Effect of EM on Nitrogen and Potassium Levels in the Rhizosphere of Bush Bean

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Abstract

The influence of Effective Microorganisms (EM) for increasing crop yields is widely reported. Thus, an experiment was conducted to determine the effect of EM 4 on growth and yield, nodulation, and nitrogen and potassium levels in the rhizosphere of bush bean (*Phaseolus vulgaris* L.) a popular vegetable in the tropics. EM was used in conjunction with three organic materials having different C:N ratios and in the presence or absence of inorganic fertilizer. EM had no significant effect on plant growth in the chemically-fertilized plots. In contrast, growth, yield and nodulation of plants grown in the presence of organic amendments, especially those with low C:N ratios, were enhanced by EM. The nitrogen and potassium levels in the rhizosphere were also significantly increased; these results could account for the higher crop yields that are often reported when organic systems are inoculated with EM. The results are presented in terms of the benefits derived from the use of EM in enhancing soil fertility and crop nutrition in organic agriculture.

Introduction

The use of organic amendments in agriculture has increased over the past years because of the escalating costs of chemical fertilizers and the demand for quality products free of chemical contamination. In the developing world, emphasis on the use of organic amendments relates mainly to the cost of chemical fertilizers incurred by small farmers in providing required plant nutrients. The problem of cost has been further compounded by the removal of fertilizer subsidies (Bolle Jones, 1978; Parsons, 1985). Thus, organic amendments might be considered a vital element in the agriculture of the future (IFIA, 1992). The value of organic amendments in crop production is centered around the ability of these animal and plant wastes to provide nutrients and to improve the chemical, physical, and biological properties of soils (Vaughan and Ord, 1985).

The regular addition of organic amendments to soil is very important in the developing world of the tropics where most traditional farming systems are not sustainable. Tropical farms are characterized by severe land degradation through soil erosion and reduced carrying capacity that result in the loss of productivity and farmer income (Lal and Miller, 1990). However, a major drawback to the use of organic wastes and residues in agricultural production is their relatively low levels of plant nutrients (Chen and Avnimelech, 1986). Thus, large quantities are needed if they are applied only for their nutrient content. This, in turn, can adversely affect the ecosystems and nutrient availability if they are not managed properly (Parr, 1975; Parsons, 1985).

The use of Effective Microorganisms (EM), a mixed culture of beneficial microorganisms, has been identified as a possible method of increasing nutrient availability of organic amendments. Among the causal phenomena attributed to EM is the activity of microorganisms isolated from natural sources, mixed, cultured and inoculated into soil where they can enhance the decomposition of organic matter and the release of nutrients. The efficacy of EM in increasing crop yields over that of traditional organic farming systems has also been identified (Sangakkara and Higa, 1992). Thus, the use of EM can be considered a new technology that enhances the efficiency of traditional organic farming and can be compared with other similar products identified in research (Bangar et al., 1989).

While most studies on EM have reported its contribution to increased crop yields, few attempts have been made to identify causal mechanisms. Rapid breakdown of organic matter as the result of increased microbial activity provided by EM is considered a major phenomenon in this technology which was developed in Japan. The process is associated with greater nutrient availability from various organic amendments (e.g., animal manures, green manures, crop residues, and municipal wastes) as a result of the activity of EM compared with farming systems without EM. However, this process has not been adequately quantified.

The objective of this study was to determine the effect of EM on the availability of nitrogen and potassium which are often lost from soils through leaching and erosion because of their greater solubility (Mengel and Kirkby, 1987). The study was conducted with bush bean (*Phaseolus vulgaris* L.), a common vegetable in the tropics, grown under smallholder conditions (Tindall, 1985) with added organic amendments. The beneficial effect of EM in enhancing nutrient availability was evaluated in terms of the nitrogen and potassium content of the bulk soil and the plant rhizosphere. The rhizosphere consists of a thin layer of soil that immediately surrounds plant roots. It is a zone of high microbial populations and activities because of the high level of nutrient enrichment (e.g., carbon, nitrogen, and growth factors) from root secretions and sloughed-off epidermal cells.

Methodology

The study was conducted on a farmer's field in close proximity to the Experimental Station of the University of Peradeniya, Sri Lanka, during the wet season of 1991. The soil at the site was an Ultisol (reddish brown latosol) with a clay loam texture, pH (1:2.5 H_2O) of 6.59, and a CEC of 413 meq/100 g soil. Rainfall over the experimental period (60 days) was 418 mm and mean temperature was 26.8^{o}C. At the inception of the study, plots with dimensions of 2 x 4 m were prepared. Three selected organic amendments, i.e., leaves of *Gliricidia sepium*, partially dried cattle manure, and rice straw were applied to the appropriate plots at a rate equivalent to 8 MT per ha. Each plot received a single type of organic matter. Thereafter, a solution of EM 4 (diluted 1:1000 with water) was applied to 50 percent of the plots containing organic matter at a rate equivalent to 2000 liters per ha, and then the organic matter was incorporated into the soil. In addition, control plots with or without the recommended chemical fertilizer (equivalent to 45 kg N, 50 kg P, and 60 kg K per ha) and EM 4 solution were included. Thus, the experiment had ten treatments, namely three organic amendments, chemical fertilizer, and the control, all with or without EM 4. The treatments were replicated three times within a randomized block design.

Uniform seeds of bush bean (germination: 86.4 percent) were planted in the plots 21 days after the application of EM 4 at a spacing of 15 x 5 cm. The crop was managed according to the recommendations of the Department of Agriculture (1988). Weeding occurred on two occasions, and irrigation was not required. Chemical fertilizer was applied 20 days after planting to those plots that had received a fertilizer application at the time of planting. During the vegetative growth phase of the crop, EM 4 was sprayed onto established plants in plots that received the treatment before planting. The concentration was 1:5000, and the rate of application was equivalent to 5000 liters per ha. Applications were made at 5, 15 and 25 days after planting.

Seed germination was determined on fixed quadrants (1 x 1 m) in all plots. After germination, 3 plants were removed from each plot at 7-day intervals up to flowering (R1 growth stage) and dry weights determined. The dry weights were used to calculate relative growth rates (g/g/wk) by regression analysis. At flowering (R1 stage), five plants were carefully removed from each plot. The soil adhering to the roots was removed as described by Bhattacharya et al. (1990) and was considered to represent the rhizosphere. Nodules per plant were also determined at this stage along with their dry weights. Samples of soil (to a depth of 15 cm) were also collected from the plots at this time.

The soil samples removed from plots and the roots were analyzed for total N (Kjeldhal) and exchangeable K (flame photometry). At crop maturity (R8 stage), pod yield was determined on ten plants per plot. The data were statistically analyzed using the general linear model described by Gomez and Gomez (1981).

Results and Discussion

Gliricidia leaves had the highest concentration of nitrogen and potassium among the three organic amendments (Table 1). The low C:N ratio along with the high nutrient content makes it an ideal organic fertilizer. Rice straw had the highest C:N ratio and it contributed a significant quantity of potassium. The nutrient content of cattle manure was lower than that of *Gliricidia* leaves and the

C:N ratio was higher. However, all of these materials are readily available in the tropics, and they are used widely by smallholder and subsistence farmers of Asia (FAO, 1978; Chen and Avnimelech, 1986).

Table 1. Selected Chemical Properties of Organic Amendments and Soil Used in the Study.

Amendments	Total N (%)	Available P (%)	Exchangeable K (%)	C:N Ratio
Gliricidia Leaves	4.14	0.27	3.04	12.1
Cattle manure	1.48	0.92	1.08	35.6
Rice straw	0.71	0.09	2.84	55.8
Soil	0.07	0.03	0.04	14.8

Organic amendments, chemical fertilizer and EM did not affect the germination of bush bean when they were planted directly in the field. The rate of germination was similar in all plots (Table 2), and the incorporation of organic matter 21 days before planting, with or without EM, reduced the phytotoxic effects of decomposing waste materials that might have affected seed germination (Marambe et al., 1991).

Table 2. Effect of Organic Amendments, Chemical Fertilizer, and Effective Microorganisms (EM) on Growth and Yield of Bush Bean (*Phaseolus vulgaris* L.).

Amendments	EM Applied	Germination (%)	RGR[1] (g/g/wk)	Yield/Plant (g pots/plant)
Gliricidia leaves	No	85	0.085	91.2
	Yes	88	0.093	126.5
Cattle manure	No	92	0.089	97.8
	Yes	89	0.096	124.2
Rice straw	No	91	0.049	68.2
	Yes	90	0.053	81
Fertilizer	No	89	0.154	125.1
	Yes	90	0.149	127.4
Soil/Control	No	84	0.041	43.8
	Yes	86	0.046	48.4
Interaction (P=0.05)		NS	*	*
LSD (P=0.05)				
Organic matter	4.26	0.012	7.45	
EM		2.99	0.004	3.69

[1]Relative growth rate was calculated by regression analysis using plant dry weights.

The greatest relative growth rate was seen in plants grown with chemical fertilizers, with or without EM. The availability of large quantities of nutrients enhanced growth rates as in all traditional inorganic farming systems. However, *Gliricidia* and cattle manure also produced high growth rates of bush bean when compared with that of plants grown with rice straw or without fertilizers.

Relative growth rates were enhanced by EM in all plots with the exception of those receiving chemical fertilizer. This illustrates the efficacy of EM to enhance vegetative growth of crops in organic systems. The toxic effects of the inorganic chemicals may have negated the positive effect of EM in the fertilized plots and warrants further study.

The highest yields were produced by plants grown with chemical fertilizers. Among the organic systems, plants grown with cattle manure and *Gliricidia* leaves produced higher yields than those grown with rice straw. The higher yields obtained from plots amended with *Gliricidia* and cattle manure could be attributed to the relatively greater quantities of plant nutrients supplied by these materials and their lower C:N ratios.

The beneficial effects of applying EM to organic systems is best illustrated in terms of harvestable yields, which determines productivity and income generation. With the exception of plots treated with chemical fertilizers, application of EM increased yields of bush bean. The smallest increase (11 percent) was seen in the control plots which did not receive any fertilizer. In contrast, the increase in yields with the application of EM to *Gliricidia*, cattle manure and rice straw were 38, 28 and 19 percent, respectively. The increases are significant and should result in greater incomes to farmers. The greatest yield increase resulted when EM was applied to organic materials with low C:N ratios. The availability of nitrogen for microbial activity and the rapid breakdown of these materials released nutrients for crop growth which could be considered the causal phenomenon. Thus, the study confirms the beneficial results reported earlier (Sangakkara and Higa, 1992) using organic materials with low C:N ratios in organic systems and the greater efficacy of EM when used with these materials.

Application of organic fertilizer changes the rhizosphere of plants (Bhattacharya et al., 1990). This is seen in the present study in terms of nodulation of bush bean (Table 3). The lowest nodule numbers per plant were observed in plants grown without any fertilizer or with rice straw. All other additives increased nodule numbers because of the availability of nutrients, especially nitrogen, for microbial activity.

Table 3. Effect of Organic Amendments, Chemical Fertilizer, and Effective Microorganisms (EM) on Nodulation of Bush Bean (*Phaseolus vulgaris* L.).

Amendments	EM Applied	Nobles/Plant (No.)	Dry Weight (mg)
Gliricidia leaves	No	21	0.376
	Yes	32	0.402
Cattle manure	No	19	0.369
	Yes	28	0.411
Rice straw	No	8	0.143
	Yes	15	0.202
Fertilizer	No	15	0.242
	Yes	18	0.251
Soil/Control	No	7	0.156
	Yes	12	0.183
Interaction (P=0.05)		*	*
LSD (P=0.05)			
Organic matter		4.11	0.012
Water		1.96	0.006

EM increased nodule numbers and weights of all plants. The lowest increase was seen in plants grown with chemical fertilizers. Thus, application of EM does not seem to be compatible in conventional, chemical-based inorganic farming systems. In all other treatments, the increase in nodulation with EM was significant. The highest increase occured when plants grown without organic amendments received EM (71 percent) and when plants grown with rice straw received EM (88 percent). Nodulation of plants grown with *Gliricidia* and cattle manure increased 52 percent and 47 percent, respectively, due to EM. The smaller increase in nodulation of the plants grown with cattle manure and *Gliricidia* leaves may be attributed to the relatively greater quantities of nitrogen supplied by these materials which could have adversely affected this biological process (Peoples and Herridge, 1990).

Application of all additives increased the nutrient content of soils at the time of flower initiation in bush bean (Table 4). As expected, the greatest increase was seen in plots treated with chemical fertilizer. The organic manures also influenced the nutrient content of the soil which in turn confirmed the benefits of these materials in enhancing crop yields. The causal effect for enhanced yield with EM in the organic system may be explained by changes in the available nutrients (nitrogen and potassium) in the rhizosphere (Table 4).

In all treatments there was an increase in these nutrients with the application of EM. The smallest increase was seen in the plots that received chemical fertilizer because of the high concentrations applied.

Table 4. Influence of Organic Amendments, Chemical Fertilizer, and Effective Microorganisms (EM) on the Nitrogen and Potassium Content of Bulk Soil and Rhizosphere Soil.

Amendments	EM Applied	Total N			Exchangeable K		
		Soil (%)	Rhizosphere (%)	Increase (%)	Soil (meq/100g soil)	Rhizosphere (meq/100g soil)	Increase (%)
Gliricidia leaves	No	0.082	0.087	6.1	527	537	1.8
	Yes	0.087	0.099	13.7	599	639	6.6
Cattle manure	No	0.071	0.074	4.2	478	489	2.3
	Yes	0.078	0.084	7.7	502	562	11.9
Rice straw	No	0.065	0.067	3.0	504	517	2.5
	Yes	0.069	0.072	4.3	525	569	8.0
Fertilizer	No	0.106	0.108	1.8	648	662	2.1
	Yes	0.108	0.11	1.8	655	669	2.2
Soil/Control	No	0.064	0.065	1.5	442	451	2.0
	Yes	0.067	0.07	4.4	469	482	2.7
Interaction (P=0.05)		*	*		*	*	
Sx		0.002	0.041		0.004	0.026	

These results indicate that EM can accelerate the decomposition of organic amendments and the release of nutrients for plant growth. Thus, the application of EM results in higher concentrations of nitrogen and potassium in the plant rhizosphere; the rhizosphere is also affected by secretions of organic and inorganic constituents from the plant roots. Plants grown with *Gliricidia* leaves and EM had a greater increase in nitrogen than potassium in the rhizosphere while the reverse was observed with plants treated with rice straw or cattle manure. The results are related to the initial nutrient content of these supplemental materials. However, in all organic systems, the increase in nitrogen and potassium concentrations in the rhizosphere with EM is significant and could be a causal factor for the higher yields of plants in these plots.

Conclusions

Yields from traditional organic farming systems are generally lower than those from conventional chemical-based systems, primarily because of the smaller quantities of nutrients added with the manures. However, the efficacy of organic manures can be significantly increased with microbial inoculants such as EM. This study clearly illustrates this phenomenon under field conditions. The application of organic amendments increased the yield of bush bean, although the increases varied with the type of amendment used. Application of EM, which contains mixed cultures of naturally-occurring beneficial microorganisms, further increased yields and clearly demonstrated its benefits in organic systems even though variations existed between different organic amendments. The causal mechanism for this observation was also seen. Nodulation was increased with EM and might have enhanced the availability of nitrogen from these legumes. EM also significantly increased nutrient concentrations (nitrogen and potassium) in the rhizosphere because of the rapid breakdown of the added organic materials. However, the application of EM did not produce significant improvements in conventional-based farming systems; this requires further study. In contrast, the use of EM is warranted in organic farming systems because of the significant impact that these organisms might have on the productivity of traditional organic systems, i.e., the acceleration of organic matter breakdown, release of greater quantities of nutrients, and changes in the rhizosophere that are favorable to the growth of crop plants.

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