Rao, 1986). Thus, it is not possible to draw final conclusions in this regard.

Red Pepper

The crop was adversely affected by heavy rains beginning in May and was also severely damaged by viral diseases. The plants grown with EM were slightly less affected than those grown without EM. The differences in yield between EM and non-EM treated plants was so distinct that no statistical analyses were necessary (Table 7). Except for rice straw, EM-treated plants produced significantly higher yields than non-EM plants. Lee (1991) also reported significantly higher yields of red pepper from EM treatment. The increased yield from application of EM may have been caused by the production of growth-enhancing compounds such as indole acetic acid and gibberelins which may have positively influenced plant growth and yield (Rao, 1986). The increased availability of plant nutrients from the rapid decomposition of organic amendments by the EM cultures may also have contributed to the higher yields in the EM plots (Higa and Wididana, 1991). Nevertheless, further investigation is needed to confirm this result.

Table 7: Effect of EM and Amendments on the Yield and Yield Contributing Characters of Red Pepper.

Treatment	Fruits/Plant (no.)	Fruits Weight/Plant (g)	Yield Increase (%)
Control			
EM	47.8	42.8	53
No EM	29.3	28.0	-
Fertilizer			
EM	48.7	50.7	98
No EM	24.3	25.6	-
Cow dung (10 t/ha)			
EM	42.5	44.5	96
No EM	25.5	22.7	-
Rice straw			
EM	45.8	45.2	-3
No EM	44.3	46.6	-
Cow dung (20 t/ha)			
EM	75.7	76.7	73
No EM	44.4	44.4	-

Indian Spinach

In the case of Indian spinach, EM failed to significantly influence the yield and other parameters (Table 8). The amendments, however, significantly influenced yield, number of harvested shoots, and weight of stems (Table 9). There were slight differences among the treatments, i.e., control, cow dung and rice straw with respect to the number of harvested shoots, weight of leaves and yield, but the fertilizer treatment produced significantly greater results. The interaction between EM and the organic amendments was non-significant for all the characters studied.

Table 8: Effect of EM on the Yield and Yield Contributing Characters of Indian Spinach.

Treatment	Harvested Shoots/Plant (no.)	Leaves/Plant (no.)	Weight of Leaves/Plant (g)	Weight of Stems/Plant (g)	Yield (t/ha)
EM	30.5	320	241	726	15.9
No EM	29,1	323	222	731	16.9
	NS	NS	NS	NS	NS

Table 9: Effect of Amendments on the Yield and Yield Contributing Characters of Indian Spinach.

Treatment	Harvested Shoots/Plant (no.)	Leaves/Plant (no.)	Weight of Leaves/Plant (g)	Weight of Stems/Plant (g)	Yield (t/ha)
Control	26.8b	318	188b	527c	14.0b
Fertilizer	35.7a	368	324a	935a	19.7a
Cow dung	30.0b	308	204a	732ab	16.7ab
Rice straw	26.4b	292	211b	719bc	15.3b
LSD(1%)	5.5	NS	82	203	3.1

Treatment means in a column sharing the same letters are not significantly different at the 1% level of probability

It is difficult to explain why EM did not influence the yield of Indian spinach in spite of its being the second test crop on the same land. Higa (1990) mentions, however, that in some cases it took as much as ten years to obtain positive effects with EM while, in other cases, the desired results were obtained in the first year; this difference depends on the physical, physico-chemical and biological characteristics of the soil.

Summary and Conclusions

A series of four experiments, one pot and three field studies, were conducted to test the effect of various amendments, with and without EM, on the production of string bean, rice, red pepper and Indian spinach. The treatments included three amendments (fertilizer, cow dung and rice straw) and a control with and without EM. The treatments were replicated three times in a split-plot design. The amendments generally gave positive yield responses compared with the controls; the increase in yield of string beans over the control plots was 20.9, 26.4 and 14.9 percent from the application of fertilizer, cow dung and rice straw, respectively. The increase in yield of rice from these treatments was non-significant but the fertilizer resulted in a 13.8 percent greater yield. These three treatments positively influenced the yield of red pepper. However, the main thrust in this investigation was the influence of EM on crop production. The percentage increase in string bean yield from EM application compared with no EM was 13l, 138, 146 and 105 percent for the control, fertilizer, cow dung and rice straw treatments, respectively. The corresponding increase (non-significant) in rice yield from EM application for these same treatments was 16.7, 8.9, 2.3 and 9.3 percent, respectively; and from red pepper the yield increase was 53, 98, 96 and -3, respectively. The yield of Indian spinach was non-significantly, but negatively, influenced by EM for reasons not understood.

The possible higher nitrogen availability because of greater nodulation may be responsible for higher yields of string beans in the EM-treated plots. The positive effect of EM on the yield of red pepper as well as that of string bean may be interpreted in terms of the production of highly active growth promoting substances by the microorganisms (Gray and Williams, 1971) and the increased fertility due to microbial metabolism (Rao, 1986). The same explanation might also hold for the slight but consistent increase in yield of rice related to EM application. For final conclusions regarding the effect of EM on yields of different crops used in these experiments, further investigation will be needed. There are reports that the effect of EM may not be seen in the first year of an experiment (Higa, 1989; Harakawa and Higa, 1991; Panchaban, 1991) and that the effect may be more pronounced in subsequent years. Thus, it is possible that repeated applications of EM on the same land would, in due course, lead to greater crop yields.

Appendix

Table 10: Weather Data at the Experimental Location (March through August 1991).

Month	Temperature (°C)				Relative Humidity (%)		Rainfall (mm)	Solar Radiation (cal/cm^2)
	Air		Soil					
	Max.	Min.	Max.	Min.	Max.	Min.		
March	35.2	24.3	30.3	23.7	90.1	34.8	17.7	389
April	36.9	26.5	33.0	27.2	88.0	38.3	21.2	398
May	34.1	27.3	30.8	26.1	88.0	64.9	560.6	305
June	34.0	29.8	31.3	27.9	87.3	68.3	298.5	396
July	34.9	30.4	32.7	28.8	94.8	71.2	223.6	387
August	34.5	29.7	32.3	29.0	94.1	70.1	345.3	364

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