Nutrient Use Efficiency of Selected Crops Grown with Effective Microorganisms in Organic Systems

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Abstract

The use of Effective Microorganisms (EM) in Kyusei Nature Farming enhances crop yields in conventional organic systems. However, the causal factors of this phenomenon have not been well-documented, although some reports indicate the improvement in soil properties. Thus, a study was conducted to evaluate the nutrient utilization efficiency of two food crops grown over three seasons under conventional organic and Kyusei Nature Farming methods. The organic amendments used were coir dust, rice straw and leaves from the legume *Gliricidia sepium*, with or without EM. Yields of all crops were enhanced with the organic amendments and to a greater extent with EM. Plant nutrient concentrations (N and K) which are important for vegetative and reproductive growth, were greater in plants grown with EM. The utilization efficiencies of the nutrients applied with organic matter were also greater. The results are discussed in terms of the accrued benefits to food crops with the use of EM in conventional organic systems adopted in the tropics.

Introduction

Organic farming is becoming increasingly popular in many agricultural sectors world-wide. This popularity arises from many factors, among which the desire for pollutant-free food by consumers is especially important particularly in the developed countries (IFIA, 1992). In the developing countries, where organic farming is practiced by small holders due to the high cost and/or non-availability of agrichemicals, the scientific aspects of these enterprises are being evaluated for their productivity and sustainability (Gliessman, 1991; NRC, 1993).

A principal problem of organic farming is the low nutrient status of most organic fertilizers (Mengel and Kirkby, 1987). The nutrient contents of organic fertilizers vary widely, depending on the source and moisture content. This problem is further compounded by the difficulties in assessing the value of organic fertilizers through direct analysis of total quantities of plant nutrients. Thus, field experiments are needed to determine the nutrient availability and efficacy of most organic fertilizers. This is due to the slow and variable release rates of nutrients during decomposition of organic materials (Cosico, 1985; Hseih and Hseih, 1990).

Microorganisms can enhance the efficacy of organic systems (Dobereiner, 1994). Thus, history records the use of these natural organisms, which has been highlighted by the very important role played by *Rhizobium* species in legume culture. More recently, the concept and technology of Effective Microorganisms (EM) developed at the University of the Ryukyus, Okinawa, Japan have been proven as a technology with a multitude of potential benefits. These range from enhancing yields of organic systems to pollution control (Parr et al., 1994; Sangakkara and Higa, 1995).

The success of EM in organic systems is attributed to the more rapid breakdown of organic matter, enhanced availability of nutrients, and improvements in soil properties (Parr et al., 1994; Sangakkara, 1994). However, the effectiveness of EM needs to be judged in terms of its ability to promote plant growth and yields through enhanced nutrient utilization efficiencies. Thus, field studies were conducted with selected food crops in the dry seasons of three consecutive years to determine the effectiveness of using EM in organic systems. Emphasis was placed on determining the ability of EM to enhance nutrient utilization efficiencies from three types of organic materials commonly found in most tropical ecosystems.

Materials and Methods

The experiments were conducted from 1990 to 1992 in the dry season, which lasts from May to September each year. The site was a farmer allotment in close proximity to the Experimental Station of the University of Peradeniya and situated in the mid-country intermediate zone of Sri Lanka. The soil at the site was an Ultisol (Rhodudult) with a pH (1:2.5 H_2O) of 6.18 $\pm$ 0.14 and organic matter content of 0.81% $\pm$ 0.06.

The mean climatic parameters over the three seasons were: rainfall; 284 mm $\pm$ 18 mm; mean daily temperature; 30.4^{o}C $\pm$ 1.8^{o}C; relative humidity; 74% $\pm$ 2.5%. The food crops grown were chili peppers or capsicum (*Capsicum annum* L., var. MI 1) and cowpea (*Vigna unguiculata* L., var. Bushitao) which are grown for green pods. The following treatments were applied in each season:

1) Application of organic amendments including fresh legume leaves (*Gliricidia*), rice straw or coir dust at a rate equivalent to 8 mt/ha.
2) Application of the three organic amendments with EM at a dilution of 1:1,000. EM was applied at a rate of 10 liters/ha on each occasion.
3) A control treatment with no organic matter or EM.

The seven treatments were imposed in a randomized block design with three replicates per treatment. Each treatment was applied on the same plot in each season. The plot dimensions were 2 x 3 m. Care was taken to prevent contamination of plots not treated with EM, by adopting suitable distances between the treatments. At the onset of the rains each season, the plots were tilled manually, and the organic materials were applied. EM was first applied to the organic materials, and then the biomass was incorporated into the soil. Uniform seedlings of capsicum and seeds of cowpea were planted in the prepared plots after 14 days, and managed according to recommendations of the Department of Agriculture (1989). EM was applied at the same dilution and rate at planting and at the V2, R1 and R4 growth stages.

No agrichemicals were applied, and hand weeding was performed on two occasions during the vegetative phase. Irrigation water was supplied when required. At the R4 growth stage, six plants were carefully removed from each plot. These were dried at 80^{o}C for 48 hours and dry weights determined. Thereafter, the samples were analyzed for nitrogen (N) and potassium (K) by Kjeldahl and flame photometric methods, respectively. The N and K values of fresh samples of the organic materials were also determined at the same time. At the R6 growth stage of the crops, which corresponds to the pod development stage, 25 plants were harvested from each plot, and the economic yield (fresh pod weight) was determined.

Based on the N and K levels and the organic materials (dry weight basis), the agronomic and apparent utilization efficiencies of these nutrients were determined for the EM-treated and conventional organic systems. The methods used were those reported earlier by Craswell and Godwin (1984) and Mengel and Kirkby (1987) according to the following relationships:

$$1)\ \text{Agronomic Efficiency (g/g)} = \frac{\text{Yield (F) - Yield (C)}}{\text{Quantity of nutrient added}}$$

$$2)\ \text{Apparent Recovery (\% of applied nutrient)} = \frac{\text{Nutrient uptake(F)-Nutrient uptake(C)}}{\text{Quantity of applied nutrient}}$$

where F and C denote the addition of a particular organic material (with or with-out EM) and the control plot, respectively.

Results and Discussion

The nutritive value of the organic materials used as fertilizers varied widely (Table 1). The legume leaves (*Gliricidia*) had a higher concentration of N which, in turn, lowered the C:N ratio and enhanced its utility value. Legume leaves are widely used as a N source in tropical organic systems (Beets, 1990). Thus, while the decomposition rates of these materials would be slower than *Gliricidia* leaves, coir dust and rice straw supply a very important nutrient (K) for tropical agriculture.

Table 1. Nutrient Content of Selected Organic Amendments.

Organic amendments	N (%)	P (%)	K (%)	C:N Ratio
Gliricidia leaves	3.42	0.14	2.64	11.8±1.42
Rice straw	0.71	0.09	2.96	54.2±2.54
Coir dust	0.84	0.11	3.01	48.6±3.22

Plots that did not receive organic manures produced the lowest yields (Table 2). This indicates the low fertility status of the soil, which is a common feature of most small holder farming systems in developing countries (Beets, 1990). Furthermore, yields of these plots declined with time indicating their low level of productivity and un-sustainability.

In contrast, the application of organic materials increased yields significantly. As expected, the addition of *Gliricidia* leaves had the greatest effect. In the first season, the application of *Gliricidia* leaves on cowpea yield was greater than with the other organic materials. The addition of rice straw and coir dust to these crops produced significantly lower yields. This could be attributed to the lower N concentrations and higher C:N ratios, which slowed the release of nutrients (Mengel and Kirkby, 1987).

Application of EM enhanced the yields of both crops, which confirmed the usefulness of these microbial cultures in organic farming. The most significant impact was observed when EM was applied with *Gliricidia* leaves due to the greater utility value of this organic fertilizer. The increment in yields due to EM and legume leaves over that of plots receiving this green manure alone was 12 and 13 percent, respectively, for capsicum and cowpea in the first season. These increments increased to 16 and 20 percent, respectively in the third season. The yields of plots receiving rice straw and coir dust with EM were also enhanced by increments ranging from 3 to 6 percent the first year and 8 to 16 percent the third year. Thus, the results clearly confirm earlier conclusions by Sangakkara and Higa (1994, 1995) of the benefits of using EM in tropical organic food production systems.

Table 2. Yields of Capsicum and Cowpea as Affected by Organic Amendments and Effective Microorganisms over Three Seasons.

Treatments	Season 1 (g/m^2)	Season 2 (g/m^2)	Season 3 (g/m^2)	Sx
Capiscum (green pods)				
No additives	825	812	769	14.22
Gliricidia leaves	1104	1182	1248	8.56
Rice straw	965	1024	1046	10.71
Coir dust	940	945	951	4.02
Gliricidia leaves+EM	1240	1381	1456	21.57
Rice straw+EM	996	1095	1180	11.61
Coir dust+EM	949	1004	1076	7.41
LSD (P=0.05)	27.1	34.1	19.9	
Cowpea (tender pods)				
No additives	126	104	102	5.10
Gliricidia leaves	314	366	424	9.92
Rice straw	208	291	315	8.60
Coir dust	198	260	299	6.23
Gliricidia leaves+EM	356	441	512	4.84
Rice straw+EM	229	315	340	7.51
Coir dust+EM	210	295	349	8.18
LSD (P=0.05)	14.8	9.4	21.4	

A primary reason for the increased benefits of EM in organic farming is presented in Table 3. A comparison of the agronomic efficiencies of N and K with and without EM strongly suggests that these microbial cultures can markedly increase the productive value of applied nutrients in organic systems over time. Thus, with EM, the yield potential of cowpea and especially capsicum (a non-legume) was enhanced per unit of applied N and K. This could be attributed to the more rapid decomposition of organic matter and greater nutrient release due to the application of EM.

More importantly, these agronomic efficiencies indicate that EM can enhance the productive value of nutrients that are in low concentrations in certain organic fertilizers. For example, the application of EM with *Gliricidia* leaves which have a low level of K, increased the agronomic efficiency of this nutrient over that of N. In contrast, the agronomic efficiency of N was significantly greater than K when EM was applied to rice straw and coir dust, which have very low concentrations of K. Again, this emphasizes the utility value of EM in organic systems. The increases in agronomic efficiencies with time resulted in greater utilization of applied nutrients in organic systems. This phenomenon culminated in higher productivity on a sustainable basis.

Table 3. Agronomic Efficiency of Applied Nitrogen and Potassium by Capiscum and Cowpea as Affected by Organic Amendments and Effective Microorganisms, over Three Seasons.

Treatments	EM applied	Season 1		Season 3	
		N	K	N	K
		(g yield/g nutrient)		(g yield/g nutrient)	
Capiscum (green pods)					
Gliricidia leaves	no	18.4	23.9	26.9	34.9
	yes	25.1	32.5	32.1	41.7
Rice straw	no	33.3	7.9	59.5	14.2
	yes	40.7	9.7	73.5	17.5
Coir dust	no	23.0	6.3	31.0	8.5
	yes	24.8	6.8	56.0	15.4
Sx		3.3	0.8	12.6	3.6
Cowpea (tender pods)					
Gliricidia leaves	no	9.1	11.8	16.4	21.3
	yes	15.7	20.3	27.7	35.9
Rice straw	no	19.5	4.6	43.5	10.3
	yes	31.6	7.5	72.1	17.2
Coir dust	no	14.4	3.8	39.4	10.8
	yes	20.8	5.5	53.4	14.7
Sx		2.8	2.0	10.7	6.0

A similar observation is shown by the apparent recovery of applied nutrients (Table 4). In capsicum, the application of EM to legume leaves increased the recovery rate of K more than N. In contrast, the apparent recovery of applied N was greater with rice straw and coir dust due to the low level of this nutrient in these materials. Thus, in the third season, the application of EM enhanced the apparent recovery of N from rice straw to 84 percent. This result may have included some N from the soil, which could have been mobilized by EM. However, this requires further study.

The application of EM enhanced the apparent recovery of N from all organic fertilizers to a greater extent when applied to cowpea. Thus, the apparent recovery of N from rice straw and coir dust exceeded 100 percent. This could be attributed to the observed ability of EM to promote nodulation and N-fixation in legumes (Sangakkara and Higa, 1994). The application of EM has a significant beneficial effect on food legumes grown in organic systems. The lower N recovery observed when EM was applied with legume leaves could be due to the greater availability of N in this organic fertilizer which may inhibit the symbiotic N-fixation process. However, these observations require further study for identifying the causal mechanisms.

Table 4. Apparent Recovery of Applied Nitrogen and Potassium in Capsicum and Cowpea as Affected by Organic Amendments and Effective Microorganisms over Three Seasons.

Treatments	EM applied	Season 1 N (%)	Season 1 K (%)	Season 3 N (%)	Season 3 K (%)
			Capiscum (green pods)		
Gliricidia leaves	no	16.1	23.2	19.0	28.7
	yes	23.0	35.3	27.0	42.5
Rice straw	no	21.4	18.8	38.5	23.9
	yes	47.1	31.2	83.9	37.7
Coir dust	no	14.4	17.7	26.8	21.9
	yes	34.6	30.0	48.0	37.1
Sx		11.3	6.5	8.9	14.5
			Cowpea (tender pods)		
Gliricidia leaves	no	46.3	37.9	59.7	52.6
	yes	57.2	48.6	86.2	87.5
Rice straw	no	51.6	28.8	138.3	41.7
	yes	113.5	39.8	230	66.1
Coir dust	no	62.4	22.3	119.8	41.4
Sx		18.5	6.2	23.9	9.2

Conclusions

Organic or nature farming systems are being called upon to provide increasing quantities of food on a sustainable basis, especially in developing countries. New technologies need to be identified, tested and adapted to increase the efficiency and sustainability of organic systems. Effective Microorganisms (EM) is a proven technology for increasing the productivity of organic systems. The benefits arise from the ability of EM to accelerate organic matter decomposition, thereby releasing greater quantities of nutrients to the soil and the plant. In addition, the present study illustrates the ability of EM to enhance the utility value of the applied nutrients, which are generally low in organic fertilizers. The agronomic efficiencies and the recovery rates of N and K, which are mobile nutrients and deficient in most tropical ecosystems, are enhanced by EM. This phenomenon can be considered as another beneficial role of these microorganisms, which makes the technology useful to organic and nature farming systems in the tropics.

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