Effect of EM on the Growth and Yield of Selected Food Crops in Sri Lanka

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Abstract

Tropical food crops are primarily grown in small landholder farming systems under subsistence conditions. Thus, production under low-input technology is relatively poor, and the response of different crops to improved management practices varies widely.

Use of effective microorganisms (EM) in agriculture has been suggested as a way to increase crop production. The fundamental basis of the process is to develop the entire ecosystem of the field in order to utilize the inherent resource capacity, optimally and in a sustainable manner, Since this technology could produce different responses in different crops, a case study evaluated the performance of four different crops using EM technology at a single location. Emphasis was placed on the yield comparisons of each crop for the different treatments over two seasons.

Treatments in the study included the use of inorganic fertilizer, EM with and without fertilizer or an organic amendment, and a control. The crops were based on farmer preference and included eggplant (*Solanum melongena*), vegetable beans (*Phaseolus vulgaris*), capsicum (*Capsicum annum*) and tomato (*Lycopersicon esculentum*). Mungbean (*Vigna radiata*) was cultivated during the intervening dry season.

During the first wet season, the beneficial influence the EM technology was the greatest with the bean crop. The solanaceous crops did not respond to the new technology to the same extent. However, it was evident that EM enhanced the efficient use of organic matter as a source of nutrients. Yields of the control plots also increased with the use of EM.

During the second wet season a greater effect of EM for increasing crop yields was evident. This confirmed earlier reports that time was required after the application of EM for the conversion of the soil ecosystem into a dymamic and zymogenic state.

Introduction

Vegetable production in Sri Lanka is predominantly the function of small landholders who are located in many parts of the country. This agricultural sector produces all of the domestic requirement for vegetables, and it also produces vegetables for export to nearby countries. The types of vegetables grown in different regions vary, and the selection is based on climatic and soil parameters of the specific location (Weerasinghe and Arulnandny, 1990).

Vegetable production systems of Sri Lanka can be classified as either intensive, subsistence, or home garden units. The productivity of the intensive sector is dependent on heavy use of agrochemicals. In addition, in the hill county, soil and organic matter (primarily animal wastes) are brought from distant locations for use as soil conditioners. In contrast, home garden and subsistence sectors which cater to the domestic markets, especially in the drier regions, use some inorganic fertilizer. Some organic matter may be added, depending on its availability (Perera, 1989), and yields in such systems are low.

The technology of effective microorganisms (EM) developed by Professor Teruo Higa at the University of the Rynkyus, Okinawa, Japan, has been identified as a potential method for increasing the utility value of most organic manures. The microorganisms, when applied in the correct manner, improve the rhizosphere by transforming the microflora and microfauna (Higa, l988). These studies suggest that the application of EM over a long period of time along with suitable organic amendments can enhance the ability of the microorganisms to increase the availability of plant nutrients in the rhizosphere.

Comparative studies on the effectiveness of EM in food production is not widely reported because the technology is currently being evaluated. Thus, we examined the efficacy of EM to produce high yields of selected, commonly-grown tropical vegetables over a two-year period. The study included two types of organic matter along with the recommended inorganic fertilizer for each crop.

Methodology

This study was conducted on a farmer's field located in close proximity to the experimental station of the University of Peradeniya (20 km away from the main campus) from 1989-1991. The mean climatic parameters of the site, obtained from an adjacent meteorological station, are presented in Table 1. The soil at the site was an Ultisol (red yellow podzolic) and its characteristics are presented in Table 2.

Table 1. Mean Climatic Conditions at the Experimental Site.

Condition	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean monthly temp. (C)	27.8	28.5	30.5	29.4	29.3	30.1	30.5	30.2	29.3	27.6	26.9	28.1
Mean monthly rainfall (mm)	184	121	42	94	165	112	65	32	23	185	265	211
Mean monthly RH (%)	79.3	77.4	76.3	76.9	82.9	81.6	81.5	81.3	80.2	79.7	81.2	80.5
Day length (hours)	9 to 10 hours throughout the year											

Table 2. Characteristics of the Soil at the Experimental Site.

Soil type - Red Yellow Podzolic Soil (Ultisol)	
7th Approximation - Rhodudults/Tropudults	
Texture - Sandy clay loam	
Bulk Density - 1.42±0.14	
Soil Color	Dry-2.5 Y 4/4 olive brown
	Wet-2.5 Y 3/2 very dark greyish brown
pH-soil:H_2O (1:1)	6.42
Organic matter	1.46%
Total N	0.14%
CEC (meq/100 g)	12.65
Exchangeable bases	
P	15.6 ppm
K	26.4 ppm
Mg	6.7 ppm
Ca	56.8 ppm

The experiment was initiated at the beginning of the wet season (October) of 1989, and the crops selected were tomato (*Lycopersicon esculentum*), eggplant (*Solanum melongena*), capsicum (*Capsicum annum*) and vegetable bean (*Phaseolus vulgaris*). The selection was based on their acceptance by farmers and their widespread cultivation in the region. The treatments developed for each crop were:

1) Recommended fertilizer
2) Application of *Gliricidia* leaves (C:N ratio, 14.8) at a rate of 6 metric tons (mt) of fresh material per ha.
3) Application of freshly harvested rice straw (C:N ratio, 56) at a rate of 6 mt per ha.
4) Application of solutions of EM 4 at a dilution of 1:1000.
5) Application of EM 4 with *Gliricidia* leaves (6 mt per ha).
6) Application of EM 4 with rice straw (6 mt per ha).
7) Application of the recommended fertilizer with EM 4.
8) Control treatment with no soil additives.

The treatments were applied to 3 x 4 m plots in a Randomized Block Design with three replicates. Organic matter was incorporated into well prepared seedbeds 2 weeks before planting. Healthy seedlings of capsicum, eggplant and tomato, raised under uniform conditions, and seeds of beans (germination 91±0.52 percent) were planted at the following spacings: capsicum, 20 x 30 cm; eggplant, 60 x 75 cm; tomato, 70 x 50 cm; and beans, 20 x 30 cm.

EM was applied at a 1:1000 dilution onto moist soil soon after incorporation of the organic matter and again two weeks after planting. Extreme care was taken to avoid cross contamination of soils in plots not receiving EM.

Fertilizer levels for these crops, used at the recommended rates for Sri Lanka (Nagarajah, 1986), were as follows: (1) capsicum and eggplant, 625 kg of 16:20:12 (N:P:K) per ha at planting and 30 kg of urea at flower initiation; (2) tomato, 600 kg of 16:20:10 (N:P:K) per ha at planting and 100 kg urea per ha at 6 weeks after planting; (3) vegetable beans, 625 kg of 14:21:14 (N:P:K) per ha followed by 100 kg urea at flowering.

Crop management followed local recommendations. Hand weeding was performed when required and the crop was sprayed with a prophylactic insecticide (Azodrin 40 percent EC diluted l:50) on two occasions. The crops were harvested at maturity and yields per square meter determined. At the beginning of the dry season (April), mungbean (*Vigna radiata*) was planted in all plots. The earlier season treatments were reapplied to the plots except for inorganic fertilizer which was applied at 250 kg of 6:25:18 (N:P:K) followed by 30 kg urea per ha at flowering. Supplementary irrigation was provided when necessary, and the crop was maintained as per local recommendations (Gunasena, 1974). The crop was harvested at maturity and seed yields (14 percent moisture) per square meter determined.

At the onset of rain for the second wet season beginning in October, 1990, the planting schedules for October 1989 were repeated. The selected crops remained the same, and they were planted in the same plots as in the pervious wet season. The crops were managed in the same way as in the wet season of 1989; and yields per square meter determined.

Results and Discussion

The climatic data (Table 1) records the occurrence of heavy rainfall during the period October to January. This is the wet season, when vegetables are generally grown under rainfed conditions in the highlands (Weerasinghe and Arulnandhy, 1990). The dry season, beginning in late April, receives less rainfall (i.e., 40 percent of the rainfall for the wet season). Ambient temperatures in the dry season are higher, and evaporation losses exceed those of the wet season. Because of these climatic factors, rainfed agriculture is difficult in dry seasons.

The establishment of selected crops in the wet season is presented in Table 3. Because of the selection of good quality planting material (seedlings of solanaceous species and seeds of beans), plant establishment was uniform for all treatments. Addition of EM, organic matter or fertilizer had no beneficial or adverse effect. These results indicated that the selected species were not influenced by soil additives at the very early stages of growth.

Table 3. Effect of EM, Inorganic Fertilizer, and Organic Matter Amendments on Establishment of Selected Crops.

Treatment	Capsicum		Eggplant		Tomato		Beans	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Inorganic fertilizer	85	89	78	80	85	81	92	88
Gliricidia leaves	81	85	76	81	84	84	90	85
Rice straw	83	86	79	78	85	84	89	87
EM	87	85	79	81	86	81	89	87
EM+ *Gliricidia*	85	84	81	80	85	80	91	87
EM + Rice straw	84	88	80	79	84	83	92	89
EM+ fertilizer	88	89	77	79	81	84	90	88
Control	83	84	77	79	86	82	91	86
Sx	8.9	7.0	7.9	4.9	4.0	7.0	5.7	6.0

Unit: (% Establishment)

A comparison of the four crops showed that establishment of beans was marginally higher than for solanaceous crops. In the field, plants established from seeds as opposed to seedlings raised in nurseries may be responsible for this phenomenon. The results did not show differences between treatments for the two seasons. However, longer term studies may show treatment differences for plant establishment.

In contrast to plant establishment, yields of the species were affected by the treatments (Tables 4 and 5). Addition of inorganic fertilizer produced the highest yields of solanaceous crops (Table 4). EM and organic matter also increased yields over the control, thus illustrating the requirement of some form of soil additive for increased production of these species. However, the greater yields resulting from the addition of inorganic fertilizers can be attributed to the availability of adequate plant nutrients in a readily available form (Mengel and Kirkby, 1987).

Table 4. Yield of Solanaceous Crops as Affeted by EM, Inorganic Fertilizer and Organic Amendments in Two Wet Seasons.

Treatment	Capsicum		Eggplant		Tomato	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Inorganic fertilizer	1491	1506	5242	5315	1524	1585
Gliricidia leaves	956	905	2109	2191	829	858
Rice straw	760	691	1545	1506	588	641
EM	595	601	959	1080	460	525
EM + *Gliricidia*	1045	1061	2459	2704	949	1011
EM + Rice straw	799	645	1684	1724	632	714
EM + Fertilizer	1480	1548	5606	5799	1604	1683
Control	484	451	759	781	408	443
LSD (P=0.05)	127	98	104	148	67	60

Unit: g/m^2

Application of organic matter with different C:N ratios also increased yields. The benefit of incorporating organic amendments with low C:N ratios was attributed to the ability of such materials to decompose rapidly and to provide the required nutrients for plant growth (Mengel and Kirkby, 1987). The ability of these organic materials to improve the soil physical properties must also be considered a contributory factor. The selected solanaceous crops responded differently to the added organic amendments. In both seasons, the addition of *Gliricidia* leaves and straw produced the greatest yield increase of eggplant which is a species adapted to a wide range of environmental conditions (Tindall, 1983). Tomato and capsicum produced similar responses (measured in terms of percentage increases in yield) to the addition of organic matter. However, increments of yield over the control are lower with these two species. Application of EM also increased yields over the control. The increments varied from 14 percent for tomato to 26 percent for eggplant in the first season. This increase, although the lowest among the treatments, indicated the ability of EM to impart beneficial effects.

Application of EM increased yields of eggplant, capsicum and tomato by 38, 33 and 18 percent, respectively, over the controls in the second season. This result suggested a long-term benefit from the use of effective microorganisms and will require further study under controlled conditions. The reported ability of EM to utilize the available organic matter and to improve soil properties (Higa, 1988) may be considered as a contributory factor. The requirement of time for the development of a suitable rhizosphere microbial population by the EM cultures could also be considered a causal factor for this observation.

EM is reported to be most beneficial when applied with organic amendments (Higa, 1988). Incorporation of EM with *Gliricidia* leaves produced greater yields than when EM was added with rice straw. This may be a result of the greater availability of nitrogen in the organic biomass of *Gliricidia* for EM activity, which in turn would produce higher yields. Again, eggplant was the most

responsive species among the selected solanaceous crops.
Addition of EM produced higher yields during the second season, which again demonstrated the long-term benefits of EM. While this could be the result of the ability of EM cultures to transform the soil into a more zymogenic state, detailed experiments are required to elucidate the causal phenomena.
Application of EM with inorganic fertilizer also increased yields marginally over plants supplied with inorganic fertilizer alone. Yields of eggplant were increased to a greater extent (7 percent) than tomato (5 percent) and capsicum (1 percent). The long term benefits of EM were also seen in these treatments; yields of eggplant, tomato, and capsicum are increased by 9, 6, and 3 percent, respectively, in the second season. This indicated the ability of EM to increase the fertilizer use efficiency of plants.
The effect of the treatments on vegetable beans in the two wet seasons are presented in Table 5. As in solanaceous crops, inorganic fertilizer increased yields over all other treatments. Addition of *Gliricidia* and straw increased yields by approximately 100 and 50 percent, respectively, in the first season; again greater benefits of incorporating organic materials with low C:N ratios was demonstrated. The high potassium content of rice straw (Amarasiri and Wickramasinghe, l983) does not seem to compensate for the high C:N ratio.

Table 5. Effect of EM, Inorganic Fertilizer and Organic Amendments on the Yield of Vegetable Beans in Two Wet Seasons.

Treatment	Season 1	Season 2
Inorganic fertilizer	985	1031
Gliricidia leaves	649	674
Rice straw	498	521
EM	414	483
EM + *Gliricidia*	931	996
EM + Rice straw	519	558
EM + Fertilizer	991	1068
Control	315	341
LSD (P=0.05)	62	51

Unit: g/m^2

Yields of vegetable beans with EM were increased to a greater extent than solanaceous crops (i.e., 31 percent in the first season). This suggests that legumes derive a greater benefit from the applied EM which might result from the ability of EM cultures to increase the biological activity of the soil including biological nitrogen fixation.
Application of EM with *Gliricidia* and straw further increased yields, although the increase was lower in plots receiving straw. The inability of straw to meet the nutrient requirements of EM cultures may be a contributory factor for this observation. Application of EM and *Gliricidia* produced yields equivalent to those obtained with inorganic fertilizer, especially in the second season. This was not seen with solanaceous crops, which again showed a better response than vegetable beans to EM application.
Application of EM with inorganic fertilizers did not produce yield increases in the first season. In the second season, EM with inorganic fertilizers increased yields by 3 percent, which was a smaller increase than observed with solanaceous crops (Table 4). By comparison, the yield increase in the second season resulting from the addition of *Gliricidia* leaves and EM was greater with beans than with the solanaceous crops. Thus, the greater response of beans to this treatment may be the result of its greater biological activity as a symbiotic nitrogen fixer. However, confirmatory studies will be required over a longer period of time.
Yields of mungbean, planted in the dry season (Table 6), also benefited from the use of EM. While the overall crop yields were low in the dry season, the magnitude of yield increases follow that of

vegetable beans. Mungbean yields were greater when planted after an application of *Gliricidia* leaves, and production increased by an additional 40 percent with the application of EM. Similarly, yields of plots receiving straw were increased by 11 percent as a result of the addition of EM. Yields of the EM plots were increased by 31 percent over the control, demonstrating the ability of EM alone to significantly increase yields of mungbean under dry conditions.

Table 6. Effect of EM, Inorganic Fertilizer and Organic Amendments on Seed Yield of Mungbean in the Dry Season.

Treatment	Yield (g/m^2)
Inorganic fertilizer	185
Gliricidia leaves	86
Rice straw	52
EM	46
EM + *Gliricidia*	121
EM + Rice straw	58
EM + Fertilizer	192
Control	35
LSD (P=0.05)	11

Conclusions

The case study conducted over two wet seasons illustrated that the application of the recommended rates of inorganic fertilizer produced the highest yields in selected crops. Application of EM with inorganic fertilizer increased the yields marginally. In contrast, application of effective microorganisms with good quality organic materials (i.e., organic amendments with a low C:N ratio) increased yields of the selected species significantly when compared with yields of plots to which the organic amendments were applied without EM. In addition, vegetable beans respond better to this treatment in wet seasons; mungbean showed a similar effect in the dry season. Crop yields were also increased when EM was applied to soil without other additives.

The results of this study demonstrated important trends in EM technology, although it did not provide reasons for the observed phenomena. Thus, detailed experiments are required on the role of EM in tropical crop production in order to identify long term benefits and causal factors of these benefits. This will enable the development of a scientific basis for EM technology in tropical agriculture.

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