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Evaluation of the usefulness of EM products using tomato (*Lycopersicon esculentum* Mill) grown under a controlled environment

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Abstract

Effective microorganisms (EM), a commercial concoction of microbes that includes yeasts, fungi, bacteria and actinomycetes, have been found to be effective in enhancing crop growth by a number of scholars. The present study was carried out mainly to investigate the effects of effective micro-organisms on growth, yield and quality of tomato (*Lycopersicon esculentum* mill) grown under a controlled environment, along with selected soil properties. Treatments included: control, effective microorganisms, mineral fertilizer, effective microorganisms + mineral fertilizer, compost, compost + effective microorganisms, compost + mineral fertilizer and compost + mineral fertilizer + effective microorganisms. EM application had a negative effect on tomato leaf dry matter yield, number of leaves, number of trusses, fruit yield and number of fruits. The negative effects of EM were ascribed to nitrogen immobilization by the effective microorganisms that could have resulted in reduced nitrogen availability to plants. The lower number of fruits associated with EM application resulted in improved average fruit weight of tomatoes grown in the greenhouse, possibly as a result of more assimilates being partitioned to the few fruits formed.

Keywords: Tomato, compost, effective microorganisms (EM), mineral fertilizer, yield.

INTRODUCTION

The intensification of agricultural production is mostly done with the use of mineral fertilizers, planting of high-yielding cultivars and the use of agro-chemicals for crop protection. The FAO, for example, estimated in 1989 that about 50% of the increase in agricultural production in the world was due to use of chemical fertilizers (FAO, 1989). This approach is, however, increasingly proving to be unsustainable as it causes soil degradation and the cost of required inputs is often beyond the financial ability of smallholder peasants who constitute more than 80% of the food producers in the developing nations (Tittonell et al., 2005).

There have been numerous attempts to develop alternative systems more suited to the needs of the tropical and subtropical smallholders. One such alternative system promotes the use of " effective microorganisms" (EM) to enhance crop growth. EM is a mixture of specially selected and cultured naturally occurring, beneficial microorganisms that have been studied and known to significantly improve soil quality and plant growth (Li and Ni, 1995). It contains selected species of microorganisms, including predominant populations of lactic acid bacteria and yeasts and smaller numbers of photosynthetic bacteria, actinomycetes and other types of organisms. All of these are claimed to be mutually compatible with one another and are able to coexist in liquid culture.

The concept of effective microorganisms (EM) was developed in 1971 by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan (Higa and Wididana, 1991). Research has shown that inoculation of the soil/plant ecosystem with EM cultures can improve soil quality, soil health, the growth, yield, and quality of crops (Higa and Parr, 1994). Daly and Steward (1999) also showed that application of EM to peas, sweet potato and onions increased yield by 31, 23 and 29%, respectively. Different brands of EM are currently being produced in about 40 countries across the globe using local microbial isolates. In South Africa EM products are produced and marketed by EMROSA (Pty) Limited.

The use of EM is not yet widespread in South Africa, although there are some reports, mainly by EMROSA in their newsletters and on their website (www.emrosa.org.za) that some commercial farmers are already using the materials and they seem to find satisfaction with its effects. During the course of this experiment, EM products were not officially registered for use on crops in South Africa. As of 2006, exact date unknown, the products are registered and can be sold in shops (Anonymous, 2006). They apparently also conform to EUREP GAP organic requirements and "you can export your products anywhere in the world" (Anonymous, 2006). There has been only one scientific report of their use in the Eastern Cape and relatively few scientific reports worldwide (Mupondi et al., 2006a, b) and a preliminary field study conducted by Ncube et al. (2011) at the University of Fort Hare yielded results that were inconclusive. This was attributed to an outbreak of blight that affected the tomato crop that first attacked the EM treated plots before spreading into chemical treated plots. The main objective of this study was therefore to evaluate the usefulness of EM products using tomato (*Lycopersicon esculentum* Mill) grown under a controlled environment.

MATERIALS AND METHODS

The experiment was conducted in a green house at the University of Fort Hare, Alice, Eastern Cape Province, South Africa.

Effective microorganisms (EM) and compost

The brands used in the trials included multiplied - EM, EM -F.P.E, EM 3- in-1 and EM - 5. The first was applied as a soil drench while the last three were applied as foliar pesticide mixtures. Multiplied - EM is a mixture of basic EM, molasses and water in a ratio of 1:1: 20. EM - F.P.E stands for fermented plant extract and was prepared by mixing chopped fresh weeds, chlorine-free water, molasses (3%) and multiplied - EM (3%) in a ratio of 40: 33: 1 : 1. EM 3-in-1 is an insect repellent and was produced in a similar way as EM - F.P.E but using different ingredients. The ingredients used in this case were fresh garlic, chili pepper, ginger (400 g of each, chopped), black pepper (200 g powdered, 600 ml of multiplied - EM and 18 L of water. EM - 5 is a mixture of multiplied - EM, molasses, vinegar, strong distillation alcohol (more than 30%) and water (Anonymous, 2004; 2003). All four brands of EM were used in EM - treated plots. Multiplied - EM was applied as a soil drench by dissolving EM in water in a ratio of 1: 300 and the resultant solution applied at a rate of 200 L per experimental unit seven days before seedlings were transplanted. During the course of the experiment, multiplied - EM solution, in a ratio of 1: 500, was applied to respective EM - treated plots at the rate of 50 L per week. Mixtures of EM - FPE, EM 3- in-1 and EM - 5 diluted with water in a ratio of 1: 800 were sprayed to control diseases and pests in EM treated plots.

Table 1. Selected properties of the experimental soil (upper 0-30 cm depth).

Characteristic	Value
pH (KCl)	5.7
Bulk density (gcm^{-3})	1.23
Total N ($g\ kg^{-1}$)	0.9
Available P ($mg\ kg^{-1}$)	59
Exchangeable K ($mg\ kg^{-1}$)	441
Exchangeable Mg ($mg\ kg^{-1}$)	246
Zn ($mg\ kg^{-1}$)	15.2
Mn ($mg\ kg^{-1}$)	46
Organic C ($g\ kg^{-1}$)	6.0
Cu ($mg\ kg^{-1}$)	2.9

An equivalent of 27 t ha^{-1} (which supplied 54, 13.5 and 10 kg ha^{-1} of N, P and K, respectively) compost was applied. The compost is made up of pine bark and other organic refuse material and is manufactured by C.S.M at Brakkerfontein, Port Elizabeth. Some characteristics of the nature's super grow compost are shown in Table 2.

Experimental design

The experiment was a randomized complete block design (RCBD) with ten replicates. Treatments were: control, EM (EM), recommended fertilizer (RF) (N 200: P 90 kg ha^{-1}), EM + RF, compost (Comp), comp + EM, comp + RF, comp + RF + EM. The soil used was from the research farm of the University of Fort Hare, Alice, Eastern Cape Province, South Africa. The soils are deep and alluvial, of the Oakleaf form (Oa), belonging to Jozini series, according to the South African system of soil classification (Soil Working Group, 1991). The soil had very low concentrations of total nitrogen, available phosphorus and organic C, but had high levels of micronutrients and exchangeable K (Table 1). The pH was 5.7 and suitable for growth of both tomato and butternut crops.

Each replicate consisted of two tomato plants in 30 cm^3 pots containing 15 kg of soil. Growth parameters measured included plant height, stem girth, number of leaves and trusses formed. Harvesting of mature fruits was done at 12 weeks after planting and yield was evaluated as number of fruits, total mass of fruits, average mass of fruit and proportion of marketable fruits. Leaf and stem biomass were also measured on a dry mass basis. Soil and leaf samples were taken at harvest time to assess treatment effects on soil and plant nutrient content. Leaf sampling was done by taking leaves from the fourth to the sixth clusters (Jones et al., 1971). The leaf dry matter was determined after oven drying to constant mass at 65^0C. The dried samples were ground in a hammer mill to pass through a 1 mm mesh sieve.

Both soil and leaf samples were taken at harvest to assess treatment effects on soil and plant nutrient content. Leaf sampling was done by taking the third youngest fully expanded leaf from shoots (Jones et al., 1971) of 10 plants from the experimental row of each experimental unit. The leaf dry matter was determined after oven drying to constant mass at 65°C. The dried samples were grounded in a hammer mill to pass through a 1 mm mesh sieve. The ground samples were digested with sulphuric acid, selenium powder and salicylic acid mixture for the determination of total P

Table 2. Selected properties of the compost materials used.

Characteristic	Nature's super grow
pH (H_2O)	4.33
EC (µS cm^{-1})	2.37
Total N (g kg^{-1})	2.0
Total P (g kg^{-1})	0.5
Total K (g kg^{-1})	0.4
Polyphenol (g kg^{-1})	9.8
Total C (g kg^{-1})	193.3
C:N	96.65
C:P	386.6

and K (Okalebo et al., 2002). Phosphorus was read on a colorimeter following colour development by the molybdenum blue method (Okalebo et al., 2002). Potassium in digested samples was determined by flame photometry. Total nitrogen was determined using a LECO TruSpec C/N auto analyzer (LECO Corporation, 2003).

Soil samples taken after harvest were air dried for 2 weeks and ground to pass through a 2 mm mesh sieve. Soil pH and electrical conductivity (EC) were determined in water extracts as described by Okalebo et al. (2002). Samples were shaken in distilled water in a ratio of 1:2:5 on a reciprocal shaker for 10 min and left standing for 30 min, then shaken again for 2 min, after which pH was read using a WTW pH 526 m, while EC was read on a WTW 330i conductivity meter. Total-N was determined using a LECO TruSpec C/N auto analyzer (LECO Corporation, 2003) and extractable P and K were determined following the Ambic-2 extraction method (Non-Affiliated Soil Analysis Work Committee, 1990).

Data analysis

The data obtained was subjected to analysis of variance (ANOVA) using the SAS statistical package while means were separated using least significance differences (LSD) at the 0.05 level of significance.

RESULTS

Effects on leaf dry matter yield

There were significant ($P \leq 0.05$) treatment effects on leaf dry matter yield. Application of EM and compost alone or their combined application did not increase leaf dry matter yield of tomato significantly over that of the control (Table 3). An 8.5% decrease in leaf dry matter yield with sole EM application was observed relative to the control. When applied with compost, a 19.3% decrease in leaf dry matter yield was observed relative to the compost treatment. The apparent depressive effect of EM was further observed when it was applied with recommended fertilizer whereby this treatment resulted in a 7.2% decrease in leaf dry matter yield relative to recommended fertilizer treatment. Application of EM with mineral fertilizer and compost resulted in a decrease in leaf dry matter yield of 3.7% relative to the mineral fertilizer and compost treatment. The results, therefore, demonstrated a definite negative trend whereby the application of EM singly or in combination with mineral fertilizer or compost depressed leaf dry matter yield.

Effects on tomato fruit yield

The treatment effects on tomato fruit yield are shown in Table 3. Application of sole EM or combined with compost or mineral fertilizer had a negative effect on fruit yield. Application of EM alone in this study resulted in a 15.4% decrease in yield over the control (Table 3). Similarly, application of EM with compost resulted in a 24.1% decrease in fruit yield relative to the compost treatment and reduced fruit yield by 6.5% when it was applied with mineral fertilizer relative to the mineral fertilizer treatment. When EM was combined with both mineral fertilizer and compost a 12.3% decrease in fruit yield was recorded relative to the compost + mineral fertilizer treatment. Treatments that received a combination of compost + mineral fertilizer gave the highest fruit yield, with a 51% fruit yield increase relative to the control treatment.

Effects on average fruit mass

Average fruit mass was significantly ($P \leq 0.05$) affected by some of the treatments. Although sole application of EM did not have a significant effect on average fruit mass, a positive trend was observed with its application. Sole application of EM resulted in an 11.6% increase in average fruit mass relative to the control. When EM was applied with compost, a 9.9% increase in average fruit mass was recorded relative to the compost treatment. On the other hand, application of EM with mineral fertilizer resulted in a 4.7% increase in average fruit mass relative to the mineral fertilizer treatment. Application of EM + mineral fertilizer + compost resulted in an 11% decrease in average fruit mass over the mineral fertilizer + compost treatment (Table 3).

Effects on plant and soil nutrient content

Leaf N, P and K content are shown in Table 4. The leaf N content ranged from 9 to 13.9 g kg^{-1} and the content for most treatments was lower than the critical level of 12 g kg^{-1} for N cited by Foth and Ellis (1988). The low leaf N content was reflected in the yellowing of some plants. Application of EM with mineral fertilizer significantly increased leaf N content relative to the control and was the only treatment that resulted in leaf N content greater than the critical level. Application of compost + RF + EM improved leaf N content and N uptake and application of sole EM increased leaf N content but not its uptake.

Application of EM singly or in combination with compost

Table 3. Effects of EM, compost and mineral fertilizer combinations on leaf dry matter yield (DMY), leaf number, number of trusses, fruit yield, fruits formed and on average fruit mass of greenhouse-grown tomato.

Treatment	Leaf DMY (g pot^{-1})	Leaf number/ pot^{-1}	Number of trusses/ pot^{-1}	Fruit yield (g pot^{-1})	Fruits formed/ pot^{-1}	Average fruit mass (g fruit^{-1})
Control	45.8^{cd}	21^{c}	11^{cd}	418.9^{de}	15^{c}	42.1^{bc}
EM	41.9^{d}	17^{c}	7^{e}	354.4^{e}	8cd	47.0^{ab}
RF	57.3^{ab}	39^{a}	16^{a}	563.4^{ab}	20^{ab}	29.8^{d}
EM+RF	53.2^{abc}	34^{ab}	15^{ab}	526.6^{bc}	17^{b}	$31.^{2d}$
Comp	$48.7b^{cd}$	20^{c}	$9d^{e}$	470.0^{cd}	10^{c}	51.5^{ab}
Comp+EM	39.3^{d}	18^{c}	8e	356.8^{e}	7d	56.6^{a}
Comp+RF	70.0^{a}	32^{b}	15ab	632.8^{a}	20^{a}	32.7^{cd}
Comp+RF+EM	59.7^{a}	33^{b}	13bc	555.1^{ab}	20^{a}	29.1^{d}
C.V (%)	16.8	22	20.7	18.3	20.2	27.2

EM: effective microorganisms, RF: recommended fertilizer, EM + RF: effective microorganisms and recommended fertilizer, comp: compost, comp + EM: compost and effective microorganisms, comp + RF: compost and recommended fertilizer,Comp + RF + EM: compost, recommended fertilizer and effective microorganisms.**Means in each column followed by the same letter are not significantly different at P≤ 0.05 accor ding to the LSD test.

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Control	45.8^{cd}	21^{c}	11^{cd}	418.9^{de}	15^{c}	42.1^{bc}
EM	41.9^{d}	17^{c}	7^{e}	354.4^{e}	8cd	47.0^{ab}
RF	57.3^{ab}	39^{a}	16^{a}	563.4^{ab}	20^{ab}	29.8^{d}
EM+RF	53.2^{abc}	34^{ab}	15^{ab}	526.6^{bc}	17^{b}	$31.^{2d}$
Comp	$48.7b^{cd}$	20^{c}	$9d^{e}$	470.0^{cd}	10^{c}	51.5^{ab}
Comp+EM	39.3^{d}	18^{c}	8^{e}	356.8^{e}	7^{d}	56.6^{a}
Comp+RF	70.0^{a}	32^{b}	15^{ab}	632.8^{a}	20^{a}	32.7^{cd}
Comp+RF+EM	59.7^{a}	33^{b}	13^{bc}	555.1^{ab}	20^{a}	29.1^{d}
C.V (%)	16.8	22	20.7	18.3	20.2	27.2

EM: effective microorganisms, RF: recommended fertilizer, EM + RF: effective microorganisms and recommended fertilizer, comp: compost, comp + EM: compost and effective microorganisms, comp + RF: compost and recommended fertilizer,Comp + RF + EM: compost, recommended fertilizer and effective microorganisms.**Means in each column followed by the same letter are not significantly different at P≤ 0.05 according to the LSD test.

led to a decrease in leaf N content and plant N uptake. The leaf phosphorus content ranged from 1.3 to 2 g kg^{-1} and was much lower than the critical leaf P content of 3 g kg^{-1} previously reported by Foth and Ellis (1988). Application of compost resulted in the highest leaf P content with application of EM + RF and Comp + RF + EM resulting in the lowest leaf P content. The leaf K content was higher than the critical level of 3 g kg^{-1} cited by Foth and Ellis (1988). Soil nutrients were not significantly influenced by treatments (Table 4).

DISCUSSION

The application of sole EM or in combination with compost or mineral fertilizer was observed to have a negative effect on leaf dry matter yield, number of leaves, number of fruit trusses and tomato fruit yield. It is possible that the inoculated effective microorganisms proliferated very fast in the soil, thriving on the native and added nutrients in the soil and resulted in their temporary immobilization. Therefore, it is speculated that introduction of EM microbes into the soils could have set in short-term competition between the microbes and the plants for nutrients such as nitrogen in the limited pot soil volumes whose net effect was reduced plant growth. The suspected nutrient immobilization could also have been exacerbated by the introduction of carbon through molasses while applying EM to the soil. This could have stimulated indigenous microbial biomass pool activities in soil (Daly and Stewart, 1999), causing N and P immobilization and reduced plant growth (Bååth et al., 1978; Ritz and Griffiths, 1987). This speculation is supported by the low N uptake observed in plots treated with EM (Table 4).

The combined application of EM with compost, as recommended by EM promoters, is scientifically sound, as the compost is expected to serve as a source of labile C and nutrients for proliferation of the microorganisms. However, results obtained from this study showed a negative effect of combined application of EM + compost. This observation could possibly be due to nitrogen immobilization by the soil microbial biomass pools as the total N content of the compost material was below the critical level of 11.5 g kg^{-1} suggested by Bartholomew (1965). Addition of organic materials with a total N content less than 11.5 g kg^{-1} can initiate N immobilization in the soil (Bartholomew, 1965). The suspected nutrient immobilization can also be explained in terms of C: N ratio and C: P ratio of the compost material. The optimum C: N ratio for speedy decomposition of organic material and subsequent N mineralization is reported to be less than 30 (Brady and Weil, 1999). In terms of C: P ratio, Rustad and Cronan (1988) suggested that the critical C: P ratio of organic materials above which nutrient immobilization can occur ranges between 350 and 480. The C: N ratio of the compost material used was 96.7. This value was far above the optimum level suggesting that addition of compost could have caused N immobilization, reducing plant-available N. However, the C: P ratio of the compost material was within the suggested range, ruling out the possibility of P immobilization.

Conclusion

Addition of EM depressed the yield of tomato and this was attributed to possible initial nutrient immobilization. These findings suggest the need for a more systematic study to provide a better understanding of the mechanisms by which EM influences plant growth. The use of compost did not have the desired effect as the compost may have induced N immobilization in soil due to its wide C: N ratio. The resultant N immobilization reduced the yield. The effect of organic material on EM effectiveness will, therefore, be explored further in a separate study) in which goat manure with a narrow C: N ratio will be used.

REFERENCES

Anonymous (2003). EM user's manual. EMROSA, (Pty) Ltd, 70 Lloys Ellis Ave, Mnandi, Centurion, R.S.A.

Anonymous (2004). EM user's manual. EMROSA, (Pty) Ltd, 70 Lloys Ellis Ave, Mnandi, Centurion, R.S.A.

Anonymous (2006). Compost tea is not tea: Undrinkable vs. EMs are drinkable. EMROSA Newsletter. 3: 8.

Bååth E, Lohm U, Lundgren B, Rosswall T, Söderstrom B, Sohlenius B, Wirén A (1978). The effect of nitrogen and carbon supply on the development of soil organisms population and pine seedlings: A microcosm experiment. Oikos, 31: 153 - 163.

Bartholomew WV (1965). Mineralization and immobilization of nitrogen in the decomposition of plant and animal residue: Soil nitrogen. Agron. J., 10: 285- 290.

Brady NC, Weil RR (1999). The nature and properties of soil. 12th edn. Prentice Hall, Upper Saddle River, New Jersey.

Daly MJ, Stewart DCP (1999). Influence of effective microorganisms on vegetable production and carbon mineralization - A preliminary investigation. Sust. Agr., 14: 15-28.

FaO (1989). Fertilizer and food production, FAO Fertilizer Program 1961-1986. Rome, Italy.

Foth HD, Ellis B (1988). Soil fertility. John Wiley & Sons, New York.

Higa T, Wididana GN (1991). The concept and theories of effective microorganisms. In: Higa T, Parr JF (eds). Beneficial and effective microorganisms for a sustainable agriculture and environment. International Nature Farming Research Centre, Atami, Japan, p. 16.

Higa T, Parr JF (1994). Beneficial and effective microorganisms for a sustainable agriculture and environment. International Nature Farming Research Center, Atami, Japan.

Jones JB (JR), Large RL, Pfleiderer DB, Klosky HS (1971). How to properly sample for a plant analysis. In: Jones JB (Jr), Case VW. (eds). Soil testing and plant analysis. 3rd edition, Soil Science Society of America, 677 S. Segoe Rd., Madison, WI 53711, USA, SSSA Book Series no 3.

Leco Corporation (2003). TruSpec CN Carbon /Nitrogen Determinator. Instruction Manual. Leco - Corporation 3000, Lakeview Avenue. St Joseph, MI.

Li W, Ni Y (1995). Research and application of EM (effective microorganisms). Chin. J. Ecol., 14: 58-62.

Mupondi LT, Mnkeni PNS, Brutsch MO (2006a). The effect of goat manure, sewage sludge and effective microorganisms on the composting of pine bark and the nutritional value of compost. Comp. Sci. Util., 14: 201-210.

Mupondi LT, Mnkeni PNS, Brutsch MO (2006b). Evaluation of pine bark or pine bark with goat manure or sewage sludge co-composts as growing media for vegetable seedlings. Comp. Sci. Util., 14: 238-243.

Ncube L, Mnkeni PSN, Brutsch MO (2011). Agronomic suitability of effective micro-organisms for tomato production. Afr. J. Agr., 6: 650-654

Non-affiliated soil analysis working group (1990). Handbook of standard soil testing methods for advisory purposes. Soil Science Society of South Africa, Pretoria.

Okalebo JR, Gathua KW, Woomer PL (2002). Laboratory methods for soil and plant analysis: A working manual. TSBF Program UNESCO ROSTA Soil Science Society of East Africa. A Technical Publication No.1. Marvel EPZ Ltd, Nairobi, Kenya.

Ritz K, Griffiths BS (1987). Effects of carbon and nitrate additions to soil upon leaching of nitrate, microbial predators and nitrogen uptake by plants. Plant Soil, 102: 229–237.

Rustad LE, Cronan C (1988). Element loss and retention during litter decay in a red spruce stand in Maine. Can. J. For. Res., 18: 947 - 953.

Soil Working Group (1991). Soil classification: A taxonomic system for South Africa. Memoirs on the Agricultural Natural Resources of South Africa No 15. Department of Agricultural Development, Pretoria, South Africa.

Tittonell P, Vanlauwe B, Leffelaar P.A, Shepherd KD, Giller KE (2005). Exploring diversity in soil fertility management of smallholder farms in western Kenya I, Heterogeneity at region and farm scale. Agr. Ecosy. Environ., 110: 149 - 165.