Effect of EM on the Growth and Yield of Sweet Potato in Wet and Dry Seasons

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Abstract

Sweet potato (*Ipomoea batatas* L.) is a tropical tuber crop, primarily cultivated by small landholders in Asia. The crop is a versatile component of the agricultural systems; it has the capacity to produce a significant quantity of carbohydrates, and the protein and vitamin content enhances its value. Thus, it is cultivated in both wet and dry seasons, although yields are generally lower under dry conditions. Experiments were conducted with a common short season variety of sweet potato using effective microorganisms (EM) as a microbial inoculant to study the effect on crop production during a wet and dry season, Effective microorganisms are reported to improve soil characteristics and to provide the required growth resources as well as a sustainable environment. Treatments over a wet and a dry season at the same location included (a) chemical fertilizer, (Z:) chemical fertilizer with organic amendments, (c) these same treatments with EM, and (d) control treatment with no additives. The data included growth and development of the crop and yield, and water holding capacity of the soil for both seasons.

The results showed that EM increased yields of sweet potato, especially in the dry season when the numbers of tubers, and bulking rates were generally lower. The study also indicated that EM maintained the water holding capacity of the soil to a greater extent during the dry season.

Introduction

Sweet potato (*Ipomoea batatas* L.) is a popular tropical tuber species, primarily grown in the developing world by small landholders. Its primary use is as a food crop; some of the surplus is sold along with other produce from home gardens (Horton *et al*., 1983). The crop is popular and widespread because of its relatively short season in comparison with most other tropical tuber crops and its adaptability to a wider range of environments (Horton, 1988).

The sweet potato requires adequate soil moisture for high yields (Onwueme, 1977). Thus, it is best adapted to regions with well distributed rainfall or with irrigation facilities because of the moisture requirement for tuber initiation and development (Martin, 1988). However, sweet potato is cultivated in Sri Lanka only as a rainfed crop under most agricultural systems, and yields vary widely with location. Hence, a primary factor for improving yields of this popular tuber crop is modification of the soil environment to retain a greater proportion of the available moisture for plant use, especially since drought has been identified as the most serious abiotic factor affecting yield (Ekanayake *et al*., 1988).

Organic matter has been a primary source of nutrients for small farm agriculture (Harwood, 1990). Addition of plant or animal wastes to the soil provides nutrients and improvements to the rhizosphere in terms of physical properties such as water holding capacity and texture (Allison, 1973). Thus, traditional agriculture of the tropics has relied on organic amendments to maintain yields, especially in dry seasons. This phenomenon has been adequately demonstrated in many studies (Wilson, 1983; Sangakkara and Ratnayake, 1988) in rainfed environments.

The value of organic amendments cannot be assessed by plant nutrient analysis alone, since nutrient availability to crops is of greater importance. In addition, the rate of decomposition and release of plant nutrients in an available form determines the usefulness of organic amendments. It is affected by the carbon : nitrogen (C:N) ratio; high values can delay microbial decomposition of organic matter. In addition, organic matter may also immobilize soil nutrients, especially nitrogen, causing temporary deficiencies to the crop (Tomar and Soper, 1981).

Recent research illustrates an alternative method for enhancing the value of organic amendments. Reports from Japan indicate that effective microorganisms (EM) have the ability to enhance the decomposition of organic materials and to improve physical, chemical and biological properties of soils (Higa, 1988). In addition, research using hydroponic cultures have indicated the ability of EM to increase root growth of selected vegetables (Hornick and Parr, 1990, Personal Communication). Thus, a study was undertaken to determine the effect of EM on growth and yield of sweet potato in both wet and dry seasons with addition of low C:N ratio organic amendments. The selection of organic materials was based on other information, i.e., the increased benefit of using low C:N organic matter with EM solutions for increasing the yields of food crops (Sangakkara and Higa, 1994).

Materials and Methods

The study was conducted on a farmer' s field in close proximity to the University Experimental Station, Kunasale, Sri Lanka. The soil was an Ultisol, with the following characteristics: pH (1:2 H_2O), 6.6; total N, 0.12 percent; available P_2O_5, 19.4 ppm; exchangeable K, 23.6 ppm. Climatic parameters for the wet and dry seasons were observed at a meteorological station in close proximity to the experimental site and are presented in Table 1.

Treatments applied to two adjacent sites in order to overcome any carryover effects were:

A. Use of fresh *Gliricidia* leaves (C:N, 14.6) as the organic amendment at a rate equivalent to 5 mt/ha.
B. Use of the recommended rate of chemical fertilizer (equivalent to 75 kg N, 60 kg P_2O_5 and 150 kg K_2O/ha).
C. Application of EM 4 to soil at a dilution of 1:1000.
D. Application of the EM dilution with the organic amendment applied at the rate indicated in A.
E. Application of the EM dilution with fertilizer rate indicated in B.
F. Application of the recommended fertilizer rate (B) with the organic amendment applied in treatment A.
G. Control treatment with no additives.

The treatments were arranged in a Randomized Block Design, with three replicates. The plot size was 4 x 3 m.

Vegetative propagules of sweet potato (variety C 26, mean dry weight of 0.2) were planted at a spacing of 100 x 30 cm at the beginning of the wet (October) and dry (April) seasons. Organic matter and EM were applied to the prepared beds two weeks before planting. A second application of the EM solution was made two weeks after planting.

Weeds were removed manually three times. No supplementary irrigation water was applied in order to conform to normal farmer practice. The following parameters were measured:

1) Water holding capacity of the soil in all plots at the beginning and end of the experiment.
2) Leaf area per plant at 30days after planting and at harvest.
3) Dry weight of shoots (g) at 30days after planting and at harvest by drying to a constant weight at 80C.
4) Total root length using a grid technique (Bohm, 1979) and dry weight of roots (g) at 30 days after planting.
5) Bulking rate of tubers (tuber weights at three-week intervals) beginning 45 days after planting.
6) Tuber numbers and weights (g) corrected to 60% moisture at final harvest.

The data for the two seasons were analyzed for treatment differences (Steel and Torrie, 1981).

Results and Discussion

Rainfall received during the dry season was approximately 35 percent of that in the wet season (Table 1); this is a characteristic feature of the region (Domros, 1974). Since evaporation exceeds rainfall in the dry season, crop growth is often adversely affected by drought; this can be overcome by supplementary irrigation. In addition, the higher temperature and lower humidity of the dry season (Table 1) increase the stress on crop plants. By comparison, rainfed agriculture can be successful in the wet season because of the more conducive climatic conditions.

The growth patterns of sweet potato plants in the wet and dry seasons are presented in Table 2. The data for all treatments illustrate the improved growth in the wet season, which is a reflection of the more conducive climatic conditions.

Table 1. Environmental Parameters of the Wet and Dry Seasons.

Parameter	Wet Season (Oct. to Feb.)	Dry Season (April to Aug.)
Cumulative rainfall (mm)	856	294
Daily Temp. (C)	27.1±4.8	32.1±3.1
Relative humidity (%)	77.4±4.8	68.2±3.1
Day length (hours)	9 to 10	11 to 12
Mean pan evaporation (mm/day)	1.98	4.26

Table 2. Effect of Treatment on Shoot Growth of Sweet Potato in the Wet and Dry Seasons.

Treatment	Leaf Area (cm^2)		Dry Weight (g)	
	30DAP	At Harvest	30DAP	At Harvest
Wet Season				
Control	426	4814	4.0	48.3
Fertilizer	1314	10412	8.8	101.9
EM	621	6064	5.1	66.2
Organic matter	842	7241	6.2	72.4
Fertilizer + Organic matter	1546	14427	10.9	110.4
Fertilizer + EM	1488	10956	9.4	104.8
Organic matter + EM	945	9145	7.3	86.5
LSD (P=0.05)	86	275	0.9	4.6
Dry Season				
Control	261	2025	2.5	25.1
Fertilizer	745	7499	6.0	61.5
EM	358	3136	3.7	38.5
Organic matter	459	4240	4.3	44.3
Fertilizer + Organic matter	1014	9246	7.5	72.6
Fertilizer + EM	919	8681	6.7	65.8
Organic matter + EM	608	5815	5.1	49.3
LSD (P=0.05)	64	189	0.6	5.0

A comparison of treatment differences during the wet and dry seasons reveal a similar trend at both harvests. The differences occur in terms of the magnitude in variation of the leaf area and shoot weight between the treatments. The results for the dry season indicate greater differences between treatments, especially in terms of dry weight of shoots, an indication of dry matter accumulation by the crop.

Shoot growth of sweet potato was reduced significantly for the control treatment; the response of this species to fertilizers or other soil additives can be easily measured in this environment. The addition of chemical fertilizer increased the leaf area and shoot weight significantly in both seasons. This clearly indicated the ability of sweet potato to increase yields with added chemical fertilizer (Onwueme, 1977). In addition, the leaf area response to added fertilizer was greater than the associated increase in shoot weight, especially in the wet season.

The leaf area of sweet potato increased with the application of organic matter in both seasons. However, the magnitude of increase was greater in the wet season, which again reflects the requirement for adequate soil moisture for high yields. With added organic matter, the increase in leaf area was greater than the associated increase in shoot weight during the wet season.

Application of organic amendments and chemical fertilizer together produced the highest values in the measured parameters (Table 2). Both leaf area and shoot dry weight increased significantly with this treatment. This result reflects the accrued benefits to the rhizosphere from the application of organic amendments (Allison, 1973), and crop response to high levels of applied nutrients (Onwueme, 1977). The ability of the organic amendments to enhance the water holding capacity of the soil, especially in the dry seasons, is a distinct advantage because it increases the availability of fertilizer nutrients to the plant.

EM is considered to be a beneficial microbial inoculant that can increase the utility of soil organic matter (Higa, 1988) so that a greater quantity of nutrients are made available to plants. EM also has a beneficial effect on the rhizosphere by establishing a more favorable microbiological equilibrium in this region (Higa, 1988).

As shown in Table 2, the addition of EM alone increased the growth of sweet potato plants over that of the control; the effect was greatest in the wet season. This effect may be a result of the availability of adequate soil moisture for microbial activity. However, the effects of EM are greatest when added with organic matter or fertilizer.

Treatment effects on root growth at 30 days after planting are similar to those on shoot growth (Table 3). Fertilizer increased root growth significantly; application of EM with fertilizer increased root growth further. Organic matter plus EM also produced a similar effect.

The magnitude of change in root growth as a result of applied EM indicated a significant crop response in both the wet and dry seasons. However, the root dry weights were higher during the wet season. The results indicate that sweet potato produced a more extensive root system with a lower dry weight in the dry season compared with the wet season, and suggests that EM may be useful in enhancing root growth under dry conditions. However, this phenomenon requires further elucidation under more controlled environments.

Table 3. Effect of Treatment on Root Growth and Dry Weight of Sweet Potato at 30 Days after Planting.

Treatment	Total Length (cm)	Dry Weight (g)
	Wet Season	
Control	316	3.4
Fertilizer	546	7.7
EM	364	4.7
Organic matter	405	5.5
Fertilizer + organic matter	597	8.4
Fertilizer + EM	586	8.3
Organic matter + EM	478	6.4
LSD (P=0.05)	65	1.0
	Dry Season	
Control	205	2.8
Fertilizer	385	5.1
EM	286	3.3
Organic matter	349	4.4
Fertilizer + organic matter	426	5.4
Fertilizer + EM	449	5.7
Organic matter + EM	374	4.9
LSD (P=0.05)	52	0.9

The effects of treatment on yield components and on yields of sweet potato in wet and dry seasons show a clear relationship between plant growth and yield characteristics in both seasons (Table 4). The treatments have similar overall growth effects on sweet potato for both seasons. Sweet potato yields were significantly greater in the wet season, confirming earlier reports on the adverse impact of dry weather on yield (Ekanayake *et al*., 1988). However, the application of fertilizer increased yields significantly (over 170 percent) in both seasons; again, sweet potato responded to added nutrients even under dry conditions (Onwueme, 1977).

Application of organic matter alone also increased yield, although not of the magnitude of chemical fertilizer. This result could be attributed to the slower release of nutrients from the organic amendments (Allison, 1973). In contrast, the addition of organic amendments with fertilizer produced maximum yields (Table 4). This result indicated the impact of combined additives; the higher yields were the result of better shoot and root growth, and the increased potential yield components.

Table 4. Effect of Treatment on Yield Components and Yield Per Plant of Sweet Potato in the Wet and Dry Seasons.

Treatment	Tubers (No./plant)	Bulking Rate (g/plant/week)	Yield/Plant (g)
		Wet Season	
Control	1.8	32.4	242
Fertilizer	4.6	71.5	656
EM	2.4	37.5	341
Organic matter	3.1	51.5	446
Fertilizer + organic matter	5.4	78.5	706
Fertilizer + EM	5.6	74.9	685
Organic matter + EM	4.2	56.4	501
LSD (P=0.05)	0.5	6.9	32
		Dry Season	
Control	1.0	25.6	196
Fertilizer	3.0	60.5	501
EM	1.6	31.5	288
Organic matter	2.3	40.5	374
Fertilizer + organic matter	3.6	67.6	601
Fertilizer + EM	3.5	65.4	577
Organic matter + EM	2.7	47.6	436
LSD (P=0.05)	0.3	5.0	21

Application of EM alone to these tropical soils produced the lowest yields compared with the controls. However, application of EM with organic matter increased yields by 12 and 16 percent in the wet and dry seasons, respectively, when compared with the productivity of plants which received organic matter alone. This phenomenon, as suggested by Higa (1988), indicated the ability of EM to increase the value of organic amendments. Similarly, the application of EM with chemical fertilizer also increased yields marginally (4 percent) over plants receiving fertilizer alone. This could also be a response to the ability of EM to enhance the rhizosphere of the crop and to improve the availability of the added fertilizer. However, these aspects will require further study.

An important feature of the current study was the response of sweet potato to EM applications in the dry season. While overall yields were lower under dry conditions, the percentage increase with EM alone or with fertilizer and organic matter were greater than in the wet season. The ability of organic matter to increase soil moisture retention under dry conditions (Allison, 1973) and the ability of EM to develop a zymogenic soil environment could be considered causal factors for this observation. In contrast, yield increases resulting from fertilizer alone were smaller in the dry season since lower soil moisture affects the utilization of applied nutrients, and production of sweet potato is affected by dry conditions (Lin *et al*., 1983).

EM is reported to improve the physical properties of soils (Higa, 1988). The data at the beginning and end of each season suggests that application of EM with organic matter helps to maintain the water holding capacity (WHC) of the soil (Table 5); under normal conditions of intensive cropping, the water holding capacity of soil is reduced with time.

At the inception of this study, the soil water holding capacity ranged from 21 to 25 percent. Plots to which organic amendments were added had the higher values. This was the result of the capacity of organic matter to improve moisture retention properties of the soil (Allison, 1973). A comparison of the water holding capacity at the end of the season illustrated that the reduction in WHC after cropping was lowest in plots to which either organic amendments or EM had been added. Water holding capacity of soil in plots to which neither of these materials was added was reduced to a greater extent at the end of the wet season.

In the dry season, application of EM, especially with organic amendments, reduced the differences between the water holding capacity of soil at the beginning and end of the cropping period. This result indicated a beneficial effect of EM which, in many instances, was not significant. However, the observed trend indicated some positive effects and warrants further detailed study.

Table 5. Water Holding Capacity of Soils as Affected by Treatments at the Beginning and End of the Wet and Dry Seasons.

Treatment	**Water Holding Capacity (%)**	
	At Planting	**After Harvest**
	Wet Season	
Control	22.6	21.2
Fertilizer	21.9	20.8
EM	23.1	22.6
Organic matter	24.6	24.1
Fertilizer + organic matter	24.9	24.2
Fertilizer + EM	23.5	23.0
Organic matter + EM	24.6	24.2
LSD (P=0.05)	0.6	0.4
	Dry Season	
Control	21.8	20.3
Fertilizer	22.1	20.9
EM	22.1	21.5
Organic matter	22.0	21.6
Fertilizer + organic matter	23.8	23.2
Fertilizer + EM	22.8	22.2
Organic matter + EM	23.9	23.5
LSD (P=0.05)	0.2	0.3

Conclusions

Sweet potato is a drought-prone crop (Ekanayake *et al.*, 1988) and soil moisture is an important abiotic factor affecting yields. The effects of drought can be partially overcome by application of organic amendments. This study illustrates that the effectiveness of organic amendments to maintain yields, especially in dry seasons, can be enhanced by the application of EM. Plant growth and yield were significantly improved when EM was added with organic matter. While maximum yields were obtained with inorganic fertilizers, these too were marginally improved when EM was added. This phenomenon was more significant in the dry season when overall yields were lower.

Evaluation of the water holding capacity of soil also demonstrated trends for the beneficial effects of EM when applied with organic amendments. Thus, improvements in the growth and yield of sweet potato, and in the rhizosphere were observed with the use of EM.

Farmers in the developing world strive to produce crops from marginal soils which are inherently low in fertility. Inorganic fertilizers are an expensive commodity, and there is a scarcity of good quality organic materials for use as soil conditioners and biofertilizers. Under such conditions, the advantages of EM will become more apparent since these beneficial microorganisms have the capacity to improve the plant use-efficiency of available nutrients. The benefits imparted to the rhizosphere will further enhance the usefulness of EM. However, confirmatory studies are required both in the field and under controlled conditions, especially in tropical regions where wide variations in climate, soil, and agroecological conditions exist. These studies will enable the development of a comprehensive package of EM technology to assist farmers in tropical regions.

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