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Full Length Research Paper

Agronomic suitability of effective micro-organisms for tomato production

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A field experiment was conducted during the 2004-2005 summer season to evaluate the agronomic suitability of effective microorganism (EM) for improvement of crop productivity and quality through enhanced soil microbial activities and pest and disease suppression. Tomato (*Lycopersicon esculentum* Mill) was used as a test crop. Treatments included: control, effective microorganism, mineral fertilizer, effective microorganism + mineral fertilizer, compost, compost + effective microorganism, compost + mineral fertilizer and compost + mineral fertilizer + effective microorganism. Application of EM significantly increased the number of fruited tomato plants, seven weeks after transplanting. However, application of EM alone or in combination with other amendments had a depressive effect on tomato yield owing to an outbreak of early and late blights which affected the EM treatments first. Combined applications of EM with amendments improved plant N content and increased soil N content above initial levels. Compost application resulted in higher soil N and P concentrations than those of the control due to nutrients released during mineralization of the compost material.

Key words: Compost, effective microorganisms, mineral fertilizer, tomato, yield.

INTRODUCTION

Soil microbial biomass pools are important component of the decomposer subsystem that regulates nutrient cycling, energy flow and plant and ecosystem productivity (Pankhurst et al., 1996). Most agricultural production systems are highly dependent on the action of the soil microbial biomass pools which responds quickly to changes in the soil environment (Pankhurst et al., 1996). Most agricultural practices affect soil quality by altering the physical, chemical and biological properties of soil systems and have led to a decrease in soil microbial populations resulting in decreased crop productivity (Valarini et al., 2002). This has led to a growing global concern about the long-term productivity of agro-ecosystems that has led to the need to develop management strategies that maintain and protect soil resources. It has also led to increased research efforts on the biological components of soil fertility dynamics micro- (Smaling and Dixon, 2006). Inoculating plants and soils with beneficial microorganisms as a way of creating an environment more conducive for plant growth is one strategy that has received considerable attention (Asia-Pacific Natural Agriculture Network, 1995).

A microbial inoculum called effective micro-organisms (EM) together with organic materials was introduced to “nature farming systems” in Japan in the early 1990s (Higa, 1994). The EM inoculants are liquid microbial concoctions containing yeasts, actinomycetes, lactic acid and photosynthetic bacteria (Daly and Stewart, 1999). Most of the species in EM inoculants are heterotrophic and require organic sources of carbon and nitrogen for their nutrition. Therefore, EM inoculation has been more effective when applied in combination with organic materials to provide both carbon and nitrogen (Yamada and Xu, 2000). The microorganisms contained in the concoctions reportedly produce plant hormones, beneficial bioactive substances and antioxidants while solubilizing nutrients (Higa and Parr, 1994).

The application of EM results in an increase in soil

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

Characteristics	Soil	Compost
pH (KCl)	5.7	-
Bulk density (g cm^{-3})	1.23	-
Total N (g kg^{-1})	0.9	12.3
Available P (mg kg^{-1})	59	-
Total P (g kg^{-1})	-	3.67
Exchangeable K (mg kg^{-1})	441	
Total K (g kg^{-1})	-	3.28
Exchangeable Ca (mg kg^{-1})	1028	-
Exchangeable Mg (mg kg^{-1})	246	-
Zn (mg kg^{-1})	15.2	-
Mn (mg kg^{-1})	46	-
Organic C (mg kg^{-1})	6.0	-
Total C (g kg^{-1})	-	215.8
Cu (mg kg^{-1})	2.9	-
C:N	-	17.5
C:P	-	58.8

organisms that are beneficial for plant growth, resulting in more rapid mineralization of organic matter, suppression of soil-borne pathogens and increased crop yield and quality (Asia-Pacific Natural Network, 1995). Other studies have shown that inoculation of the agro-ecosystem with EM leads to an improvement in soil and crop quality in addition to higher crop yields (Higa and Parr, 1994; Li and Ni, 1995).

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 Ltd. The use of EM is, however, 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. There is, however, only limited scientific information on the effectiveness and use of EM in South Africa. In a composting study, Mupondi et al. (2006a) found that co-composting of pine bark with EM had no effect on the composting process and compost quality, but the resultant compost improved cabbage seedling growth (Mupondi et al., 2006b). This study was, therefore, conducted to obtain more information on the effects of applying EM on soil and on crop growth in the Eastern Cape, South Africa. The specific objectives of the study were to evaluate (i) the effects of EM on the growth and yield of tomato in an Oakleaf soil in the Eastern Cape, (ii) the effects of co-application of EM with mineral fertilizer and compost, on the yield of tomato, and (iii) the Effects of EM application on selected soil properties.

MATERIALS AND METHODS

Location of the study area

The experiment was conducted on the Research Farm of the University of Fort Hare, Alice, Eastern Cape Province, South Africa during the 2004 to 2005 summer season. The farm is located at longitude 32º46' S and latitude 26º50' E at an altitude of about 535 m a.s.l. It has a warm temperate climate with an average annual rainfall of about 575 mm received mainly during the summer months. 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 the growth of tomato.

Effective microorganisms (EM) and compost

Multiplied-EM, EM-fermented plant extract (F.P.E), M 3-in-1 and EM–5 are the four brands of EM used in EM treated plots. Multiplied-EM was dissolved in water in a ratio of 1:300 and applied as a soil drench at a rate of 200 L per experimental unit, 7 days prior to transplanting. 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, mixed at a ratio of 1: 1: 1, then diluted with water at a ratio of 1: 800 were sprayed to control diseases and pests in EM treated plots. An equivalent of 27 t ha^{-1} of compost (which supplied 332.1, 99.09 and 88.56 kg ha^{-1} of N, P, and K, respectively) was applied. Some characteristics of the compost are shown in Table 1.

Experimental design

The experiment was laid out in a randomized complete block design (RCBD) with six replicates. The treatments were: control, effective microorganisms (EM), recommended fertilizer (RF) (N 200: P 90 kg ha^{-1}), EM + RF, compost (Comp), comp + EM, comp + RF, comp + RF + EM. These amendments were applied to plots measuring 4.5 m x 5 m. Tomato cv Hytec 36 was used as a test crop. The seeds for EM-treated plots were soaked in 0.1% multiplied - EM for 30 min. The other seeds were soaked for 30 min in distilled water only prior to sowing.

Soil and leaf analysis

Soil and leaf samples were taken at harvest. Leaf sampling was as described by Jones et al. (1971). The leaf dry matter was determined after oven drying to constant mass at 65ºC. The dried samples were ground in a hammer mill to pass through a 1 mm mesh sieve. The ground samples were analyzed for P and K as described by Okalebo et al. (2002). Total nitrogen was determined using a LECO TruSpec C/N auto analyzer (LECO Corporation, 2003).

Soil samples taken at 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). 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 and means separated using least significance differences (LSD) at the 0.05 level of significance.

RESULTS

Effects on number of fruited plants, seven weeks after transplanting (7WAT)

There were significant ($p < 0.05$) treatment effects on the number of fruited tomato plants, 7WAT. EM application appeared to promote earliness of fruiting. For example, application of EM alone, mineral fertilizer, EM with mineral fertilizer and EM with compost resulted in 33.3% increase in the number of fruited plants relative to the control.

Effects on tomato fruit yield

Treatment effects on tomato fruit yield are shown in Table 2. Only the reference fertilizer increased yield relative to the control while sole application of EM as well as its application with compost, reference fertilizer or both, resulted in yield decreases. For example, the sole application of EM resulted in a 26.9% decrease in fruit yield relative to the control while its application with compost resulted in a 23.2% decrease in fruit yield relative to the compost treatment. The combination of EM and mineral fertilizer decreased fruit yield by 46% relative to the fertilizer treatment and a 49.6% decrease in fruit yield was observed relative to the compost + mineral fertilizer treatment when EM was co-applied with mineral fertilizer and compost.

Effects on plant and soil nutrient content

Application of different amendments, singly and in combination, significantly affected leaf N content (Table 3). Leaf N content ranged from 36 to 49.9 g kg^{-1}. Combined applications of EM with the amendments improved leaf N content compared to single application of the amendments. EM alone increased leaf N content by 38.6% relative to the control. Application of EM + RF increased leaf N content by 15.1% relative to the mineral fertilizer treatment. When applied with compost, a 21.6% increase in leaf N content was observed relative to the compost treatment. Application of Comp + RF + EM resulted in a 16.3% increase in leaf N content relative to the Comp + RF treatment. The highest leaf N content was observed in plots treated with EM + RF but the greatest effect of EM on leaf N content was attained with application of EM alone. The content of N and K in leaves was higher than the critical levels of 12 g kg^{-1} for N and 3 g kg^{-1} for K. Leaf P content, on the other hand, was lower than the critical level of 3 g kg^{-1} for P reported by Foth and Ellis (1988). There were significant treatment effects on residual soil nutrient concentration. Residual soil N content ranged from 6.1 to 10.3 g kg^{-1}. Residual soil N in plots treated with sole EM, RF and EM + RF was not significantly different from the control (Table 3).

Application of compost alone or across treatments significantly increased soil N concentration relative to the control treatment. A similar trend was observed with available P. Soil extractable P ranged from 0.5 to 1.5 g kg^{-1}. Soil available K ranged from 35 to 61 g kg^{-1}. Application of Comp + EM increased available K relative to the control.

DISCUSSION

Effects on number of fruited plants seven weeks after transplanting

The results obtained in this study showed that EM had a positive effect on fruiting of tomato plants, with the highest number of fruited plants being observed where EM was applied with mineral fertilizer. This suggests the possible existence of some synergistic activities between mineral fertilizer and EM that could lead to improved fruiting in tomato. Treatments with combined applications of EM and chemical fertilizer had a significantly higher

Table 2. Effects of EM, compost and recommended fertilizer combinations on the proportion of plants that had fruited 7WAT of tomato, on total fruit yield (t ha^{-1}) and on marketable yield (t ha^{-1}).

Treatment	No. of fruited Plants ha^{-1} (10^{-3})	Yield (t ha^{-1})	Marketable Yield (t ha^{-1})
Control	2.0b	28.3abc	13.0ab
EM	4.0ab	20.7dc	7cd
RF	4.0ab	36.3a	15.0a
EM+RF	7.0a	19.6cd	6.0d
Comp	1.0b	25.9bcd	13.0abc
Comp + EM	4.0ab	19.9cd	8.0cd
Comp + RF	1.0b	34.7ab	15.0a
Comp + RF + EM	3.0b	17.5d	9.0bcd
CV (%)	22.0	29.9	21

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.

possibly due to the production of plant growth regulators by microorganisms associated with the EM amendment, as suggested by Arshad and Frankenberger (1992).

Similar results were obtained by Xu et al. (2000) where application of EM increased fruit yield and plant growth of a tomato crop. Apparently, the application of EM into the soil is usually associated with an increase in soil microbial biomass which increases the rate of symbiotic biological nitrogen fixation through increases in Azotobacter bacteria (Hussain et al., 1994).

Effects on tomato fruit yield

Although, application of EM had a positive effect on fruiting of tomato plants, its application alone or in combination with compost or fertilizer appeared to have had a negative effect on tomato fruit yield. The apparent depressive effects of EM on tomato fruit yield could have been a result of a severe blight infestation on the tomato crop which started in the EM-treated plots before rapidly spreading to the other treatments. In plots treated with EM, only EM - FPE, EM - 5 and EM - 3 in 1 were used to try to control diseases and pests. The EM residues (molasses rich in C and N) on the leaves of treated plants could have served as a good substrate for microorganisms, some of them pathogenic, like those causing tomato blight.

The application of EM was totally ineffective in controlling the blights. It is possible that in other instances where EM has been found to have positive effects on tomato yield, the weather may not have been favorable for blight attack. In the Eastern Cape, South Africa where this experiment was carried out, the weather is at times very conducive to the development of blight and the results clearly indicate that EM may not be effective in controlling it.

These results suggest that one could use EM initially to stimulate better flowering and fruiting but use fungicides to control fungal diseases if conditions are conducive to their development.

Effects on plant and soil nutrient content

Although, application of EM had a negative effect on tomato fruit yield, its application had a positive effect on leaf N and soil N content at harvest time. Both single and combined applications of EM and amendments increased soil N above initial levels as well as over the control (Tables 1 and 3) which resulted in enhanced leaf N levels (Table 3). These results could be attributed to the effect of EM stimulating mineralization of organic matter, with subsequent release of more nutrients into the soil-plant system (Higa and Kinjo, 1991; Daly and Stewart, 1999). The leaf N content ranged from 36 to 50 g N kg^{-1} (Table 3) and was therefore well within the normal range of 28 to 49 g N kg^{-1} expected in the leaves of healthy tomato plants (Dangler and Locasio, 1990; Olasantan, 1991). It is, therefore unlikely that the observed enhanced leaf N levels observed in this study could have stimulated disease infestation of the tomato plants. Therefore, the observed negative effect of EM on field grown tomato yield was, as noted earlier, due to the blight attack which EM was ineffective in controlling.

Conclusions

The results of this study are inconclusive with respect to the effectiveness of EM on crop growth. They however, suggested that EM application could potentially increase the yields of tomato as it significantly increased the proportion of fruited plants in the field. The increased

Table 3. Effects of EM, compost and recommended fertilizer combinations on leaf and soil N, P and K.

Treatment	Leaf			Soil		
	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})
Control	36.0c	0.8ab	22.3	6.1d	0.5d	41.3b
EM	49.9a	0.8ab	23.0	7.0cd	0.5cd	42.9b
RF	43.6abc	0.7ab	24.4	6.8d	0.7cd	39.4b
EM + RF	50.2a	0.9a	25.3	7.7bcd	0.9bc	35.0b
Comp	40.8bc	0.7ab	21.3	9.8a	1.3a	35.9b
Comp + EM	49.6ab	0.8ab	25.4	9.6ab	1.2ab	61.0a
Comp + RF	41.7abc	0.8ab	19.8	10.3a	1.5a	45.1ab
Comp + RF + EM	48.5ab	0.6b	22.1	9.0abc	1.5a	42.0b
CV (%)	17.2	28.0	23.2	20.8	33.1	33.4

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.

fruiting did not, however, translate into positive yield increases presumably due to the inability of EM to control severe blights that affected the tomato crop during the late part of the growing season. These mixed findings suggest the need for a more detailed study designed to provide a better understanding of the mechanisms by which EM influences plant growth.

REFERENCES

Arshad M, Frankenberger WT (1992). Microbial production of plant growth regulators. In: Xu et al (eds) Effects of organic fertilizers and a microbial inoculant on leaf photosynthesis and fruit yield and quality of tomato plants. Crop Prod. 3: 173-182.

Asia-Pacific Natural Agriculture Network (1995). EM application manual for APNAN countries. M. Shintani (ed). Asia-Pacific Natural Agriculture Network, Bangkok, Thailand. http://www.agriton.nl/apnanman.html

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

Dangler, JM, Locasio, SJ (1990). Yield of trickle-irrigated tomatoes as affected by time of N and K application. J. Amer. Soc. Hort. Sci. 115: 585-589.

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

Higa T, Parr JF (1994). Beneficial and effective microorganisms for a sustainable agriculture and environment. International Nature Farming Research Center, Atami, Japan. http://www.agriton.nl/higa.html

Higa T (1994). Effective microorganisms - A new dimension for nature farming. In: Parr JR, Hornic SB, Whitman CE (eds). Proceedings of the 2nd International Nature Farming Conference. USDA; Washington, pp. 20 - 23.

Higa T, Kinjo S (1991). Effect of lactic acid fermentation bacteria on plant growth and soil humus formation. In: Parr JR, Hornic SB & Whitman CE (eds). Proceedings of the 1st International Conference on Kyusei Farming, 17-21 October 1989, Khan Kaen, Thailand, pp. 140 – 147..

Hussain T, Ahmad R, Jilani G, Higa T (1994). Applied EM technology. Nature Farming Research Center. University of Agriculture, Faisalabad, pp 1 - 6.

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.

Marschner, H (1995). Mineral nutrition of higher plants, Academic Press

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.

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.

Olasantan FO (1991). Response of tomato and okra to nitrogen fertilizer in sole cropping and intercropping with cowpea. J. Hort. Sci., 66: 191-199.

Pankhurst CE, Ophel-Keller K, Doube BM, Gupta VVSR (1996). Biodiversity of soil microbial communities in agricultural systems. Biol. Conserv. 5: 197 - 209.

Smaling EMA, Dixon J (2006). Adding a soil fertility dimension to the global farming systems approach, with cases from Africa. Agr. Ecosyts. Envm., 116: 15 - 26.

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.

Valarin PJ, Alveraz MCD, Gasco JM, Guerrero F Tokeshi H (2002). Integrated evaluation of soil quality after the incorporation of organic matter and micro-organisms. Braz. J. Micr., 33: 35 – 40.

Xu HL, Wang RA, Mridha MAU (2000). Effects of organic fertilizers and a microbial inoculant on leaf photosynthesis and fruit yield and quality of tomato plants. Crop Prod., 3: 173 - 182.

Yamada K, XU HL (2000). Properties and applications of an organic fertilizer inoculated with effective microorganisms. Crop Prod., 3: 255 - 268.