Effect of EM on the Production Of Vegetable Crops in Indonesia

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Abstract
Indonesian farmers have learned to use Effective Microorganisms (EM) on vegetable crops much like a foliar fertilizer, akin to the foliar application of a micronutrient. On-farm tests and demonstrations have shown that foliar applications of EM can increase the growth and yield of vegetable crops in a relatively short time, even though no organic amendment is added to the soil. A field plot study was conducted during 1993 (March to August) in collaboration with the Directorate of Horticultural Production Development to determine the effects of foliar applied EM on the production of garlic, onion, tomato, and watermelon, compared with the recommended application of chemical fertilizer as a control. Foliar solutions of EM, at concentrations of 0.1%, 0.5% and 1% (by volume), were applied at one- and two-week intervals. Most vegetable yields were generally higher with foliarly applied EM compared with the chemical fertilizer control. The highest yield of garlic was obtained with EM at 0.1% applied at one-week intervals, and was 12.5% greater than the fertilized control. The highest yield of onion and tomato resulted from weekly applications of EM at 1%; yields for these two crops were 11.5% and 19.5% greater than the fertilized control. There was no significant increase in watermelon yields from foliar application of EM at any dilution level. Various factors which influence the mechanisms of how EM affects the rhizosphere and phyllosphere to enhance plant growth and yield are discussed.

Introduction

Horticultural crops such as garlic, onion, tomato and watermelon have a high cash market value in Indonesia. Consequently, farmers are interested in ways of increasing the yield of these crops through intensification and extensification. Intensification efforts have focused on methods and techniques that can provide optimum economic yields, but without excessive increase in the farmer’s costs. Thus, the most important consideration in the selection of new technologies is that they enhance the availability of plant nutrients and their uptake by crops.

The concept and technology of Effective Microorganism (EM) were developed by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan. EM consists of mixed cultures of naturally-occurring beneficial microorganisms (i.e., bacteria, fungi, actinomycetes and yeasts) that are applied as inoculants to change the microbial diversity and interaction in soils and plants. In turn, EM has been shown to improve soil health, and the growth, yield and quality of crops over a wide range of agroecological conditions (Higa, 1988; Higa and Parr, 1994).

When EM cultures are applied to soil they stimulate the decomposition of organic wastes and residues thereby releasing inorganic nutrients for plant uptake. Foliar application of EM appears to suppress the occurrence of plant diseases and facilitates the up-take of simple organic molecules that can increase plant growth and yield. It is often difficult to establish the predominance of EM cultures in soil with only a single application and during only one growing season. Certain soil properties and the indigenous soil microbial populations are often constraints to the establishment of EM cultures. Studies have shown that these constraints can be overcome through periodic repeated applications of EM at least during the first several years, Such practice will ensure that all of the possible benefits for improving soil quality and plant growth, yield and quality will be realized (Higa and Wididana, 1991; Imai and Higa, 1994; Minami and Higa, 1994; Higa and Parr, 1994).

The Asia-Pacific Natural Agricultural Network (APNAN) has conducted studies on the effect of EM on various cultivated crops, usually rice-based cropping systems, since 1989. In Indonesia, most of the research on EM has involved foliar application to food crops through on-farm trials with farmer’s participation (Wididana, 1994). Generally, Indonesian farmers have come to consider

EM in the same way they would any foliar fertilizer, especially micronutrients which many of them use. They often observe a quicker response to foliar application of micronutrients than soil application, and believe that foliar application is more efficient. Moreover, foliar application of EM avoids many of the biotic and abiotic factors and constraints of the soil environment (Higa and Wididana, 1991).

The purpose of this study was to investigate the effect of foliar applications of EM on the yield of garlic, onion, tomato and watermelon grown according to the Indonesian farmer's traditional methods.

Materials and Methods

A field study consisting of on-farm trials was conducted in collaboration with the Directorate of Horticultural Production Development, Indonesian Department of Agriculture, to determine the effect of foliar-applied EM on the yield of selected food crops. The study was initiated during March to August 1993 by the Center for Production of Horticultural Crops in Lembang, West Java. The soil was a red Latosol with pH 6.5 and subject to intensive cultivation. Treatments were imposed according to a randomized complete block design (RCBD) with three replications and individual plot size of 20 x 20 m (400 m^2). All plots for a particular crop received chemical fertilizer and manure at the recommended rates shown in Table 1. EM concentrate was diluted with water to concentrations of 0.1, 0.5 and 1.0% (v/v) and foliar-applied to each crop at intervals of either one-week or two-weeks through the growing season. Control plots for each crop received only the recommended rates of chemical fertilizer and manure (Table 1).

Table 1. Rates of Chemical Fertilizers and Animal Manure Applied to Each Crop in the Study.

Crop	Chemical fertilizers applied (kg ha^{-1})				Manure applied ($t\ ha^{-1}$)
	Urea	AS	TSP	KCl	
Garlic	150	600	400	200	15
Onion	267	269	300	175	15
Tomato	250	-	200	150	15
Watermelon	100	200	200	50	15

Watermelon received an additional 25 kg ha^{-1} of a mixed N-P-K fertilizer.
Values indicate actual amounts of each product that was applied.
TSP = treble superphosphate; AS = ammonium sulfate; KCl = potassium chloride.

In summary, the study was conducted according to the following treatments:

T1 - Control (fertilizer + manure only)
T2 - EM (0.1%) applied weekly
T3 - EM (0.5%) applied weekly
T4 - EM (1.0%) applied weekly
T5 - EM (0.1%) applied biweekly
T6 - EM (0.5%) applied biweekly
T7 - EM (1.0%) applied biweekly

Treatments T2-T7 received the same dosage of fertilizer and manure as the control for a particular crop.

Vegetative propagules of garlic (*Allium sativum*) and onion (*Allium cepa*) were planted at a spacing of 10 x 15 cm, while the planting space of tomato (*Lycopersicon esculentum*) and watermelon (*Citrullus vulgaris*) were 50 x 60 cm and 60 x 60 cm respectively. The yield of garlic and onion was based on the final weight after being dried in the sun for 7 days. The yield of tomato and watermelon was based on fresh fruit weight.

Results and Discussion

The microbiological and chemical analysis of the EM stock culture used in this study are reported in Table 2. The analysis shows that EM does not contain any of the genera of microorganisms that might be considered as harmful to animals and humans such as *E. Coli*, *Salmonella*, *Staphylococcus*, and *Clostridium*. However, the analysis shows that EM does contain an array of beneficial microorganisms that can enhance the growth and yield of plants including phosphate-solubilizing bacteria, *Lactobacillus* spp., yeast, fungi, cellulolytic bacteria, and *Streptomyces* sp. The analysis also indicates that the chemical content of the EM culture is very low and, thus, unlikely to significantly affect plant growth and yield, especially after it is diluted for field application. Nevertheless, some scientists continue to believe that the nutrient content of EM is largely responsible for the increased growth and yield response. However, for reasons already stated, this is rather unlikely.

Foliar application of EM results in a large number of beneficial microorganisms at the leaf surface, or phyllosphere. It is believed that certain microorganisms in the EM culture including photosynthetic bacteria and N-fixing bacteria, can enhance the plant's photosynthetic rate and efficiency, and its N-fixing capacity as well (Pati and Chandra, 1981). Through foliar application, microorganisms in EM appear to suppress the development of harmful plant pathogens at the leaf surface, thereby providing a measure of plant protection through biocontrol. Another example of the beneficial effects of phyllosphere microorganisms was reported by Atlas and Bartha (1981). They found that pigmented yeast and bacteria that colonized leaf surfaces could afford some protection to the plant from excessive exposure to direct sunlight.

Table 2. Microbiological and Chemical Analysis of a Culture of Effective Microorganisms (EM)

Microbiological Analysis	Population (CFU ml^{-1})	Chemical analysis	Chemical content
Total plate count	$1.2x10^7$	N	0.47%
E Coli	0	P	<0.1ppm
Other coliforms	0	K	0.22ppm
Salmonella sp.	0	B	<0.57ppm
Staphylococcus sp.	0	S	<0.1ppm
Clostridium spp.	0	Fe	51ppm
Enterobacter	0	Mn	1ppm
N-fixing bacteria		Cu	<0.03ppm
a. *Azospirillum* sp.	0	Mo	<0.2ppm
b. *Azotobacter* sp.	0	Co	<0.05ppm
c. *Rhizobium* sp.	0		
P-Solubilizing bacteria	$2.0x10^3$		
Lactobacillus spp.	$2.0x10^6$		
Yeast	$6.2x10^5$		
Fungi	70		
Celluloytic bacteria	$4.3x10^3$		
Streptomyces sp.	$8.6x10^3$		

Data were reported by the Bogor Institute of Agriculture and superintending Company of Indonesia.
CFU = Colony Forming Unit.

Table 3. Effect of EM Concentration and Frequency of Application on the Yield of Horticultural Crops.

Treatments		Yield of horticultural crops (kg ha^{-1})			
EM (%)	**Interval (weeks)**	**Garlic**	**Onion**	**Tomato**	**Watermelon**
Control	-	87.5b	150.2c	221.7e	21.8a
0.1	1	98.4a	156.7d	223.1de	20.3a
0.5	1	94.6a	164.7b	224.5d	21.8a
1.0	1	96.0a	167.4a	265.0a	19.7a
0.1	2	94.4a	150.7e	226.7c	18.0a
0.5	2	88.6b	166.5ab	223.3d	20.2a
1.0	2	86.2b	159.3c	249.6b	20.0a

EM stock culture was diluted with water on a v/v basis and applied to the crops at intervals of one or two weeks.
Treatment means in a column sharing the same letters are not significantly different at the 5% level of probability.
Control plots for each crop received chemical fertilizer and manure according to rates shown in Table 1. All other treatments received the same rates of chemical fertilizer and manure plus EM applied at the concentration and interval indicated.

As shown in Table 3, the foliar application of EM resulted in a significant increase in the yield of garlic, onion and tomato at most concentrations of EM and at both application intervals. The highest garlic yield (98.4 kg ha^{-1}) was obtained with EM applied at 0.1% at one-week intervals; the highest yield of onion (167.4 kg ha^{-1}) with 1.0% EM at one week intervals; and the highest yield of tomato (265.0 kg ha^{-1}) with 1.0% EM at one-week intervals. This corresponded to a percentage increase in yield of garlic, onion and tomato (from EM) of 12.5, 11.5 and 19.5% compared with the fertilized (no EM) controls, respectively (Table 4).

Table 4. Effect of EM Concentration and Frequency of Application on the Percentage Increase in Yield of Crops Compared with Control.

Treatments		Yield increase from EM (% increase compared with control)		
EM (%)	**Interval (weeks)**	**Garlic**	**Onion**	**Tomato**
Control	-	unity	unity	unity
0.1	1	12.5	4.3	0.6
0.5	1	8.1	9.7	1.3
1.0	1	9.7	11.5	19.5
0.1	2	7.9	0.3	2.3
0.5	2	1.3	10.9	0.7
1.0	2	-1.7	6.1	12.6

EM solutions were formulated with water on a v/v basis and applied to the crops at intervals of one or two weeks.
Control plots for each crop received chemical fertilizer and manure according to rates shown in Table 1. All other treatments received the same rates of chemical fertilizer and manure plus EM applied at the concentration and interval indicated.

The highest yields for garlic, onion and tomato were associated with the highest levels of EM initially applied, and indicated that these plants responded favorably to foliar-applied EM. An exception was watermelon which showed no significant increase in yield from EM at any dilution level. This suggests that the watermelon phyllosphere was not favorable to the survival, growth and establishment of EM. According to Higa (1990, personal communication), the application of substrates and growth factors to the phyllosphere of crops (such as watermelon) along with EM would greatly facilitate the growth and establishment of EM organisms where they could then enhance crop growth, yield and protection from pathogens and diseases.

Foliar application of beneficial microorganisms such as antagonistic bacteria and fungi have been shown to suppress certain plant pathogens in the phyllosphere of crop plants. Atlas and Bartha (1981) reported that the types, numbers and diversity of microorganisms to be found on the leaf surface of plants depend on the species and variety of plant, age of the leaf, and agroclimatic conditions. Once established in the phyllosphere, beneficial microorganisms can enhance biocontrol mechanisms to protect the plant, thereby ensuring an optimum photosynthetic rate and efficiency (Higa, 1990 personal communication). Pati and Chandra (1981) and Sen Gupta et al. (1982a,b) also reported that the foliar application of N-fixing microorganisms to the phyllosphere of crop plants markedly increased their yield.

Conclusions

The introduction of beneficial microorganisms into the phyllosphere to enhance the protection, nutrition, growth and yield of crops is a relatively new area of research. In the present study, an adequate amount of chemical and organic fertilizer was applied to sustain an optimum yield of the selected crops. Yet, clearly, when EM was foliar-applied at certain concentrations and time intervals there was a significant increase in crop yield. Exactly what mode-of-action or mechanism was affected by EM to reflect these yield increases is not known. One can certainly speculate on how EM may have directly or indirectly affected photosynthesis, plant protection and certain auxin-mediated events. Consequently, there is an urgent need to elucidate these mechanisms under carefully controlled conditions and according to the time, rate and frequency of EM application. This will provide a better understanding of how foliar-applied EM can be used to greater advantage in achieving a higher level of crop yield, quality and protection.

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