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COMENTARIO

Effective Microorganisms: Myth or reality?

Microorganismos eficaces: mito o realidad?

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Aníbal F. Cóndor_Golec[1], Pablo González Pérez[2] y Chinmay Lokare[3]

[1] Agronomist Engineer, MSc Organic Plant Production, Researcher. Address: Calle Francisco de Cuellar 451 casa 18, Monterrico, Lima 33, Lima-Perú.

Email Anibal Cóndor: **anibalfcg@yahoo.com**

[2] Agronomist Engineer, MSc Organic Farming. Address: Calle Arado 3, 4B 47014 Valladolid. Spain.

Email Pablo González: **pgonzamail@yahoo.es**

[3] BSc Botany, MSc Greenhouse Horticulture. Address: 11-12 Malati Madhay B, 819 Bhandarkar Road, Pune 411004 Maharashtra. India

Email Chinmay Lakre: **chinmay.lokare@gmail.com**

Introduction

The increase in population has lead to intensification of agricultural systems. Due to the use of pesticides the productivity of agricultural systems has increased but environmental deterioration and unsustainable systems are the consequences of these ways of management.

The environmentally friendly Effective Microorganisms (EM) technology claims an enormous amount of benefits (claimed by the companies). The use of EM as an addictive to manure or as a spray directly in the fields may increase the microfauna diversity of the soil and many benefits are derived from that increase. It seems that sufficient information is available about this new technology.

The aim of this project is to make an analysis of the literature about EM and answer the following questions: 1) how much is known about EM?, 2) how much research is done on EM?, 3) what are the principals of EM?, what are the socio-economic implications of EM?. We want to answer these questions in order to publish the facts about EM and its socio-economic implications.

Principles of Effective Microorganisms

The principle of activity of the EM is by increasing the bio diversity of the micro flora increasing the yield of the crop. Photosynthetic bacteria are the back bone of the EM, working synergistically with other microorganisms to provide the nutritional requirement to the plant and also reduce the disease problem.

There are primarily 5 types of bacteria used to prepare EM solution. Photosynthetic bacteria (Phototrophic bacteria): are independent self supporting microorganisms. These bacteria synthesize amino acids, nucleic acids, bioactive substances and sugars, substances from secretions of roots, organic matter (carbon) by using sunlight and the heat of soil as sources of energy. They can use the energy from infrared band of solar radiation from 700 nm to 1200 nm to produce the organic matter, while plants can not. So the efficiency of the plants is increased. These metabolites are absorbed into plants directly and also act as substrates for bacteria increasing the biodiversity of the micro flora. Adding photosynthetic bacteria in the soil enhances other effective microorganisms. For example, VA (vesicular-arbuscular) mycorrhiza in the rhizosphere is increased due to the availability of nitrogenous compounds (amino acids) for use as substrates secreted by Photosynthetic bacteria. VA mycorrhiza increases the solubility of phosphates in soils thereby supplying unavailable phosphorus to plants. VA mycorrhiza can coexist with *Azotobactor* as nitrogen fixing bacteria and enhance nitrogen fixing ability of legumes. Lactic acid bacteria: produces lactic acid from sugars. Food and drinks such as yogurt and pickles have been made by using lactic acid bacteria. However, lactic acid is a strong sterilizer. It suppresses harmful microorganisms and increases rapid decomposition of organic matter. Moreover Lactic acid bacteria enhances the breakdown of organic matter such as lignin and cellulose, and ferment these materials which normally take plenty of time. Lactic acid bacteria have the ability to suppress Fusarium propagation which is a harmful microorganism that causes disease problem in continuous cropping. Under *Fusarium* conditions promotes the increase of harmful nematodes. The occurrence of nematodes disappears gradually, as lactic acid bacteria suppress the propagation and function of *Fusarium*. **Yeasts:** synthesize antimicrobial and useful substances for plant growth from amino acids and sugars secreted by photosynthetic bacteria, organic matter and plant roots. Bioactive substances such as hormones and enzymes produced by yeasts promote active cell and root division. Their secretions are useful substrates for effective microorganisms such as lactic acid bacteria and actinomycetes. *Actinomycetes*: are the structure of which is intermediate to that of bacteria and fungi, produces antimicrobial substances from amino acids secreted by photosynthetic bacteria and organic matter. These antimicrobial substances suppress harmful fungi and bacteria. Actinomycetes can coexist with photosynthetic bacteria. Thus, both species enhance the quality of the soil environment, by increasing the antimicrobial activity of the soil.

Fermenting Fungi: such as *Aspergillus* and *Penicillium* decompose organic matter rapidly to produce alcohol, esters and antimicrobial substances. These suppress odors and prevent infestation of harmful insects and maggots. (Asian-Pacific Natural Agriculture, 1996; http://www.royalgcol.ac.uk/research/conferences/tabo.htm; http://www.emtrading.com; http://www.emtechnologynetwork.org; http://www.emrousa.com)

Claims by the producers about EM

Enhances soil fertility, increase crop yield and crop quality, helps to correct nutritional and physiological crop disorders, reduces the infestation of pests and diseases, accelerates the decomposition of organic waste, reduces adverse effects of continuous cropping, enhances soil physical characteristics, increases beneficial micro organisms in the soil and helps control pathogens by competitive exclusion. (Asian-Pacific Natural Agriculture, 1996; http://www.royalgcol.ac.uk/research/conferences/tabo.htm; http://www.emtrading.com; http://www.emtechnologynetwork.org; http://www.emrousa.com)

Table 1. Results of soil physical properties in the fours areas with EM and green manure treatments. (+)

Area	Tillages (no.)	Textural Class (depth 0-15 cm)	Compaction: strokes/decimeter (depth 21-23 cm)	Compaction Increase (%)	Basic water infiltration rate (%)	Macroporosity Increase (%) (depth 6-10cm)
M-1	4-8	Sandy clay	0,9*	0,0	232,0	145,0
Orchard	1	Clay	3,7	317,0	0,0	0,0
M-3	4-8	Clay	0,2 a	0,0	1762,0	144,0
Corn-Pasture	1	Clay	2,3b/2,2b	833,0-798,0	0,0	0,0

M-1 and M-3 areas had 2 to 4 annual vegetable cropping cycles.Orchard area contained a mixture of weeds.Corn-pasture area was a rotation of these crops.

*Means having different letters are significantly different (P < 0,01).

+Modified from Third International Conference on Kyusei, Nature Farming. Proceedings of a Conference on nature Farming for a Sustainable Agriculture Held in Santa Barbara, California, USA. (1993).

This work was done from November to December 2004 in The Netherlands. Information about EM was collected in the first stage of the project and then this bibliography was deeply analyzed. Some interviews were done within the time and means available. The information was found in agricultural journal, books, research done by different universities and the internet.

1. Effect of EM and Green Manure on Soil Productivity in Brazil

This trial intended to show the use of EM with green manure so as to improve soil physical properties and productivity by suppressing lettuce leaf drop (*Sclerotinia sclerotiorum*). This was done in a brazilian farm which had applied EM with green manure for a period of 2 to 3 years. The farm had been cultivated with 2 to 4 annual vegetable cropping cycles with 4 to 8 tillage operations using a rotovator or plow. Four plots of 1 hectare were considered in the trial, 2 of them treated with EM (M-1 and M-3) and the other two without EM (Orchard and Corn-pasture), used as control. These latter plots were not cultivated with vegetables, one contained a mixture of weeds and the other had a corn-pasture rotation. The results showed that application of EM and green manure increase soil aggregation, reduce compaction (without having clay deposition) and increase of soil porosity, water infiltration (no analysis of variance done because of difficulties in determining it), and rooting depth. Thus, irrigation frequency and erosion declined, and the soil became suppressive to lettuce leaf drop.

It seemed as if the treatments were not adequately proposed to compare the EM effects because the 2 control plots had many differences, lacking of homogeneity between all the plots, for instance the texture of the EM treated soil in one plot is different from the one that is compared with the untreated EM soil. These untreated plots, had in the first case a mixture of weeds on it and the other had a corn-pasture rotation on it. Also the comparisons were not done between all the plots. They were done for instance with the orchard and M-1 plot and the Pasture-Corn rotation and M-3. So EM benefits cannot be reliable without homogeneity in the experiment.

2. Effect of EM on Soil properties and Nutrient Cycling in a Citrus Agroecosystem

In an experiment carried out in a brazilian citrus orchard, soil and plants were analysed to see the effects of EM applications through the soil (EMS) (2,5 ml EM/m^2), plants (EMP) (2,5 ml EM/m^2 of tree surface), and both soil and plant (EMSP). The species tested were *Citrus sinensis* and *Citrus limonia.* The experimental design was Randomized Complete Block Design with 4 replicates for each of the 4 treatments, a control treatment included. Each plot in each of the 4 blocks had 32 trees from which 10 of the central ones were treated. Soils and leaves were evaluated after 5 EM applications. Organic matter content of the treated soils increased to significant levels (P<0,05) at the two depths tested (0-20 cm and 20-40 cm), this is due to the ability of EM to form humus from a grass mulch. The pH and cation exchange capacity (CEC) were also increased at both sampled depths. There were no significant differences in the nutrients and other physical properties such as bulk density and compaction between the treatments. Citrus leaves chemical characteristics had no statistically significant differences between treatments due to the possible stage of physiological dormancy at the time the experiment was conducted (fall: March-June).

This study considered the homogeneity of the plots treated in order not to have interferences by the experimental results. Being in this way a more reliable trial because of its adequate set-up. Compared to the previous study described.

Table 2. Soil chemical characteristics after 5 EM applications

Depth Macropores Treatment	0-20 cm Organic matter (g kg^{-1})	pH	CEC (cmol kg^{-1})	P (mg dm^{-3})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	11cm Compaction (strokes dm^{-1})	0-4 cm Bulk density	(%)
Control	20,1	3,2	6,7	3,7	0,3	0,8	0,3	5,8	1,24	25,4
EMS	23,3	4,8	7,1	5,8	0,4	0,8	0,4	5,5	1,20	26,4
EMP	24,1	5,3	8,3	3,5	0,3	0,9	0,3	4,6	1,24	23,9
EMPS	24,4	5,0	7,9	3,8	0,3	0,7	0,3	5,1	1,22	24,9

Modified from Third International Conference on Kyusei, Nature Farming. Proceedings of a Conference on nature Farming for a Sustainable Agriculture Held in Santa Barbara, California, USA. (1993)

Table 3. Average effect of EM applications on organic cucumbers yields and pickle worm infection

Treatment	Yield (g m-2)	Weight (g)	Yield nfected (%)	Yield not infected (g m-2)
Water (control)	3,29 aa	222,3 a	80,0 aa	629,0 a
EM-FPE	4,41 b	235,6 b	36,0 b	2800,0 b
EM-FPE+EM5	4,81 b	232,8 b	9,0 c	4415,0 c

Treatments means and percentages in a column sharing the same letter are not significantly different from each other according to Duncan's Multiple Range test.

Modified from http://www.emtrading.com

3. EM-Fermented plant extract and EM5 for controlling pickleworm (*Diaphania nitidalis*) in organic cucumbers

The experiment was about how foliar applications of EM-Fermented Plant Extract (EM-FPE) and EM5. Cucumbers were organically grown in a randomized complete block of 12 blocks, 15 plants per block. Each block was a raised bed which received 21 Kg of compost and 3 Kg of EM banana bokashi 14 days before seeding. There were three foliar treatments with 4 replications applied in the same volume every 4 days: one control, EM-FPE (dilution 1:500), and EM-FPE(dilution 1:500) with EM5 (dilution 1:500). Results showed that there were more significantly yields and less significantly infection of pickle worm with the EM treatments, being the EM-FPE the best for the moth control(Table 3) (http://www.emtrading.com). This trial was not very well done because all the beds had an addition of EM banana bokashi before the main foliar EM treatments so that important fact leads to say that it lacks of reliability.

4. Control of secondary salinization in soils through effective microbes

It was a field experiment done in China in two farms: Qianjin (arid climate, heavy clay soil) and Baiquan (humid climate, loam clay soil). Both lands affected by salts due to irrigation with neglect of drainage especially in the arid one. There two blocks used with and without subdrainage system (Sd). 8 plots were given at 2 blocks of both sites containing one replicate of each of the 8 treatments. Rice was sown in this trial. EM bokashi (EMb) with subsurface treatments were the most effective treatments in controlling the secondary salinization of soil. Due to the improvement of permeability and aeration capacity of soils which increased the leaching of soils and raising rice grain yields (Table 4) (http://www.emtrading.com).

No statistical analyses were presented in this trial. The results of the treatments under subdrainaged system should not be compared because it helped to reduce the salinization so EM benefits were not directly seen.

5. Bananas with EM and compatible technologies, and economic consequences

A research a done in Bananas (in Costa Rica) revealed that the use of EM plus fermented plant extracts sprayed on the bunch had an effect on the growth of black sigatoka fungus (*Mycosphaerella fijiensis*) may be due to an anti-toxin that prevented the growth and eventual coalescence of the lesions. Also comparisons between chemical nematicides and the use of EM Bokashi and *Paecilomyces lilacinus* plus EM Bokashi resulted in lower average of nematode population after 26 weeks of observation, with 688 and 825 respectively, compared to the chemicals such as carbofuran (furadan) and *Trichoderma lignorum* (nemout) with 6933 and 4198, respectively. This was attributed to both biodiversity and anti-oxidation capability of EM. It was also noted that after windstorms treatments with bokashi were not blown down meaning that these bananas plants had a very strong rooting system. The antioxidant effect was also seen in the absence of premature ripening, with no signs of a yellow flesh.

The limiting aspect of EM bokashi was the high cost ended up ten times the cost of chemical fertilizer at this experiment. The costs tended to be more or less 43% more per unit product on a cost analysis (http://www.royalgcol.ac.uk/research/conferences/tabo.htm). The trial lacked of an experimental analysis to make good comparisons between treatments.

Table 4. Effect of EM bokashi on Organic soil matter content, desalinization degree and rice yields in the arid farm Quianjin

	Organic matter (g kg^{-1})	Desalinization degree (%)	Rice Yields (t ha^{-1})
Fertilizer-Sd	8,2	4,1	5,0
Manure+Fertilizer-Sd	10,5	8,2	5,4
EMb+Fertilzer-Sd	12,3	16,3	5,8
EMb-Sd	15,6	18,4	6,0
Fertilizer+Sd	8	70,4	6,0
Manure+Fertilizer+Sd	9,7	75,5	6,2
EMb+Fertilizer+Sd	12,1	81,6	7
EMb+Sd	14,9	84,7	7,5

Fertilizer: N and P local recommendations levels
Sd: subdrainage system
EMb: EM bokashi
Modified from Iwaishi, S. (2000).

6. Research about the effectiveness of EM by the Soil Quality department (by Dr. Petra van Vliet) of Wageningen University-The Netherlands. Published in Applied Soil Ecology (2005).

Petra van Vliet and her team at the Soil Quality Department of Wageningen University have done a study to determine the effect of EM. The research was started since some farmers were using EM and wanted to know if any effects of EM on manure quality were to be expected. Apart from EM there is another product sold by the company (Agriton) called Agrimest which has a secret formulation and has a synergic effect on EM. One of the benefits claimed by the sellers of EM is that by using EM the ratio of Nmineral:Norganic decreases resulting in less nitrogen leached and volatilized. The Nmineral:Norganic and C:N organic ratio was measured in this study since they are good indicators of the quality of the manure. According to the company who sells EM, at least 6 weeks of incubation with EM treatment is needed, for the EM to have an effect on the manure. Four different treatments were carried out: +Agrimest+EM, -Agrimest+EM, +Agrimest-EM and -Agrimest-EM. These combinations were added to manure in buckets, which were kept at 20 ^{0}C for 6 weeks. No significant differences were found in the Nmineral:Norganic ratio and the C:N organic ratio for the four treatments indicating that EM has no effects on compost quality. Furthermore, the product resulting from the incubation study with EM was used in a pot experiment in the glasshouse. There were no significant differences in plant biomass (shoots plus roots) and in nitrogen uptake between the different treatments. Again the EM did not affect the recorded growth parameters. DNA-analysis showed that in the EM stock solution (as it can be bought) a low number of different bacteria was found although after activation (after adding water and molasses and wait for 7 days) the number increased.

Using DNA-analysis, bacteria types present in the manures with the treatments+Agrimest+EM, -Agrimest+EM, +Agrimest-EM and -Agrimest-EM were compared with bacteria present in the activated EM solution. The results clearly showed that many of the bacteria present in the EM were not present in the manure to which the EM solution was added. Also some bacteria types present in the EM solution were already present in the manure

The main conclusion after these results is that EM had no clear effect on the quality of the manure and that the yield of a grass was not affected by EM solutions.

Discussion

Most of the information found has not been published yet or has been published in journals with a low impact factor (which can be used as a measure of reliability) like Brazilian-Journal-of-Microbiology, Journal of crop production, Journal of sustainable agriculture, American journal of alternative agriculture, Pakistan Journal of Arid Agriculture, Journal of Agriculture and Rural Development or Pakistan Journal of Biological Sciences. The majority of the research carried out about EM has been done in Oriental countries (Pakistan, Indonesia, Philippines, Thailand, China) at different Universities and has not been published in journals. Also much of the information was published in books as a summary of different International Conferences about EM all over the world. This information was not scientifically (or seriously assessed) proven and claimed enormous benefits of the EM. This type of information was also seen in the information of the companies which sell EM solutions.

Very well known and rated scientific journals related with soil quality have been used in our work and in none of them EM technology was mention. The Journals are: Clays and clay minerals, European Journal of Soil Biology, Geoderma, Soil Biology and Biochemistry, Soil science society of American Journal, Soil and Tillage Research, Agriculture Ecosystems & Environment, Applied Soil Ecology, Australian journal of Soil Research and Catena.

From all the bibliography compiled, most of it did not make a serious analysis of the effects of EM in soil health and its benefits. Many mistakes in the set up of the experiments were found and in some no statistical analysis was performed at all. A valid research done at Wageningen University showed that EM was not effective, at least under conditions in The Netherlands.

However, a lot of farmers still use EM. The mechanisms to explain this behaviour is the amount of positive information circulating all over the world about EM. This information is easily spread among the farmers. Often experiments made by the farmers to test the effectiveness of EM in their own farms are not correct and wrong conclusions are obtained. These wrong positive conclusions are also easy to spread and are probably obtained after applying EM because of the greater sensibility of the organic farmers (the ones who would use EM) to their crops. These farmers that are more sensible would look after the fields where EM was applied with more enthusiasm. There are known principles in the ecology of the soils that reject straight forward the effectiveness of the EM: principally the effect of EM in the soil is difficult to achieve since the amount of microorganisms added by the EM solution in comparison with the amount of microorganisms in the soil (about 10^{9}) is insignificant and no effects can be expected. Taking also into account the complex competitive and symbiotic relations among the microorganisms in the soil and the stability of this relations, a disturbance by the addition of EM will end up in a quick reestablishment of the initial equilibrium. The ecology of the soil is not easy to change. It could be possible that in other areas, (tropical countries) where EM has been tested by different department of different Universities (although without publishing the results), EM showed positive effects due to the lower amount of microfauna in the soil.

There are important social and economic implications. From the serious research done in Wageningen University for the dutch conditions a main conclusion can be obtained: EM is not worthy to use.

Regarding the social aspects the reliability of the information is an important issue. The farmers (and the society in general) should be informed and educated in order to be critical with the information available in the media. A campaign might be needed from the government to inform the farmers about the results of the research carried out at Wageningen University.

Conclusions

1. There is a great amount of non-reliable information about EM. This in formation is always positive about the effectiveness of EM with a clear business oriented targets.

2. Educate the society towards a critical way of thinking when choosing a product to use. Having on mind that there is no magic product that solves their problems.

3. Due to the fact that there could be a beneficial effect of EM

in tropical countries (where research has been carried out with satisfactory results although no reliable and testable data have been published) and unexpected findings with potential benefits have been found, more research is needed.

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