Research on the Technology of Effective Microorganisms in Sri Lanka

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Abstract

A comprehensive research program was initiated in 1990 to identify the benefits of Effective Microorganisms (EM) on the productivity of organic systems. Leaves of *Gliricidia sepium* and rice straw, which have different C:N ratios and are commonly available, were used as sources of organic matter. In addition, suitable controls were maintained in order to determine the beneficial effects of EM. Yields of legumes were enhanced with EM to a greater extent than non-legumes. The beneficial impact of EM was also greater with *Gliricidia* which had a lower C:N ratio. EM applied to the bare soil also produced some yield stability. In contrast, EM did not influence yields of chemically-fertilized crops. The benefits of EM were greater in a wet season. EM and organic matter enhanced selected soil physical characteristics over the three years of the study. Possible causes of the effectiveness of EM on the enhancement of soil properties are discussed.

Introduction

The comparison of population growth and food needs illustrates an important agricultural factor. Population growth tends to be smooth while agricultural production fluctuates widely in response to variations in weather (Pendleton and Lawson, 1989). Thus, total food production needs to increase especially in developing countries until yields stabilize (Hare, 1981).

The dense human populations of the world exist in the humid tropics (Pendleton and Lawson, 1989). Shifting cultivation or subsistence agriculture is the dominant food production system in this region; land is cleared and planted in a diverse range of intensities and crop combinations (Pendleton and Lawson, 1989). However, with increasing pressure on land, permanent agriculture is now being practiced (Okigbo, 1983).

Maintaining and improving soil fertility with organic matter is an important aspect of managing tropical soils (Jaya and van der Zaag, 1991). Furthermore, it is widely acclaimed as a vital element in future agricultural systems (IFIA, 1992) especially in developing countries because of the increased cost of chemical fertilizers, reduced incomes for farmers, and the increased loss of fertility in tropical soils. Hence, organic matter, with its proven value as a source of plant nutrients and soil physical property maintenance (Wade and Sanchez, 1983), has a significant role in the agricultural sector of the humid tropics. This is further accentuated by the current export market available for food grown under natural conditions, free of agrichemicals.

A primary limitation in the use of organic matter for crop production is its low nutrient content; this necessitates the use of large quantities to sustain crop nutrient requirements. The slow release and loss of nutrients during decomposition and vital nutrient balances such as C:N ratios affect the usefulness of organic matter. These features make extensive use of organic matter difficult; in smallholdings, it results in low yields that do not produce a stable and sufficient income for farmers.

With an increasing demand for high quality agricultural products grown under natural conditions without agrichemicals, research is being conducted to enhance the value of organic matter and to improve environmental quality. Thus, studies on the use of new technologies of natural farming could be considered a vital link in the agriculture of the humid tropics where more efficient use of organic matter would result in increased yields on a sustainable basis.

The technology of Effective Microorganisms (EM) is a proven method for increasing crop yields in nature farming (Higa, 1991). EM solutions, which contain naturally occurring microorganisms, enhance the value of organic matter by accelerating its decomposition and releasing greater quantities of nutrients for crop utilization (Higa and Wididana, 1991). Studies (Lin, 1991; Sangakkara and Higa, 1992) have proven its usefulness for many food crops in different environments. The causal mechanisms for the increases in crop yields with EM have not been quantified, although the beneficial nature of the organisms have been reported. Thus, a long-term study was implemented in two selected locations in Sri Lanka to test the efficacy of EM for increasing the yield of four important food crops selected on the basis of their diversity in growth habit and duration, harvested product, and response to dry and wet seasons over which the experiments were conducted. The experiments were conducted over three years using two sources of organic matter, and the changes in some soil physical properties in relation to the application of organic matter were evaluated with and without EM.

Methodology

The study was conducted at two sites in close proximity to the experimental station of the University of Peradeniya, Sri Lanka (7°N, 81°E, 372m above sea level), situated in the intermediate, mid-country zone of the island. The seasons that determine the agriculture of the country, which correspond to the northeast monsoon (October to February, WET -MAHA season) and southwest monsoon (April to July, DRY - YALA season), were selected for the study. Thus, the seasons of experimentation were WET - 1990/91, 1991/92 and 1992/93 and DRY - 1991, 1992 and 1993 (Table 1).

The soil at the sites was an Alfisol with the following characteristics: Texture, sandy clay loam; water holding capacity, 18.26% ± 0.48% (v/v); bulk density, 1.54 ± 0.08 g/cm^3; pH (1:5 H_2O), 6.24 ± 0.12; and an organic C content of 1.02% ± 0.18%.

The crops selected were:

WET SEASON: Mungbean (*Vigna radiata* L. Wilezek variety Type 51)
Sweet potato (*Ipomoea batatas* L. Iocally available material)

DRY SEASON: Bush bean (*Phaseolus vulgaris* L. variety Top Crop)
Tomato (*Lycopersicon esculentum* L. variety local selection)

The treatments adopted over the entire experimental period were as follows:

A: Control - no additives
B: Recommended chemical fertilizer regime (Department of Agriculture, 1988)
C: EM 4 inoculated into soil without additives
D: *Gliricidia* leaves (C:N ratio, 11.8 ± 1.5)
E: Rice straw (C:N ratio, 55.1 ± 2.1)
F: *Gliricidia* leaves plus EM 4
G: Rice straw plus EM 4
H: Recommended chemical fertilizer regime plus EM 4

The same crops were used in all three years. Individual plots (3 x 4 m) received the same treatment throughout the study. For each cropping season, the legume was followed by the non-legume. The layout of the trials was a factorial experiment with three replications per treatment in each season. The plots were separated by 50-cm alleys. Plots receiving EM were clustered together within a replication to avoid contamination and spray drifts.

Organic matter was applied to the plots at a rate equivalent to 10 MT of fresh material two weeks before planting. Chemical fertilizer was also applied at the same time. EM 4 solution was sprayed onto the selected plots and the soil was mixed. EM 4 was diluted 1:500 with water and the rate of application was 3000 liters per ha.

The crops were planted and managed according to local recommendations for rainfed agriculture (Department of Agriculture, 1988). At the important stages of crop growth, EM 4 (diluted to 1:10,000 with water) was applied (5000 liters per ha); thus, each crop received three applications after planting. At crop maturity, yields were determined.

The water-holding capacity and bulk density of the soil were determined at the onset of the experiment (Table 2). At the end of each dry season (1991, 1992 and 1993) the same determinations were made for each plot (Black. 1965).

The data were subjected to statistical analysis using a General Linear Model to determine treatment differences.

Results and Discussion

The wet seasons over the experimental period (October to February) received approximately 65 percent of the mean annual rainfall (Table 1). Thus, crops established in the dry season were subjected to some moisture and heat stress, which is a characteristic of the agroclimate of the region (Domros, 1974). The crops selected for cultivation under rainfed conditions in the wet season are drought-avoiding, tolerant or resistant species.

As shown in Table 3, the highest yields were obtained when EM was applied to mungbean or sweet potato in the wet season with or without organic manures or chemical fertilizer. The lowest yields were obtained from the control plots. These results emphasize that additives are necessary in order to obtain high yields in this soil. The gradual decline in yield over time also indicates the inability of the soil to sustain production without additives.

Table 1. Mean Climatic Parameters over the Experimental Period.

Parameter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Rainfall (mm/month)	146	265	251	182	108	37	95	156	109	87	24	21
Temperature (°C)	28.6	27.1	27.2	26.1	27.2	29.5	29.1	28.3	30.6	30.2	29.5	29.6
Humidity (%)	76.5	82.4	74.5	78	75.4	75.1	75.6	81	81.6	80.5	78.3	74.1
Daylength					11	to	12	hours				
Seasons	WET							DRY				

Wet season: October to February
Dry season: April to July

Table 2. Effect of EM on Selected Soil Physical Properties.

Treatment	Water-Holding Capacity (% v/v)				Bulk Density (g/cm³)			
	1991	1992	1993	sd	1991	1992	1993	sd
Control	18.24	18.95	18.46	0.021	1.51	1.51	1.54	0.017
Fertilizer	18.52	18.65	18.51	0.008	1.53	1.57	1.59	0.011
EM	18.26	18.34	18.35	0.003	1.52	1.53	1.51	0.042
Gliricidia leaves	18.64	18.72	18.85	0.005	1.51	1.5	1.48	0.01
Rice straw	18.58	18.61	18.75	0.011	1.52	1.5	1.5	0.008
Gliricidia + EM	18.72	18.82	19.26	0.021	1.5	1.48	1.45	0.018
Rice straw + EM	18.65	18.74	18.89	0.011	1.52	1.5	1.49	0.005
Fertilizer + EM	18.54	18.62	18.65	0.008	1.53	1.52	1.52	0.004
LSD (P=0.05)	0.142	0.039	0.052		0.012	0.006	0.004	

Measurements were taken at the end of the dry season (August) of each year, beginning in 1991.

Table 3. Yield of Mungbean and Sweet Potato as Affected by Organic Amendments, Chemical Fertilizer and EM during Three Wet Seasons (1990/91, 1991/92 and 1992/93).

Mungbean

Amendment	EM Applied	Year1 (g/m²)	Year2 (g/m²)	Year3 (g/m²)
Gliricidia leaves	Yes	314	358	417
	No	224	247	280
Rice straw	Yes	184	217	261
	No	140	165	190
Chemical fertilizer	Yes	415	404	412
	No	421	384	404
Control (No amendment)	Yes	97	102	107
	No	78	68	65
LSD (P=0.05)	Amendment	46.4	27.1	19.8
	EM Applied	4.8	10.7	7.1
	Interaction	*	*	*

Sweet Potato

Amendment	EM Applied	Year1 (g/m^2)	Year2 (g/m^2)	Year3 (g/m^2)
Gliricidia leaves	Yes	675	745	798
	No	561	384	604
Rice straw	Yes	483	525	562
	No	401	422	431
Chemical fertilizer	Yes	1174	1304	1289
	No	1101	1248	1262
Control (No amendment)	Yes	281	259	254
	No	247	241	208
LSD (P=0.05)	Amendment	39.5	18.7	50.5
	EM Applied	11.1	14.7	27.6
	Interaction	NS	*	*

The highest yields of both species were harvested from plots supplied with chemical fertilizers. This clearly implies the requirement for additional nutrients in this environment and the reason for fertilizer use by farmers.

Application of organic matter also increased yields of both species over that of the control. However, *Gliricidia* leaves, with a low C:N ratio, had a greater impact on yields, thereby illustrating the value of leguminous materials as green manures. Rice straw, with its higher C:N ratio, did not affect yields similarly since the straw generally requires enrichment prior to application as a fertilizer (Bangar et al., 1989).

EM 4 enhanced yields of all plots significantly with the exception of those receiving chemical fertilizer in which case the increase was marginal. This suggested the existence of some inhibitory influence of chemical fertilizers on the effective microorganisms, which might be similar to the effect of nitrates on the activity of *Rhizobium* spp. (Sprent and Sprent, 1990). This warrants further study.

Application of EM to the soil increased yields of mungbean and sweet potato by approximately 25 and 14 percent, respectively, in the first season when compared to the control plots. The increase in yields resulting from EM application to the soil was greater for mungbean (50%) in subsequent seasons. However, a similar increase was not observed in sweet potato. This indicated a greater influence of EM on legume crops that have greater microbial activity related to biological nitrogen fixation in the rhizosphere. Thus, farmers who do not apply any additives to soils may also benefit from the application of EM alone, especially on legume crops which are popular in the tropics.

The most significant impact of EM was seen when it was applied with *Gliricidia* leaves; *Gliricidia* has a low C:N ratio. The yield increase in plots supplied with EM and *Gliricidia* when compared to that of plots with the green manure alone was 40 percent for mungbean in the first year. This trend increased in subsequent seasons. A similar phenomenon was seen with sweet potato, although the magnitude of the increase was lower (i.e., 20 percent in the first season with a gradual increase in later years).

The application of EM to rice straw during the wet season increased yields of mungbean and sweet potato by 32 and 20 percent, respectively, when compared with plots that received only rice straw (Table 3). The increases in yield were enhanced with time although to a lesser degree than when EM was applied with *Gliricidia* leaves. This indicates the benefits of applying EM to organic systems to enhance yields, although the magnitude of benefits may vary with the type of manure used.

Table 4 shows that the yields of bush bean and tomato were increased with the application of EM in the dry season. The beneficial effect of EM was again greatest when applied with *Gliricidia* leaves and confirmed the suitability of this green manure for organic systems. The effect of EM with rice straw showed lesser yield increases with both species. The percentage yield increase as a result of EM addition was also enhanced with time during this season. Application of EM with *Gliricidia* leaves increased yields of beans from 27 percent in the first dry season to 45 percent in 1993. The increase in tomato yields with time, resulting from EM application with *Gliricidia* leaves, was 21 percent in 1991 and 36 percent in 1993. EM with rice straw also produced similar results although the magnitude of yield increases were lower for both species. These results again indicated the greater beneficial effect of EM with legume crops when combined with suitable organic matter. However, application of EM with chemical fertilizers had no effect on yields of either species.

Table 4. Yield of Bush Bean and Tomato as Affected by Organic Amendments, Chemical Fertilizer and EM during Three dry Seasons (1991, 1992 and 1993).

Bush Bean

Amendment	**EM Applied**	**Year1 (g/m^2)**	**Year2 (g/m^2)**	**Year3 (g/m^2)**
Gliricidia leaves	Yes	65	74	83
	No	51	53	57
Rice straw	Yes	42	48	53
	No	36	39	40
Chemical fertilizer	Yes	116	142	138
	No	118	134	132
Control (No amendment)	Yes	18	23	27
	No	12	11	14
LSD (P=0.05)	Amendment	20.5	16.3	9.2
	EM Applied	4.6	3.9	1.8
	Interaction	*	*	*

Tomato

Amendment	**EM Applied**	**Year1 (g/m^2)**	**Year2 (g/m^2)**	**Year3 (g/m^2)**
Gliricidia leaves	Yes	1536	1581	1772
	No	1268	1261	1304
Rice straw	Yes	1132	1318	1460
	No	968	1051	1092
Chemical fertilizer	Yes	1941	2214	2180
	No	2131	2138	2196
Control (No amendment)	Yes	758	741	784
	No	711	723	704
LSD (P=0.05)	Amendment	54.7	39.2	70.5
	EM Applied	11.8	9.3	40.8
	Interaction	*	*	*

A comparison of the yield increases as a result of EM application in both seasons showed a greater beneficial effect in the wet season which provided abundant moisture for microbial activity in the soil. The warm temperatures with lower rainfall might reduce the activity of EM. Thus, the supply of irrigation water might provide a more suitable environment in the dry season but this aspect requires further study.

Analysis of the physical properties of the soil (Table 2) illustrated some causal factors for the beneficial effects of EM. The bulk density of plots with no additives increased with time but with no significant change in water-holding capacity. This detrimental effect could be a factor in the lower yields of these plots especially when cropped without fertilizers.

Application of organic matter alone increased the water-holding capacity over the three years and reduced bulk density. The impact of *Gliricidia* leaves was greater than rice straw. Application of EM enhanced the beneficial effects in all plots. The impact of EM was most prominent when added to plots with *Gliricidia* leaves as the organic amendment. The detrimental changes to the measured soil parameters were less evident when EM was applied to the control plots or to those supplied with inorganic fertilizer. Thus, the observed increases in yield were again related to this phenomenon although there could have been other changes in the soil chemical and biological properties which warrant further investigation.

Conclusions

Organic farming is generally associated with low yields; conventional systems using agrichemicals produce higher yields from similar land areas (Fageria, 1992). This phenomenon was apparent in this study which was conducted over a three-year period. However, continued use of organic matter increased yields in both seasons.

EM technology enhances productivity of organic systems (Higa, 1991) by changing the plant rhizosphere into more conducive conditions for supporting plant growth. Thus, application of suitable concentrations of EM provide better conditions for crop growth in organic systems. The benefits become clear over time with changes in the rhizosphere.

Application of EM alone does not provide significant benefits. Thus, EM should be applied with a suitable organic amendment as in all nature farming systems. The selection of the organic amendment is important and material with a low C:N ratio increases the efficacy of EM because it provides readily available carbon for growth and activity of microorganisms which, in turn, enhances the release of greater quantities of plant nutrients with minimal loss (Higa, 1991). However, this study further illustrates that EM has the capacity to improve the physical properties of the rhizosphere. Similar changes in the chemical and biological properties also require study. The influence of EM was greater in the wet seasons. This indicates that an adequate amount of soil moisture must be maintained to achieve maximum effectiveness of the mixed cultures of beneficial microorganisms provided by EM. Irrigation in the dry season might provide similar results.

Smallholder farming systems in the developing world and home gardeners worldwide use organic amendments to improve soil fertility and productivity (Pendleton and Lawson, 1989). The productivity patterns of these systems are generally characterized by low yields although different types of organic matter may be added. This phenomenon is also true of commercial organic farms. As was shown in this study, the technology of Effective Micro-organisms (EM) offers a method for significantly improving the productivity of organic systems on a sustainable basis under rainfed conditions. Even though all of the causal mechanisms are not known, the technology of EM can provide a more meaningful direction to organic farming systems by enhancing and maintaining productivity over time.

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