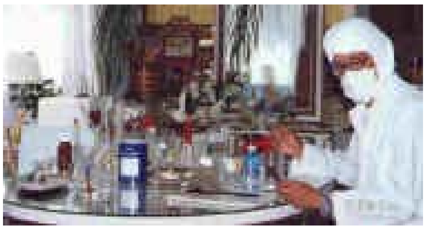
NEW BIOSPHERE AGRICULTURE

EM =
EFFECTIVE
MICROORGANISMS



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What is EM?

EM stands for Effective Microorganisms. EM comes in a liquid form and consists of naturally occurring beneficial microorganisms. The microbes in EM are non-harmful, non-pathogenic, not-genetically-engineered or modified (non-GMO), and not-chemically-synthesized, and EM is not a medicine either. The basic groups of microorganisms in EM are lactic acid bacteria (commonly found in yogurt, cheeses), yeast (bread, beer), and phototrophic bacteria.

EM is used in a variety of ways, mostly by mixing it with or applying it to other organic materials. The EM microbes can be activated by being fermented with (organic) molasses and quality (filtered) water.

Originally, EM was developed for use in agriculture (crop farming) as an alternative to agricultural chemicals. However, EM is not a fertilizer and unlike the purpose of fertilizers, the purpose of EM is to increase the number of beneficial microorganisms in the soil. This is to improve the soil's microbial health and promote a healthy environment for plants.

EM is mixed with organic matter to ferment it (usually the least expensive, most abundant and easily available material, such as rice bran or wheat bran, and other materials, including fish meal, bone meal, crab shells, etc. can be added to match nutrient requirements of the crop). This produces EM Bokashi ("bokashi" is a Japanese term meaning fermented organic matter). It is then applied to the soil as fertilizing material. (EM itself is not a fertilizer.)

From crop farming, its application flowed naturally into livestock. Outside the U.S., EM is actively used in livestock operations, including hog, cattle/dairy, and poultry.

From livestock, the positive effects on the livestock waste and effluent into lagoons and rivers led to the use of EM for environmental purposes: from land/soil remediation to water purification.

EM environmental applications throughout the world have included cleaning polluted waterways, lakes and lagoons, in septic systems, municipal wastewater treatment plants, landfills/dump sites.

In the U.S., EMRO USA began manufacturing (on November 1, 2002) the following EM products:

EM·1 Microbial Inoculant -- for application to soils, turf, and cover crops.

EM·1 Waste Treatment -- for wastewater, wastewater treatment plants, sewer systems, lagoons, pond systems, solid waste, food waste, livestock holding facilities, and odor treatment.

EM·1 Waste Treatment: For Septic Systems -- for septic systems applications, on-site systems, holding tanks, recreational vehicles, boats, and portable restrooms.

EMRO USA currently also manufactures these products for designated distributors in Canada, Mexico and certain Caribbean countries. The parent office, EM Hawaii, Inc., manufactures EM•1 for Hawaii (see Resource Directory for contact information).

The development of EM technology also led to the development of the EM philosophy by Prof. Dr. Teruo Higa, the developer of EM. The EM philosophy is a crucial part of the successful application of EM and is therefore EMRO USA's company vision statement.

> EMRO USA - Company Vision Statement
> Improve humanity by developing a society of coexistence and co-prosperity through sustainability, safety, convenience, low cost, high quality, and exchange of information through the use of EM technology.

Introduction to EM

EM stands for effective micro-organisms. It is a special, symbiotic blend of beneficial microbes developed by a horticultural chemist from Japan. Dr. Teruo Higa. Dr. Higa began investigating the synergistic qualities of many naturally occurring microbes in the 1970's and in the 1980's he developed EM. It is a combination of many microbes, the exact species that are used differ slightly from region to region. It always contains phototropic bacteria, lactic acid bacteria, and fermenting yeasts. The least explored group of microbes that EM contains by far is the phototropic bacteria. The phototropics or photosynthetic bacteria are a group of bacteria which, according to evolutionary theories, are the ancestors of chloroplasts in the more complex cells in plants. Chloroplasts convert light energy into useable cellular energy for plants so it should come as no surprise to biologists that their ancestors would be so important to understanding the microbial community.

EM proves to be a revolution in the natural farming practices in Japan helping farmers eliminate many toxic chemicals from their agricultural practices while improving yields and saving money. It is the symbiotic combination of beneficial microbes which has been demonstrated to promote the growth of beneficial microbes already present, while converting or digesting pathogenic bacteria. In this manner, EM is used in many different ways to attain a balanced soil and plant microbial condition.

EM has no genetically modified organisms.

EM has proven to be a revolutionary technology for many types of environmental remediation efforts, solid waste, wastewater, and composting among them with future application in virtually any waste or contamination issue. In Japan this research has been ongoing for over 20 years. EM use has spread extensively throughout Asia and most of the third world and is finally gaining momentum in western countries where unfortunate regulations make its spread more complicated.

In Asia, from it's inception, research with EM has included not only environmental remediation and horticulture but has consistently pointed towards huge benefits for use with animals and possibly for human health. None of the studies about medical use of EM have been translated to English nor are there any sales of EM products for these uses in the US. Additionally, the use of EM as an animal pro-biotic, although extensive in Asia, has yet to be embraced by the US FDA partly due to the fact that Phototropic bacteria are not on the FDA's GRAS (Generally Recognized As Safe) list. Given the apparent significant ancestry of these microbes it sure seems ridiculous to keep them off this list.

EM cannot currently be sold in the US, Canada or Europe for use as an animal pro-biotic or for human consumption.

Among many areas of research, EM offers major environmental and economic benefits in many industrial applications. At home, EM's uses include improved composting of food wastes, simplified septic system maintenance, as well as gardening and landscaping to name just a few.

EM offers cost-effective solutions to a multitude of environmental problems through controlled fermentation. On this page we will post as many research papers, as well as instructional and informative files on EM and related technologies that we are allowed. Enjoy the learning and please tell us about your experiences as you begin or continue to explore the world of EM - we all will learn faster that way. I do offer technical support on planning and utilizing EM in all sorts of applications - I look forward to hearing from you!

What is EM?

EM (formally Kyusei EM) stands for Effective Microorganisms. EM consists of common and food-grade aerobic (oxygen-loving) and anaerobic (oxygen-hating) microorganisms: photosynthetic bacteria, lactobacillus, streptomyces, actinomycetes, yeast, etc. Each strain of the microorganisms is commonly available from the microbes banks or from the environment. There is no genetically engineered varieties used.

Who developed EM?

EM was developed by **Dr. Teruo Higa**, the professor of the Horticulture Department of University of the Ryukus in Okinawa, in 1982.

He has written about a half dozen books on EM recently. One of his books, *The Revolutionary Change That Saves the Earth*, and its sequel *The Revolutionary Change That Saves the Earth II* became bestsellers in Japan. I believe altogether more than 300,000 copies were sold.

Dr. Higa has not personally benefited monetary from the explosive use of EM. He considers EM as a valuable asset for the mankind. He regards respecting this nature's gift is to make it available at every corner of the world, to clean up the polluted environment, and to produce safe food to everybody on the Earth.

Why is it so revolutionary?

They are the microcosm of the 21st century world: the utopian society and ecosystem. Instead of just one specie of organism dominates and wipes out all others under a certain condition and eventually self-destructs when the condition changes, all the species are interdependent on each other and live in harmony.

That is the reason they can flourish in a diverse range of conditions, and decompose organic matters, neutralize harmful substances, synthesize nutrients, reduce oxidized substances and suppress detrimental microorganisms. Yukio Funai (‘D˜ä　K’j) calls it one of the "true technologies" that will take us to the 21st century.

Using microbes is nothing new. Since almost the beginning of the human history man has been utilizing them for his advantage. Making wine, cheese, yogurt and antibiotics are just a few examples. Since each strain of microbes for a specific purpose has a distinctive requirement, man has to precisely control and satisfy that requirement in order to get a good result. Otherwise wine becomes sour and cheese becomes rotten. Therefore, using microbes in open environment such as farms and sewer systems used be out of question except for naturally occurring varieties.

How effective is it?

Brazil has the largest production and consumption of EM today with an annual production of more than 8,000 tons. A typical Brazilian organic EM farmer has increased his crop yield somewhere between 20 to 30 percent while cutting his costs to one-third.

What about the safety?

Dr. James F. Parr, Soil Microbiologist, Agriculture Research Service, U.S. Department of Agriculture, stated in his letter dated June 27, 1995 as follows: The Agriculture Research Service of USDA has conducted laboratory, greenhouse and field tests with Kyusei EM and has found it to be a mixed culture of common bacteria, photosynthetic bacteria, yeasts, and actinomycetes. These microorganisms are not "engineered" or exotic type, and are not known to be harmful to plants or human beings.

A varieties of EM are denoted with "A" (Allowed) on the Brand Names List of the Certification Handbook 1995 issued by California Certified Organic Farmers. Therefore, organic farmers in California are allowed to use EM.

How is it used?

EM is mostly used to increase the food production while virtually eliminating the need of chemical fertilizers and pesticides. Unlike ordinary composting process which wastes energy as heat, nutrients as gases, and produces harmful substances, the EM fermentation composting at the lower temperature produces nutrients such as water-soluble carbohydrates, amino acids, vitamins and hormones with little waste.

Generally speaking it increases the efficiency of organic farming four-fold. The EM organic farming is even more cost effective than the conventional farming that relies on the chemical fertilizers and pesticides.

EM is used to solve the waste management problems by converting harmful byproducts into new resources. It is use to clean up the contaminated environment.

Where is it used?

EM is produced in about 15 countries including Japan, China, Thai, Brazil, the U. S. About 50 countries are using or testing EM around the world.

What did experts say about it?

During the Round Table Discussion by USDA scientists held on October 7, 1993 just after the Third International Conference on Kyusei Nature Farming in Santa Barbara, California they were quoted as follows:

"I have conducted a few studies using EM, with hydroponic solutions, and various nitrogen rates. I found that the few vegetables that grew had a much higher root yield, overall yield and, most importantly, when I analyzed them for vitamin C, the experiments I conducted with EM at the same nitrogen rate had much higher ascorbic acid or vitamin levels. ... Those vegetables that were grown at the same nitrogen rate without EM had significantly lower levels of vitamin C. ... So EM technology could have a very significant impact on the overall nutritional quality of corps. ... One way of ensuring that our food supply is safe and of superior quality is to enhance soil quality and reduce the input of agrichemicals, particularly pesticides. It appears that EM could be an important tool to meet these goals." Dr. Sharon B. Hornick

"Those of us who are familiar with EM technology view it as an exciting new and potentially useful tool that could help us to enhance the attributes of soil quality and sustainable agriculture. ... I'm most interested in how EM technology can be used to improve aggregation and stabilize soils that are prone to both wind and water erosion. ... I believe that the impact of EM technology or similar technologies will take us toward a more ecologically-oriented agriculture and one that is more holistic in its approach. This will mean that we'll try to utilize natural systems and cycles that are advantageous and beneficial to soil productivity, and crop production and protection. EM technology could be very beneficial in helping to integrate these new farming systems. So I think that EM technology, and technologies similar to ENM, will lead us in a direction that is more compatible with nature. " Dr. Robert I. Papendick

"We see EM technology as a potentially valuable tool to help farmers through an often difficult, high risk transiton period (to a more sustainable agriculture). ... EM has, I think, great potential. After working with APNAN (Asia-Pacific Natural Agricultural Network), and seeing some of the data that's coming in, I'm very much encouraged by what they have been learning in developing countries." Dr. James F. Parr

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What is the future of EM?

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Where can I get more information?

- In Canada
    - Friends of EM (in Vancouver, B.C.)
    - `Phone (604)255-6247 or (604)856-0755`
    - `Fax   (604)255-0764 or (604)856-0773`

- In the U.S.
    - EM Study Group in San Mateo (near San Francisco)

  - Meeting on every 3rd Tuesday from 7:30 p.m.
  - Phone (650)348-1274 or (510)376-3501
  - Fax (650)348-8246

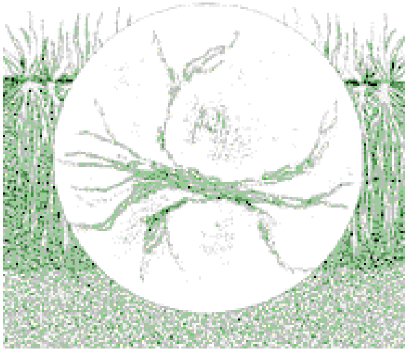
- L.A. EM Outreach Group
- U.S. Rep. for EM Research Organization, Okinawa, Japan
- Mr. Takao Chikudate (near Los Angeles)
- Phone (909)595-4749
- Fax (909)595-6883

- Manufacturer of EM in the U.S. and affiliated company

  - EM Technologies, Inc.
  - EME, Inc.

BENEFICIAL AND EFFECTIVE MICROORGANISMS

http://www.agriton.nl/higa.html



FOR A SUSTAINABLE AGRICULTURE AND ENVIRONMENT

Dr. Teruo Higa
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University of the Ryukyus
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Soil Microbiologist
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Beltsville, Maryland, USA

International Nature Farming Research Center
Atami, Japan
1994

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In 1989, the National Research Council of the National Academy of Sciences issued a highly significant report on "Alternative Agriculture" which was defined as a system of food and fiber production that applies management skills and information to reduce costs, improve efficiency, and maintain production levels through such practices as crop rotations, proper integration of crops and livestock, nitrogen fixing legumes, integrated pest management, conservation tillage, and recycling of on-farm wastes as soil conditioner: and biofertilizers. The report encouraged the collective adoption of these practices by U.S. farmers as the best alternative to the continued and intensive use of chemical fertilizers and pesticides which have often impaired the quality of our soil, water, and food.

Again, in 1993 the National Academy of Sciences left no doubt as to these earlier concerns when the National Research Council released a report on "Pesticides in the Diets of Infants and Children" which concluded that people in this age group could be at considerable health risk from consumption of foods containing pesticide residues.

Both of these reports have raised considerable speculation about the future of our chemical-based agricultural production system. A growing consensus of consumers, environmentalists, legislators, and many farmers is that our current farming practices will have to change considerably to achieve a significant reduction in pesticide usage in U.S. agriculture. The ultimate goal of sustainable agriculture according to the National Research Council, and other sources as well, is to develop farming systems that are productive, profitable, energy conserving, environmentally sound, conserving of natural resources, and that ensure food safety and quality. Consequently, the leading question that U.S. farmers are asking is, "How can I make these changes, reduce my chemical inputs, and achieve an acceptable level of economic and environmental sustainability?"

A successful transition from chemical-based farming systems to a more sustainable agriculture will depend largely on what farmers do to improve and maintain the quality of their agricultural soils. Indeed, soil quality is the "key" to a sustainable agriculture. Not surprisingly, the alternative agricultural practices advocated by the National Research Council are mainly those that can improve and maintain soil quality. Experience has shown that the transition from conventional agriculture to nature farming or organic farming can involve certain risks, such as initially lower yields and increased pest problems. Once through the transition period, which might take several years, most farmers find their new farming systems to be stable, productive, manageable and profitable without pesticides.

Dr. Teruo Higa, Professor of Horticulture, University of the Ryukyus, Okinawa, Japan has conducted pioneering work in advancing the concept of "Effective Microorganisms" (EM). He has developed microbial inoculants that have been shown to improve soil quality, crop growth and yield and have gained attention worldwide. As farmer: seek to change from chemical-based, conventional farming systems to more sustainable kinds of agriculture they will need to utilize the most effective means available if they are to be successful. Certainly, this includes the aforementioned alternative agricultural practices recommended by the National Research Council. We view EM technology as a potentially valuable tool that can help farmer: develop farming systems that are economically, environmentally, and socially sustainable.

Dr. James F. Parr
Agricultural Research Service
U.S. Department of Agriculture
Beltsville, Maryland, USA

INTRODUCTION

The uniqueness of microorganisms and their often unpredictable nature and biosynthetic capabilities, given a specific set of environmental and cultural conditions, has made them likely candidates for solving particularly difficult problems in the life sciences and other fields as well. The various ways in which microorganisms have been used over the past 50 years to advance medical technology, human and animal health, food processing, food safety and quality, genetic engineering, environmental protection, agricultural biotechnology, and more effective treatment of agricultural and municipal wastes provide a most impressive record of achievement. Many of these technological advances would not have been possible using straightforward chemical and physical engineering methods, or if they were, they would not have been practically or economically feasible.

Nevertheless, while microbial technologies have been applied to various agricultural and environmental problems with considerable success in recent years, they have not been widely accepted by the scientific community because it is often difficult to consistently reproduce their beneficial effects. Microorganisms are effective only when they are presented with suitable and optimum conditions for metabolizing their substrates Including available water, oxygen (depending on whether the microorganisms are obligate aerobes or facultative anaerobes), pH and temperature of their environment. Meanwhile, the various types of microbial cultures and inoculants available in the market today have rapidly increased because of these new technologies. Significant achievements are being made in systems where technical guidance is coordinated with the marketing of microbial products. Since microorganisms are useful in eliminating problems associated with the use of chemical fertilizers and pesticides, they are now widely applied in nature farming and organic agriculture (Higa, 1991; Parr et al 1994).

Environmental pollution, caused by excessive soil erosion and the associated transport of sediment, chemical fertilizers and pesticides to surface and groundwater, and improper treatment of human and animal wastes has caused serious environmental and social problems throughout the world. Often engineers have attempted to solve these problems using established chemical and physical methods. However, they have usually found that such problems cannot be solved without using microbial methods and technologies in coordination with agricultural production (Reganold et al., 1990; Parr and Hornick, l992a).

For many years, soil microbiologists and microbial ecologists have tended to differentiate soil microorganisms as beneficial or harmful according to their functions and how they affect soil quality, plant growth and yield, and plant health. As shown in Table 1, beneficial microorganisms are those that can fix atmospheric nitrogen, decompose organic wastes and residues, detoxify pesticides, suppress plant diseases and soil-borne pathogens, enhance nutrient cycling, and produce bioactive compounds such as vitamins, hormones and enzymes that stimulate plant growth. Harmful microorganisms are those that can induce plant diseases, stimulate soil-borne pathogens, immobilize nutrients, and produce toxic and putrescent substances that adversely affect plant growth and health.

A more specific classification of beneficial microorganisms has been suggested by Higa (1991; 1994; 1995) which he refer to as "Effective Microorganisms" or EM. This report presents some new perspectives on the role and application of beneficial microorganism, including EM, as microbial inoculants for shifting the soil microbiological equilibrium in ways that can improve soil quality, enhance crop production and protection, conserve natural resources, and ultimately create a more sustainable agriculture and environment The report also discusses strategies on how beneficial microorganisms, including EM. can be more effective after inoculation into soils.

THE CONCEPT OF EFTECTIVE MICROORGANISMS: THEIR ROLE AND APPLICATION

The concept of effective microorganisms (EM) was developed by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan (Higa, 1991; Higa and Wididana, 1991a). EM consists of mixed cultures of beneficial an naturally-occurring microorganisms that can be applied as inoculants to increase the microbial diversity of soils and plant. Research has shown that the inoculation of EM cultures to the soil/plant ecosystem can improve soil quality, soil health, and the growth, yield, and quality of crops. EM 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 mutually compatible with one another and can coexist in liquid culture.

EM is not a substitute for other management practices. It is, however, an added dimension for optimizing our best soil and crop management practices such as crop rotations, use of organic amendments, conservation tillage, crop residue recycling, and biocontrol of pests. If used properly, EM can significantly enhance the beneficial effects of these practices (Higa and Wididana, 1991b).

Throughout the discussion which follows, we will use the term "beneficial microorganisms" In a general way to designate a large group of often unknown or ill-defined microorganisms that interact favorably in soils and with plants to render beneficial effects which are sometimes difficult to predict. We use the term "effective microorganisms" or EM to denote specific mixed cultures of known, beneficial microorganisms that are being used effectively as microbial inoculants.

UTILIZATION OF BENEFICIAL MICROORGANISMS IN AGRICULTURE

What Constitutes an Ideal Agricultural System?

Conceptual design is important in developing new technologies for utilizing beneficial and effective microorganisms for a more sustainable agriculture and environment. The basis of a conceptual design is imply to first conceive an ideal or model and then to devise a strategy and method for achieving the reality. However it is necessary to carefully coordinate the materials, the environment, and the technologies constituting the method. Moreover one should adopt a philosophical attitude in applying microbial technologies to agricultural production and conservation systems.

There are many opinions on what an ideal agricultural system is. Many would agree that such an idealized system should produce food on a long-term sustainable basis. Many would also insist that it should maintain and improve human health, be economically and spiritually beneficial to both producers and consumers, actively preserve and protect the environment, be self-contained and regenerative, and produce enough food for an increasing world population (Higa, 1991).

Efficient Utilization and Recycling of Energy

Agricultural production begins with the process of photosynthesis by green plants which requires solar energy, water, and carbon dioxide. It occurs through the plants ability to utilize solar energy in "fixing" atmospheric carbon into carbohydrates. The energy obtained is used for further biosynthesis in the plant, including essential amino acids and proteins. The materials used for agricultural production are abundantly available with little initial cost. However, when it is observed as an economic activity, the fixation of carbon by photosynthesis has an extremely low efficiency mainly because of the low utilization rate of solar energy by green plants. Therefore, an integrated approach is needed to increase the level of solar energy utilization by plants so that greater amounts of atmospheric carbon can be converted into useful substrates (Higa and Wididana, 1991a).

Although the potential utilization rate of solar energy by plants has been estimated theoretically at between 10 and 20%, the actual utilization rate is less than 1%. Even the utilization rate of C4 plants, such as sugar cane whose photosynthetic efficiency is very high, barely exceeds 6 or 7% during the maximum growth period. The utilization rate is normally less than 3% even for optimum crop yields.

Past studies have shown that photosynthetic efficiency of the chloroplasts of host crop plants cannot be increased much further; this means that their biomass production has reached a maximum level. Therefore, the best opportunity for increasing biomass production is to somehow utilize the visible light, which chloroplasts cannot presently use, and the infrared radiation; together, these comprise about 80% of the total solar energy. Also, we must explore ways of recycling organic energy contained in plant and animal residues through direct utilization of organic molecules by plants (Higa and Wididana, 1991a).

Thus, it is difficult to exceed the existing limits of crop production unless the efficiency of utilizing solar energy is increased, and the energy contained in existing organic molecules (amino acids, peptides and carbohydrates) is utilized either directly or indirectly by the plant. This approach could help to solve the problems of environmental pollution and degradation caused by the misuse and excessive application of chemical fertilizers and pesticides to soils. Therefore, new technologies that can enhance the economic-viability of farming systems with little or no use of chemical fertilizers and pesticides are urgently needed and should be a high priority of agricultural research both now and in the immediate future (National Academy of Sciences, 1989; 1993).

Preservation of Natural Resources and the Environment

The excessive erosion of topsoil from farmland caused by intensive tillage and row-crop production has caused extensive soil degradation and also contributed to the pollution of both surface and groundwater. Organic wastes from animal production, agricultural and marine processing industries, and municipal wastes (e.i., sewage and garbage), have become major sources of environmental pollution in both developed and developing countries. Furthermore, the production of methane from paddy fields and ruminant animals and of carbon dioxide from the burning of fossil fuels, land clearing and organic matter decomposition have been linked to global warming as "greenhouse gases" (Parr and Hornick, 1992b).

Chemical-based, conventional systems of agricultural production have created many sources of pollution that, either directly or indirectly, can contribute to degradation of the environment and destruction of our natural resource base. This situation would change significantly if these pollutants could be utilized in agricultural production as sources of energy.

Therefore, it is necessary that future agricultural technologies be compatible with the global ecosystem and with solutions to such problems in areas different from those of conventional agricultural technologies. An area that appears to hold the greatest promise for technological advances in crop production, crop protection, and natural resource conservation is that of beneficial and effective microorganisms applied as soil, plant and environmental inoculants (Higa, 1995).

Beneficial and Effective Microorganisms for a Sustainable Agriculture Towards Agriculture Without Chemicals and With Optimum Yields of High Quality Crops.

Agriculture in a broad sense, is not an enterprise which leaves everything to nature without intervention. Rather it is a human activity in which the farmer attempts to integrate certain agroecological factors and production inputs for optimum crop and livestock production. Thus, it is reasonable to assume that farmers should be interested in ways and means of controlling beneficial soil microorganisms as an important component of the agricultural environment. Nevertheless, this idea has often been rejected by naturalists and proponents of nature farming and organic agriculture. They argue that beneficial soil microorganisms will increase naturally when organic amendments are applied to soils as carbon, energy and nutrient sources. This indeed may be true where an abundance of organic materials are readily available for recycling which often occurs in small-scale farming. However, in most cases, soil microorganisms, beneficial or harmful, have often been controlled advantageously when crops in various agroecological zones are grown and cultivated in proper sequence (i.e., crop rotations) and without the use of pesticides. This would explain why scientists have long been interested in the use of beneficial microorganisms as soil and plant inoculants to shift the microbiological equilibrium in a way that enhances soil quality and the yield and quality of crops (Higa and Wididana, 1991b; Higa, 1994:1995).

Most would agree that a basic rule of agriculture is to ensure that specific crops are grown according to their agroclimatic and agroecological requirements. However, in many cases the agricultural economy is based on market forces that demand a stable supply of food, and thus, it becomes necessary to use farmland to its full productive potential throughout the year.

The purpose of crop breeding is to improve crop production, crop protection, and crop quality. Improved crop cultivars along with improved cultural and management practices have made it possible to grow a wide variety of agricultural and horticultural crops in areas where it once would not have been culturally or economically feasible. The cultivation of these crops in such diverse environments has contributed significantly to a stable food supply in many countries. However, it is somewhat ironic that new crop cultures are almost never selected with consideration of their nutritional quality or bioavailability after ingestion (Hornick, 1992).

As will be discussed later, crop growth and development are closely related to the nature of the soil microflora, especially those in close proximity to plant roots, i.e., the rhizosphere. Thus, it will be difficult to overcome the limitations of conventional agricultural technologies without controlling soil microorganisms. This particular tenet is further reinforced because the evolution of most forms of life on earth and their environments are sustained by microorganisms. Most biological activities are influenced by the state of these invisible, minuscule units of life. Therefore, to significantly increase food production, it is essential to develop crop cultivars with improved genetic capabilities (i.e., greater yield potential, disease resistance, and nutritional quality) and with a higher level of environmental competitiveness, particularly under stress conditions (i.e., low rainfall, high temperatures, nutrient deficiencies, and agressive weed growth).

To enhance the concept of controlling and utilizing beneficial microorganisms for crop production and protection, one must harmoniously integrate the essential components for plant growth and yield including light (intensity, photoperiodicity and quality), carbon dioxide, water, nutrients (organic-inorganic) soil type, and the soil microflora. Because of these vital interrelationships, it is possible to envision a new technology and a more energy-efficient system of biological production.

Low agricultural production efficiency is closely related to a poor coordination of energy conversion which, in turn, is influenced by crop physiological factors, the environment, and other biological factors including soil microorganisms. The soil and rhizosphere microflora can accelerate the growth of plants and enhance their resistance to disease and harmful insects by producing bioactive substances. These microorganisms maintain the growth environment of plants, and may have secondary effects on crop quality. A wide range of results are possible depending on their predominance and activities at any one time. Nevertheless, there is a growing consensus that it is possible to attain maximum economic crop yields of high quality, at higher net returns, without the application of chemical fertilizers and pesticides. Until recently, this was not thought to be a very likely possibility using conventional agricultural methods. However, it is important to recognize that the best soil and crop management practices to achieve a more sustainable agriculture will also enhance the growth, numbers and activities of beneficial soil microorganisms that, in turn, can improve the growth, yield and quality of crops (National Academy of Sciences, 1989; Hornick, 1992; Parr et al., 1992).

CONTROLLING THE SOIL MICROFLORA: PRINCIPLES AND STRATEGIES

Principles of Natural Ecosystems and the Application of Beneficial and Effective Microorganisms

The misuse and excessive use of chemical fertilizers and pesticides have often adversely affected the environment and created many a) food safety and quality and b) human and animal health problems. Consequently, there has been a growing interest in nature farming and organic agriculture by consumers and environmentalists as possible alternatives to chemical-based, conventional agriculture.

Agricultural systems which conform to the principles of natural ecosystems are now receiving a great deal of attention in both developed and developing countries. A number of books and journals have recently been published which deal with many aspects of natural farming systems. New concepts such as alternative agriculture, sustainable agriculture, soil quality, integrated pest management, integrated nutrient management and even beneficial microorganisms are being explored by the agricultural research establishment (National Academy of Sciences, 1989; Reganold et al., 1990; Parr et al., 1992). Although these concepts and associated methodologies hold considerable promise, they also have limitations. For example, the main limitation in using microbial inoculants is the problem of reproducibility and lack of consistent results.

Unfortunately certain microbial cultures have been promoted by their suppliers as being effective for controlling a wide range of soil-borne plant diseases when in fact they were effective only on specific pathogens under very specific conditions. Some suppliers have suggested that their particular microbial inoculant is akin to a pesticide that would suppress the general soil microbial population while increasing the population of a specific beneficial microorganism. Nevertheless, most of the claims for these single-culture microbial inoculants are greatly exaggerated and have not proven to be effective under field conditions. One might speculate that if all of the microbial cultures and inoculants that are available as marketed products were used some degree of success might be achieved because of the increased diversity of the soil microflora and stability that is associated with mixed cultures. While this, of course, is a hypothetical example, the fact remains that there is a greater likelihood of controlling the soil microflora by introducing mixed, compatible cultures rather than single pure cultures (Higa, 1991).

Even so, the use of mixed cultures in this approach has been criticized because it is difficult to demonstrate conclusively which microorganisms are responsible for the observed effects, how the introduced microorganisms interact with the indigenous species, and how these new associations affect the soil/plant environment. Thus, the use of mixed cultures of beneficial microorganisms as soil inoculants to enhance the growth, health, yield, and quality of crops has not gained widespread acceptance by the agricultural research establishment because conclusive scientific proof is often lacking.

The use of mixed cultures of beneficial microorganisms as soil inoculants is based on the principles of natural ecosystems which are sustained by their constituents; that is, by the quality and quantity of their inhabitants and specific ecological parameters, i.e., the greater the diversity and number of the inhabitants, the higher the order of their interaction and the more stable the ecosystem. The mixed culture approach is simply an effort to apply these principles to natural systems such as agricultural soils, and to shift the microbiological equilibrium in favor of increased plant growth, production and protection (Higa, 1991; 1994;Parr et al., 1994).

It is important to recognize that soils can vary tremendously as to their types and numbers of microorganisms. These can be both beneficial and harmful to plants and often the predominance of either one depends on the cultural and management practices that are applied. It should also be emphasized that most fertile and productive soils have a high content of organic matter and, generally, have large, populations of highly diverse microorganisms (i.e., both species and genetic diversity). Such soils will also usually have a wide ratio of beneficial to harmful microorganisms (Higa and Wididana, 1991b).

Controlling the Soil Microflora for Optimum Crop Production and Protection

The idea of controlling and manipulating the soil microflora through the use of inoculants organic amendments and cultural and management practices to create a more favorable soil microbiological environment for optimum crop production and protection is not new. For almost a century, microbiologists have known that organic wastes and residues, including animal manures, crop residues, green manures, municipal wastes (both raw and composted), contain their own indigenous populations of microorganisms often with broad physiological capabilities.

It is also known that when such organic wastes and residues are applied to soils many of these introduced microorganisms can function as biocontrol agents by controlling or suppressing soil-borne plant pathogens through their competitive and antagonistic activities. While this has been the theoretical basis for controlling the soil microflora, in actual practice the results have been unpredictable and inconsistent, and the role of specific microorganisms has not been well-defined.

For, many years microbiologists have tried to culture beneficial microorganisms for use as soil inoculants to overcome the harmful effects of phytopathogenic organisms, including bacteria, fungi and nematodes. Such attempts have usually involved single applications of pure cultures of microorganisms which have been largely unsuccessful for several reasons. First, it is necessary to thoroughly understand the individual growth and survival characteristics of each particular beneficial microorganism, including their nutritional and environmental requirements. Second, we must understand their ecological relationships and interactions with other microorganisms, including their ability to coexist in mixed cultures and after application to soils (Higa, 1991; 1994).

There are other problems and constraints that have been major obstacles to controlling the microflora of agricultural soils. First and foremost is the large number of types of microorganisms that are present at any one time, their wide range of physiological capabilities, and the dramatic fluctuations in their populations that can result from man's cultural and management practices applied to a particular farming system. The diversity of the total soil microflora depends on the nature of the soil environment and those factors which affect the growth and activity of each individual organism including temperature, light, aeration, nutrients, organic matter, pH and water. While there are many microorganisms that respond positively to these factors, or a combination thereof, there are many that do not. Microbiologists have actually studied relatively few of the microorganisms that exist in most agricultural soil, mainly because we don't know how to culture them; i.e., we know very little about their growth, nutritional, and ecological requirements.

The "diversity" and "population" factors associated with the soil microflora have discouraged scientists from conducting research to develop control strategies. Many believe that, even when beneficial microorganisms are cultured and inoculated into soils, their number is relatively small compared with the indigenous soil inhabitants, and they would likely be rapidly overwhelmed by the established soil microflora. Consequently, many would argue that even if the application of beneficial microorganisms is successful under limited conditions (e.g., in the laboratory) it would be virtually impossible to achieve the same success under actual field conditions. Such thinking still exists today, and serves as a principle constraint to the concept of controlling the soil microflora (Higa, 1994).

It is noteworthy that most of the microorganisms encountered in any particular soil are harmless to plants with only a relatively few that function as plant pathogens or potential pathogens. Harmful microorganisms become dominant if conditions develop that are favorable to their growth, activity and reproduction. Under such conditions, soil-borne pathogens (e.g., fungal pathogens) can rapidly increase their populations with devastating effects on the crop. If these conditions change, the pathogen population declines just as rapidly to its original state. Conventional farming systems that tend toward the consecutive planting of the same crop (i.e., monoculture) necessitate the heavy use of chemical fertilizers and pesticides. This, in turn, generally increases the probability that harmful, disease-producing, plant pathogenic microorganisms will become more dominant in agricultural soils (Higa, 1991; 1994; Parr and Hornick, 1994). Chemical-based conventional farming methods are not unlike symptomatic therapy. Examples of this are applying fertilizers when crops show symptoms of nutrient-deficiencies, and applying pesticides whenever crops are attacked by insects and diseases. In efforts to control the soil microflora some scientists feel that the introduction of beneficial microorganisms should follow a symptomatic approach. However, we do not agree. The actual soil conditions that prevail at any point in time may be most unfavorable to the growth and establishment of laboratory-cultured, beneficial microorganisms. To facilitate their establishment, it may require that the farmer make certain changes in his cultural and management practices to induce conditions that will (a) allow the growth and survival of the inoculated microorganisms and (b) suppress the growth and activity of the indigenous plant pathogenic microorganisms (Higa, 1994; Parr et al., 1994).

An example of the importance of controlling the soil microflora and how certain cultural and management practices can facilitate such control is useful here. Vegetable cultivars are often selected on their ability to grow and produce over a wide range of temperatures. Under cool, temperate conditions there are generally few pest and disease problems. However, with the onset of hot weather, there is a concomitant increase in the incidence of diseases and insects making it rather difficult to obtain acceptable yields without applying pesticides. With higher temperatures, the total soil microbial population increases as does certain plant pathogens such as Fusarium, which is one of the main putrefactive, fungal pathogens in soil. The incidence and destructive activity of this pathogen can be greatly minimized by adopting reduced tillage methods and by shading techniques to keep the soil cool during hot weather. Another approach is to inoculate the soil with beneficial, antagonistic, antibiotic-producing microorganisms such as actinomycetes and certain fungi (Higa and Wididana, 1991a; 1991b).

Application of Beneficial and Effective Microorganisms: A New Dimension

Many microbiologists believe that the total number of soil microorganisms can be increased by applying organic amendments to the soil. This is generally true because most soil microorganisms are heterotrophic, i.e., they require complex organic molecules of carbon and nitrogen for metabolism and biosynthesis. Whether the regular addition of organic wastes and residues will greatly increase the number of beneficial soil microorganisms in a short period of time is questionable. However, we do know that heavy applications of organic materials, such as seaweed, fish meal, and chitin from crushed crab shells, not only helps to balance the micronutrient content of a soil but also increases the population of beneficial antibiotic-producing actinomycetes. This changes the soil to a disease-suppressive condition within a relatively short period.

The probability that a particular beneficial microorganism will become predominant, even with organic farming or nature farming methods, will depend on the ecosystem and environmental conditions. It can take several hundred years for various species of higher and lower plants to interact and develop into a definable and stable ecosystem. Even if the population of a specific microorganism is increased through cultural and management practices, whether it will be beneficial to plants is another question. Thus, the likelihood of a beneficial, plant-associated microorganism becoming predominant under conservation-based farming systems is virtually impossible to predict. Moreover, it is very unlikely that the population of useful anaerobic microorganisms, which usually comprise only a small part of the soil microflora, would increase significantly even under natural farming conditions.

This information then emphasizes the need to develop methods for isolating and selecting different microorganisms for their beneficial effects on soils and plants. The ultimate goal is to select microorganisms that are physiologically and ecologically compatible with each other and that can be introduced as mixed cultures into soil where their beneficial effects can be realized (Higa, 1991; 1994; 1995).

Application of Beneficial and Effective Microorganisms: Fundamental Considerations

Microorganisms are utilized in agriculture for various purposes; as important components of organic amendments and composts, as legume inoculants for biological nitrogen fixation as a means of suppressing insects and plant diseases to Improve crop quality and yields, and for reduction of labor. All of these are closely related to each other. An important consideration in the application of beneficial microorganisms to soils is the enhancement of their synergistic effects. This is difficult to accomplish if these microorganisms are applied to achieve symptomatic therapy, as in the case of chemical fertilizers and pesticides (Higa, 1991; 1994).

If cultures of beneficial microorganisms are to be effective after inoculation into soil, it is important that their initial populations be at a certain critical threshold level. This helps to ensure that the amount of bioactive substances produced by them will be sufficient to achieve the desired positive effects on crop production and/or crop protection. If these conditions are not met, the introduced microorganisms, no matter how useful they are, will have little if any effect. At present, there are no chemical tests that can predict the probability of a particular soil-inoculated microorganism to achieve a desired result. The most reliable approach is to inoculate the beneficial microorganism into soil as part of a mixed culture, and at a sufficiently high inoculum density to maximize the probability of its adaptation to environmental and ecological conditions (Higa and Wididana, 1991b; Parr et al., 1994).

The application of beneficial microorganisms to soil can help to define the structure and establishment of natural ecosystems. The greater the diversity of the cultivated plants that are grown and the more chemically complex the biomass, the greater the diversity of the soil microflora as to their types, numbers and activities. The application of a wide range of different organic amendments to soils can also help to ensure a greater microbial diversity. For example, combinations of various crop residues, animal manures, green manures, and municipal wastes applied periodically to soil will provide a higher level of microbial diversity than when only one of these materials is applied. The reason for this is that each of these organic materials has its own unique indigenous microflora which can greatly affect the resident soil microflora after they are applied, at least for a limited period.

CLASSIFICATION OF SOILS BASED ON THEIR MICROBIOLOGICAL PROPERTIES

Most soils are classified on the basis of their chemical and physical properties; little has been done to classify soils according to their physicochemical and microbiological properties. The reason for this is that a soil's chemical and physical properties are more readily defined and measured than their microbiological properties. Improved soil quality is usually characterized by increased infiltration; aeration, aggregation and organic matter content and by decreased bulk density, compaction, erosion and crusting. While these are important indicators of potential soil productivity, we must give more attention to soil biological properties because of their important relationship (though poorly understood) to crop production, plant and animal health, environmental quality, and food safety and quality. Research is needed to identify and quantify reliable and predictable biological/ecological indicators of soil quality. Possible indicators might include total species diversity or genetic diversity of beneficial soil microorganisms as well as insects and animals (Reganold et al., 1990; Parr et al., 1992).

The basic concept here is not to classify soils for the study of microorganisms but for farmers to be able to control the soil microflora so that biologically-mediated processes can improve the growth, yield, and quality of crops as well as the tilth, fertility, and productivity of soils. The ultimate objective is to reduce the need for chemical fertilizers and pesticides (National Academy of Sciences, 1989; 1993).

Functions of Microorganisms: Putrefaction, Fermentation, and Synthesis

Soil microorganisms can be classified into decomposer and synthetic microorganisms. The decomposer microorganisms are subdivided into groups that perform oxidative and fermentative decomposition. The fermentative group is further divided into useful fermentation (simply called fermentation) and harmful fermentation (called putrefaction). The synthetic microorganisms can be sub-divided into groups having the physiological abilities to fix atmospheric nitrogen into amino acids and/or carbon dioxide into simple organic molecules through photosynthesis. Figure 1 (adapted from Higa) is a simplified flow chart of organic matter transformations by soil microorganisms that can lead to the development of disease-inducing, disease-suppressive, zymogenic, or synthetic soils.

Fermentation is an anaerobic process by which facultative microorganisms (e.g., yeasts) transform complex organic molecules (e.g., carbohydrates) into simple organic compounds that often can be absorbed directly by plants. Fermentation yields a relatively small amount of energy compared with aerobic decomposition of the same substrate by the same group of microorganisms. Aerobic decomposition results in complete oxidation of a substrate and the release of large amounts of energy, gas, and heat with carbon dioxide and water as the end products. Putrefaction is the process by which facultative heterotrophic microorganisms decompose proteins anaerobically, yielding malodorous incompletely oxidized, metabolites (e.g., ammonia, mercaptans and indole) that are often toxic to plants and animals.

The term "synthesis" as used here refers to the biosynthetic capacity of certain microorganisms to derive metabolic energy by "fixing" atmospheric nitrogen and/or carbon dioxide. In this context we refer to these as "synthetic" microorganisms, and if they should become a predominant part of the soil microflora, then the soil would be termed a "synthetic" soil.

Nitrogen-fixing microorganisms are highly diverse, ranging from "free-living" autotrophic bacteria of the genus Azotobacter to symbiotic, heterotrophic bacteria of the genus Rhizobium, and blue-green algae (now mainly classified as blue-green bacteria), all of which function aerobically. Photosynthetic microorganisms fix atmospheric carbon dioxide in a manner similar to that of green plants. They are also highly diverse, ranging from blue-green algae to green algae that perform complete photosynthesis aerobically to photosynthetic bacteria which perform incomplete photosynthesis anaerobically.

Relationships Between Putrefaction, Fermentation, and Synthesis

The processes of putrefaction, fermentation, and synthesis proceed simultaneously according to the appropriate types and numbers of microorganisms that are present in the soil. The impact on soil quality attributes and related soil properties is determined by the dominant process. The production of organic substances by microorganisms results from the intake of positive ions, while decomposition serves to release these positive ions. Hydrogen ions play a pivotal role in these processes. A problem occurs when hydrogen ions do not recombine with oxygen to form water but are utilized to produce methane, hydrogen sulfide, ammonia, mercaptans and other highly reduced putrefactive substances most of which are toxic to plants and produce malodors. If a soil is able to absorb the excess hydrogen ions during periods of soil anaerobiosis and if synthetic microorganisms such as photosynthetic bacteria are present, they will utilize these putrefactive substances and produce useful substrates from them which helps to maintain a healthy and productive soil.

The photosynthetic bacteria, which perform incomplete photosynthesis anaerobically, are highly desirable, beneficial soil microorganisms because they are able to detoxify soils by transforming reduced, putrefactive substances such as hydrogen sulfide into useful substrates. This helps to ensure efficient utilization of organic matter and to improve soil fertility. Photosynthesis involves the photo-catalyzed splitting of water which yields molecular oxygen as a by-product. Thus, these microorganisms help to provide a vital source of oxygen to plant roots.

Reduced compounds such as methane and hydrogen sulfide are often produced when organic materials are decomposed under anaerobic conditions. These compounds are toxic and can greatly suppress the activities of nitrogen-fixing microorganisms. However, if synthetic microorganisms, such as photosynthetic bacteria that utilize reduced substances, are present in the soil, oxygen deficiencies are not likely to occur. Thus, nitrogen-fixing microorganisms, coexisting in the soil with photosynthetic bacteria, can function effectively in fixing atmospheric nitrogen even under anaerobic conditions.

Photosynthetic bacteria not only perform photosynthesis but can also fix-nitrogen. Moreover, it has been shown that, when they coexist, in soil with species of Azotobacter, their ability to fix nitrogen is enhanced. This then is an example of a synthetic soil. It also suggests that by recognizing the role, function, and mutual compatibility of these two bacteria and utilizing them effectively to their full potential, soils can be induced to a greater synthetic capacity. Perhaps the most effective synthetic soil system results from the enhancement of zymogenic and synthetic microorganisms; this allows fermentation to become dominant over putrefaction and useful synthetic processes to proceed.

Classification of Soils Based on the Functions of Microorganisms

As discussed earlier (Figure 1), soils can be characterized according to their indigenous microflora which perform putrefactive, fermentative, synthetic and zymogenic reactions and processes. In most soils, these three functions are going on simultaneously with the rate and extent of each determined by the types and numbers of associated microorganisms that are actively involved at any one time.

A simple diagram showing a classification of soils based on the activities and functions of their predominant microorganisms is presented in Fig. 2.

Disease-Inducing Soils. In this type of soil, plant pathogenic microorganisms such as Fusarium fungi can comprise 5 to 20 percent of the total microflora if fresh organic matter with a high nitrogen content is applied to such a soil, incompletely oxidized products can arise that are malodorous and toxic to growing plants. Such soils tend to cause frequent infestations of disease organisms, and harmful insects. Thus, the application of fresh organic matter to these soils is often harmful to crops. Probably more than 90 percent of the agricultural land devoted to crop production worldwide can be classified as having disease-inducing soil. Such soils generally have poor physical properties, and large amounts of energy are lost as "greenhouse" gases, particularly in the case of rice fields. Plant nutrients are also subject to immobilization into unavailable forms.

Disease-Suppressive Soils. The microflora of disease-suppressive soils is usually dominated by antagonistic microorganisms that produce copious amounts of antibiotics. These include fungi of the genera Penicillium, Trichoderma, and Aspergillus, and actinomycetes of the genus Streptomyces. The antibiotics they produce can have biostatic and biocidal effects on soil-borne plant pathogens, including Fusarium which would have an incidence in these soils of less than 5 percent. Crops planted in these soils are rarely affected by diseases or insect pests. Even if fresh organic matter with a high nitrogen content is applied, the production of putrescent substances is very low and the soil has a pleasant earthy odor after the organic matter is decomposed. These soils generally have excellent physical properties; for example, they readily, form water-stable aggregates and they are well-aerated, and have a high permeability to both air and water. Crop yields in the disease-suppressive soils are often slightly lower than those in synthetic soils. Highly acceptable crop yields are obtained whenever a soil has a predominance of both disease-suppressive and synthetic microorganisms.

Zymogenic Soils. These soils are dominated by a microflora that can perform useful kinds of fermentations, i.e., the breakdown of complex organic molecules into simple organic substances and inorganic materials. The organisms can be either obligate or facultative anaerobes. Such fermentation-producing microorganisms often comprise the microflora of various organic materials, i.e., crop residues, animal manures, green manures and municipal wastes including composts. After these amendments are applied to the soil, their number: and fermentative activities can increase dramatically and overwhelm the indigenous soil microflora for an indefinite period. While these microorganisms remain predominant, the soil can be classified as a zymogenic soil which is generally characterized by a) pleasant, fermentative odors especially after tillage, b) favorable soil physical properties (e.g., Increased aggregate stability, permeability, aeration and decreased resistance to tillage c) large amounts of inorganic nutrients, amino acids, carbohydrates, vitamins and other bioactive substances which can directly or indirectly enhance the growth, yield and quality of crops, d) low occupancy of Fusarium fungi which is usually less than 5 percent, and e) low production of greenhouse gases (e.g., methane, ammonia, and carbon dioxide) from croplands, even where flooded rice is grown.

Synthetic Soils. These soils contain significant populations of microorganisms which are able to fix atmospheric nitrogen and carbon dioxide into complex molecules such as amino acids, proteins and carbohydrates. Such microorganisms include photosynthetic bacteria which perform incomplete photosynthesis anaerobically, certain Phycomycetes (fungi that resemble algae), and both green algae and blue--green algae which function aerobically. All of these are photosynthetic organisms that fix atmospheric nitrogen. If the water content of these soils is stable, their fertility can be largely maintained by regular additions of only small amounts of organic materials. These soils have a low Fusarium occupancy and they are often of the disease-suppressive type. The production of gases from fields where synthetic soils are present is minimal, even for flooded rice.

This is a somewhat simplistic classification of soils based on the functions of their predominant types of microorganisms, and whether they are potentially beneficial or harmful to the growth and yield of crops. While these different types of soils are described here in a rather idealized manner, the fact is that in nature they are not always clearly defined because they often tend to have some of the same characteristics. Nevertheless, research has shown that a disease-inducing soil can be transformed into disease-suppressing, zymogenic and synthetic soils by inoculating the problem soil with mixed cultures of effective microorganisms (Higa, 1991; 1994; Parr et al., 1994). Thus it is somewhat obvious that the most desirable agricultural soil for optimum growth, production, protection, and quality of crops would be the composite soil indicated in Fig. 2, i.e., a soil that is highly zymogenic and synthetic, and has an established disease-suppressive capacity. This then is the principle reason for seeking ways and means of controlling the microflora of agricultural soils.

SUMMARY AND CONCLUSIONS

Controlling the soil microflora to enhance the predominance of beneficial and effective microorganisms can help to improve and maintain the soil chemical and physical properties. The proper and regular addition of organic amendments are often an important part of any strategy to exercise such control.

Previous efforts to significantly change the indigenous microflora of a soil by introducing single cultures of extrinsic microorganisms have largely been unsuccessful. Even when a beneficial microorganism is isolated from a soil, cultured in the laboratory, and reinoculated into the same soil at a very high population, it is immediately subject to competitive and antagonistic effects from the indigenous soil microflora and its numbers soon decline. Thus, the probability of shifting the "microbiological equilibrium" of a soil and controlling it to favor the growth, yield and health of crops is much greater if mixed cultures of beneficial and effective microorganisms are introduced that are physiologically and ecologically compatible with one another. When these mixed cultures become established their individual beneficial effects are often magnified in a synergistic manner.

Actually, a disease-suppressive microflora can be developed rather easily by selecting and culturing certain types of gram-positive bacteria that produce antibiotics and have a wide range of specific functions and capabilities; these organisms include facultative anaerobes, obligate aerobes, acidophilic and alkalophilic microbes. These microorganisms can be grown to high populations in a medium consisting of rice bran, oil cake and fish meal and then applied to soil along with well-cured compost that also has a large stable population of beneficial microorganisms, especially facultative anaerobic bacteria. A soil can be readily transformed into a zymogenic/synthetic soil with disease-suppressive potential if mixed cultures of effective microorganisms with the ability to transmit these properties are applied to that soil.

The desired effects from applying cultured beneficial and effective microorganisms to soils can be somewhat variable, at least initially. In some soils, a single application (i.e., inoculation) may be enough to produce the expected results, while for other soils even repeated applications may appear to be ineffective. The reason for this is that in some soils it takes longer for the introduced microorganisms to adapt to a new set of ecological and environmental conditions and to become well-established as a stable, effective and predominant part of the indigenous soil microflora. The important consideration here is the careful selection of a mixed culture of compatible, effective microorganisms properly cultured and provided with acceptable organic substrates. Assuming that repeated applications are made at regular intervals during the first cropping season, there is a very high probability that the desired results will be achieved.

There are no meaningful or reliable tests for monitoring the establishment of mixed cultures of beneficial and effective microorganisms after application to a soil. The desired effects appear only after they are established and become dominant, and remain stable and active in the soil. The inoculum densities of the mixed cultures and the frequency of application serve only as guidelines to enhance the probability of early establishment. Repeated applications, especially during the first cropping season, can markedly facilitate early establishment of the introduced effective microorganisms.

Once the "new" microflora is established and stabilized, the desired effects will continue indefinitely and no further applications are necessary unless organic amendments cease to be applied, or the soil is subjected to severe drought or flooding.

Finally, it is far more likely that the microflora of a soil can be controlled through the application of mixed cultures of selected beneficial and effective microorganisms than by the use of single or pure cultures. If the microorganisms comprising the mixed culture can coexist and are physiologically compatible and mutually complementary, and if the initial inoculum density is sufficiently high, there is a high probability that these microorganisms will become established in the soil and will be effective as an associative group, whereby such positive interactions would continue. If so, then it is also highly, probable that they will exercise considerable control over the indigenous soil microflora which, in due course, would likely be transformed into or replaced by a "new" soil microflora.

REFERENCES

Higa, T. 1991. Effective microorganisms: A biotechnology for mankind. p.8-14. In J.F. Parr, S.B. Hornick, and C.E. Whitman (ed.) Proceedings of the First International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C., USA.

Higa, T. and G.N. Wididana 1991a. The concept and theories of effective microorganisms. p. 118-124. In Parr, S.B. Hornick, and C.E. Whitman (ed.) Proceedings of the First International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C., USA.

Higa, T. and G.N. Wididana 199lb. Changes In the soil microflora Induced by effective microorganisms. p.153-162. In J.F. Parr, S.B. Hornick, and C.E. Whitman (ed.) Proceedings of the First International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C., USA.

Higa, T. 1994. Effective Microorganisms: A New Dimension for Nature Farming. p. 20-22. In J.F. Parr, S.B. Hornick, and M.E. Simpson (ed.) Proceedings of the Second International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C, USA.

Higa, T. 1995. Effective microorganisms: Their role in Kyusei Nature Farming and sustainable agriculture. In J.F. Parr, S.B. Hornick, and M.E. Simpson (ed.) Proceedings of the Third International Conference on Kyusei Nature Farming. U.S. Department of Agriculture, Washington, D.C., USA. (In Press).

Hornick, S.B. 1992. Factors affecting the nutritional quality of crops. Amer. J. Alternative Agric. 7:63-68.

National Academy of Sciences. 1989. Alternative Agriculture. Committee on the Role of Alternative Agriculture Farming Methods in Modern Production Agriculture. National Research Council, Board on Agriculture. National Academy Press, Washington, D.C., USA. 448 p.

National Academy of Sciences. 1993. Pesticides in Diets of Infants and Children National Research Council, Board on Agriculture. National Academy Press, Washington, D.C., USA. 373 p.

Parr, J.F. and S.B. Hornick 1992a. Agricultural use of organic amendments: A historical perspective. Amer. J. Alternative Agric. 7:181-189.

Parr, J.F. and S.B. Hornick. 1992b. Utilization of municipal wastes. p.545-559. In F.B. Metting (ed.) Soil Microbial Ecology: Applications in Agriculture and Environmental Management. Marcel Dekker, Inc., New York, USA.

Parr, J.F., R.I. Papendick, S.B. Hornick, and R.E. Meyer. 1992. Soil quality: Attributes and relationship to alternative and sustainable agriculture. Amer. J. Alternative Agric. 7:5-11.

Parr, J.F. and S.B. Hornick. 1994. Assessment of the Third International Conference on Kyusei Nature Farming: Round Table Discussion by USDA Scientists, October 7, 1993. Published by the Nature Farming Research and Development Foundation, Lompoc, California, USA.

Parr, J.F., S.B. Hornick, and D.D. Kaufman. 1994. Use of microbial Inoculants and organic fertilizers in agricultural production. In Proceedings of the International Seminar on the Use of Microbial and Organic Fertilizers in Agricultural Production. Published by the Food and Fertilizer Technology Center, Taipei, Taiwan.

Reganold, J.P., R.I Papendick, and J.F. Parr. 1990. Sustainable Agriculture. Scientific American 262(6): 112-120.

Table 1.
Some Common Functions of Beneficial and Harmful Soil Microorganisms as they Affect Soil Quality, Crop Production, and Plant Health.

Functions of Beneficial Microorganisms

- Fixation of atmospheric nitrogen
- Decomposition of organic wastes and residues
- Suppression of soil-borne pathogens
- Recycling and increased availability of plant nutrients
- Degradation of toxicants including pesticides
- Production of antibiotics and other bioactive compounds
- Production of simple organic molecules for plant uptake
- Complexation of heavy metals to limit plant uptake
- Solubilization of insoluble nutrient sources
- Production of polysaccharides to improve soil aggregation

Functions of Harmful Microorganisms

- Induction of plant diseases
- Stimulation of soil-borne pathogens
- Immobilization of plant nutrients
- Inhibition of seed germination
- Inhibition of plant growth and development
- Production of phytotoxic substances

Fig 1 Flow chart of organic matter transformations by soil microorganisms and the development of soils that may be disease-inducing, zymogenic or synthetic (adapted from Prof. Dr. Teruo Higa).

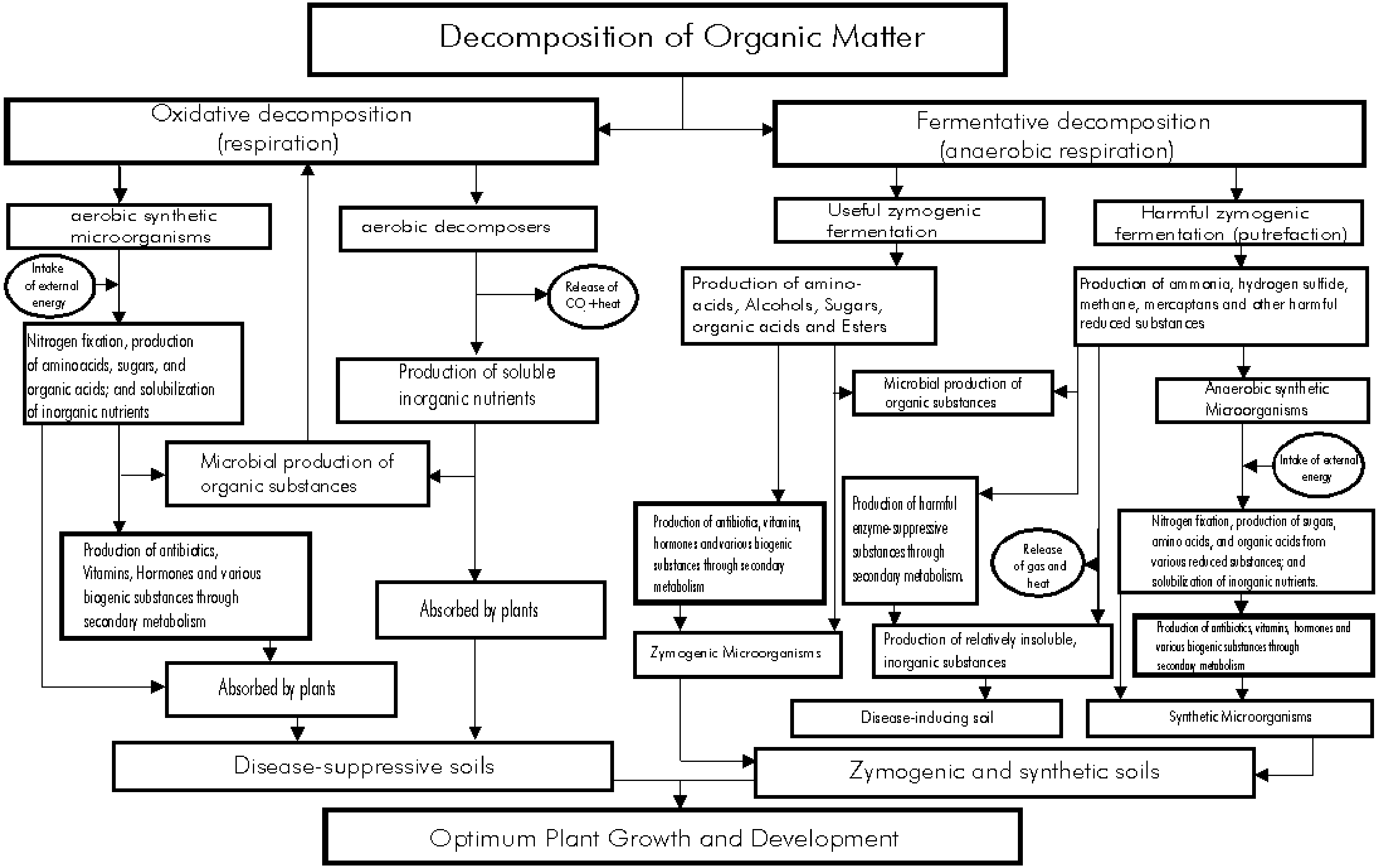
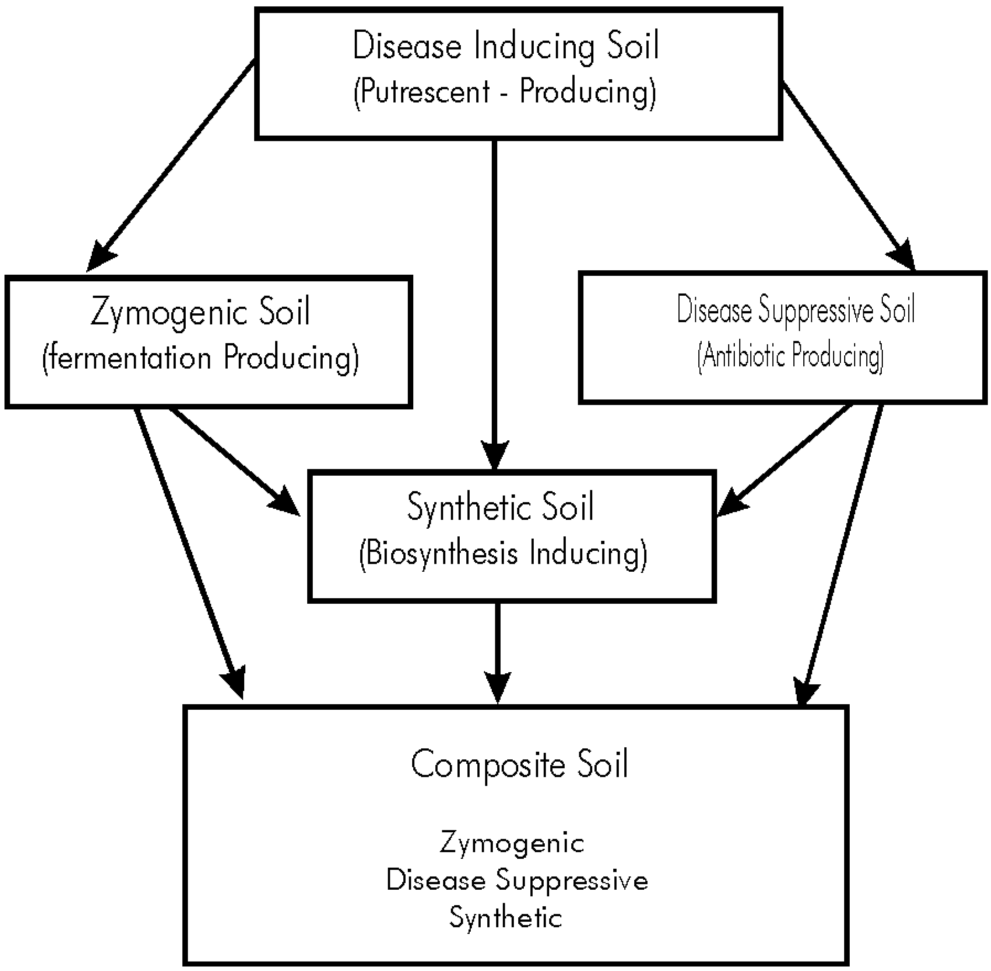


Fig 2

Classification of soils based on the activities and functions of their predominant microorganisms.

Disease-inducing soils can be transformed into disease suppressing, zymogenic and synthetic soils that are more conducive to growth and health of plants by introducing beneficial microorganisms as microbial inoculants and following best management practices. The ideal soil for a more sustainable agriculture is a composite of the other three soil types and contains associative groups of beneficial microorganisms to enhance the optimum growth, yield and quality of crops.



THE TECHNOLOGY OF EFFECTIVE MICROORGANISMS – CASE STUDIES OF APPLICATION

http://www.royagcol.ac.uk/research/conferences/sangakkara.htm

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ABSTRACT

The technology of Effective Microorganisms (commonly termed (EM Technology) was developed in the 1970's at the University of the Ryukyus, Okinawa, Japan. The inception of the technology was based on blending a multitude of microbes, and was subsequently refined to include three principal types of organisms commonly found in all ecosystems, namely Lactic Acid Bacteria, Yeast Actinomyces and Photosynthetic bacteria. These were blended in a molasses or sugar medium and maintained at a low pH under ambient conditions.

The technology was introduced to the world through an International Conference held in Thailand in 1989, where a research program to test its efficacy was undertaken by 13 countries in the Asia Pacific region. Thereafter, this program encompassed many international fora, including the International Federation of Organic Agriculture Movements (IFOAM).

The original concept of using EM in crop production, primarily in organic systems to overcome the inherent problems such as low productivity was well proven in many environments. Thus the technology spread gradually to all continents.

Today EM is used in many systems pertaining to agriculture and environmental management. These range from crop and animal production systems, to livestock and aquaculture units. EM is used widely in environmental management for decomposition and more importantly for recycling of wastes, both solids and liquids. More recently research from Japan and projects in the USA have reported the ability of EM based products to reduce dioxin contents.

The programs on EM undertaken in over 60 countries show its success. The initial research undertaken in agriculture paved the way for case studies and large-scale use of EM in a diverse range of environments. These include laboratory scale identification of the microbes and their role in the DPR Korea, to the use of the solution in crop production in over 500,000 hectares in the same country. It is used in the USA, Europe, Africa, Asia, Mid and South America and Oceania in a multitude of ways. The reports from these projects highlight successes although some do show marginal results. The important aspect has been its use by practitioners, who adopt technologies due to proven successes and not research reports. The presentation will cover the practical benefits of using EM on the basis of research results and case studies where the solution has been used extensively for either agriculture or environmental management.

INTRODUCTION

The 21st century has dawned, with renewed hope for a better livelihood for the populations of this earth. Hence the themes often discussed at international fora on human welfare and agriculture range from sustainability, food security and safety to the provision of a productive and healthy environment to humankind and its future generations. Hence there is often a great deal of optimism about the possibilities of solving the multitude of problems in relation to the provision of food and a clean healthy environment for all.

Although the picture being painted seems rosy with numerous possibilities, the reality is not that simple. The future is not too optimistic. The post war agricultural revolution has brought about problems of pollution, which are increasing in magnitude, although the agricultural development projects have increased yields in both developed and developing countries. The problems also arise from over production of agricultural commodities in the developed countries, while inadequate production and unequal distribution of food and resources in the developing countries is a common phenomenon. There is excessive pollution caused by industrialized agriculture, loss of biodiversity and increased incidence of pests and diseases. The use of genetically modified organisms has raised concerns about food safety. All these problems need solutions to maintain and possibly enhance the quality of the environment and provision of food for humankind and also all forms of life on earth (HRH The Prince of Wales, 1998).

ORGANIC OR NATURE FARMING

Organic or nature farming is considered a possible solution to many of the problems caused by industrialized agriculture (Litterick et al, 2001). This is based on the fact that organic or nature farming is a holistic concept, involving all components of the ecosystem. Hence organic and nature farming are considered useful and sustainable systems to produce safe and quality food, both in the developed and developing world.

Organic farming in the developing world is viewed as a system of alternative agriculture, which could enhance the quality of degraded environments currently farmed intensively by smallholders to produce food and fodder. In the recent past, organic products have also become export commodities, which earn much-needed foreign exchange to these countries. In all instances, organic farming alone may not provide the required quantities of food, although it certainly has the potential of improving the environment and more importantly, the sustainability of the farming systems.

A primary problem of organic or nature farming is the low yields procured, when compared to that of conventional chemical farming systems. This is principally observed in the developing countries. Hence the promotion and development of organic systems in these regions must be coupled with technologies that would enhance yields while preserving and possibly improving the sustainability of the systems and also the environment.

MICROBES IN AGRICULTURE

Microbes are a vital component in all ecosystems. In agriculture, their value cannot be overemphasized, due to their role in the soil and as an interlink between the biotic and abiotic components and also between the grazing and detritus food chains. However, their role has often been neglected in conventional chemical farming systems. The interaction between microbes and plants developed with the process of evolution in plants, and hence the use of microbes singly or in mixtures of free living and naturally occurring species could enhance the productivity of most farming systems significantly (Zarb et al, 2001). Thus the most importance and often-used species of microbes in agriculture are Fungi, Bacteria, Actinomyces and Yeast.

Although the use of microbes in the form of animal manure and slurries has a long history in traditional agriculture, the use of Rhizobium and Mycorrhizal inoculation added a new dimension to the technology of microorganisms in agriculture. In the recent times, research has clearly shown the benefits of using inoculations of naturally occurring microbes in increasing productivity of both conventional and organic farming systems (Tisdal, 1994, Zarb et al, 2001). However, the use of microbial inoculation containing many species obtained from the respective ecosystems to develop multiple benefits has not received much attention.

THE TECHNOLOGY OF EFFECTIVE MICROORGANISMS

Fungi, Bacteria, Actinomyces and Yeast are found in all ecosystems. They are used widely in the food industry, and these species play a vital role in agriculture to maintain and also enhance productivity (Zarb et al, 2001). The technology of Effective Microorganisms (EM) also uses these species namely Lactic Acid Bacteria, Photosynthetic Bacteria, Yeast and Actinomyces isolated from the respective environments in which EM is used.

Professor Dr Teruo Higa developed the technology of EM in the 1970's at the University of the Ryukyus, Okinawa, Japan. The first solutions contained over 80 species from 10 genera isolated from Okinawa and other environments in Japan. With time, the technology was refined to include only the four important species cited earlier, namely Lactic Acid Bacteria, Photosynthetic Bacteria, Actinomyces and Yeast. These are isolated from the respective locations where EM is used extensively and is blended into a mixture in a sugar-based medium. The sugar commonly used is molasses or raw sugar, and the solution is maintained a low pH ranging between 3 .0 – 4.0 The mixture does not contain any organism imported from Japan, nor does it contain any genetically modified organisms. Hence, EM is made in over 40 countries in all continents, from species isolated from the different localities. The technology is thus safe, effective and environmentally friendly, and is accessible to farmers in both developed and developing countries. On this basis, the technology is used or researched upon in countries ranging from Austria to Zimbabwe.

PRACTICAL USES OF EM

The practical uses of EM can broadly be classified into two principal components –

- Agriculture
- Environmental Management

The research programs and case studies on the benefits of EM in these two principal components have been reported from all continents of the world. However, a setback in the wide scale publicity of these very useful studies has been the lack of publications in international journals, due to the emphasis on one particular product. Most studies have been reported at two fora, namely the International Conferences of IFOAM (International Federation of Organic Agriculture Movements) beginning 1987 and the International Conferences on Kyusei Nature Farming beginning in 1989. However, the usefulness and potential values of the technology is accepted internationally as shown by the development of separate sessions on EM at the IFOAM conferences beginning in New Zealand in 1994.

EM IN AGRICULTURE

The original use of EM was for agriculture. Hence EM was first applied to enhance productivity of organic or nature farming systems. EM was applied directly onto organic matter added to cropping fields, or to compost, which reduced the time required for the preparation of this biofertilizer. EM is also added in the form of Bokashi (Compost) made with waste material such as rice husk and saw dust as a carrier, mixed with nitrogen rich material such as rice, corn or wheat bran, fish meal or oil cakes.

The studies on the success of EM in crop production are many. Research on papaya in Brazil (Chagas et al, 2001), herbage grasses in Holland and Austria (Bruggenwert, 2001, Hader, 2001), vegetables in New Zealand and Sri Lanka (Daly and Stewart, 1999, Sangakkara and Higa, 2000) and apples in Japan (Fujita, 2000) illustrates this phenomenon very clearly. All these studies are examples of a multitude of projects and they clearly highlight that the use of EM or EM based products such as Bokashi increase yields of traditional organic systems over a period of time.

The causal phenomenon of these results has been attributed to many factors. These include greater release of nutrients from organic matter when composted with EM (Sangakkara and Weerasekera, 2001) enhanced photosynthesis (Xu et al, 2001) and protein activity (Konoplya and Higa, 2001). Studies also identify greater resistance to water stress (Xu, 2000), greater mineralization of carbon (Daly and Stewart, 1999) and increased soil properties (Hussein et al 2000) and better penetration of roots (In Ho and Ji Hwan, 2001) with the use of EM.

The impact of EM in promoting plant growth by controlling or suppressing pests and diseases has also been reported from many countries. Kremer et al (2001) reports the control of Sclerotinia in turf grass with EM. Guest (1999) and Wang et al (2000) highlight the control of Phytopthora with EM derivatives in China and Australia Wood et al (1999) also states the control of pickleworm in cucumber with EM. The control of black Sigatoka with EM is a success in Costa Rica (Elango et al, 1999). These are just a handful of many reports that present the success of EM in crop production. More importantly, all these highlight the benefits of EM in a wide range of environments. which is the key to its success and adaptability.

The use of EM in animal husbandry is also clearly identified in many parts of the world. Studies in Asia where EM was first introduced and is used extensively (e.g. Chantsawang and Watcharangkul, 1999) and in Belarus (Konoplya and Higa 2000) report the successful use of EM in poultry and swine units. EM is added to feed and sprayed for sanitation in these units. Integrated animal units and poultry farms in South Africa (Hanekon et al, 2001, Safalaoh and Smith, 2001) use EM to increase productivity. Swine units and fish units in Austria also use EM for procuring greater productivity (Hader, 2000).

The causal phenomenon of these has also been identified in research projects. These are greater physiological activity in animals and better feed conversion efficiencies (Safalaoh and Smith, 2001, Konoplya and Higa, 2000).

As cited earlier, the reports on EM in increasing the productivity of animal units are numerous. The setback in further progress is the lack of international publications of these studies, although carried out in a systematic and scientific manner. However the benefits are clearly identified as exemplified by the adoption of the technology by farmers and producers despite warning by skeptical scientists. This is the final judgement of the success of the technology for agriculture.

EM IN ENVIRONMENTAL MANAGEMENT

The management of the environment is a key and controversial issue in modern agriculture. The disposal of farm wastes, the discharge of polluted waters and the mitigation of dioxin developed through incineration or disintegration of wastes are all problems faced by humankind. Thus legislation is being introduced in many countries to preserve the existing environment and possibly improve it.

The role of EM in environmental management is of significant importance. This microbial solution, which was originally developed for nature or organic farming systems, was further expanded to overcome environmental issues, thereby facilitating the reuse of most wastes.

The first concept of using EM in environmental management was in the process of composting. Crop residues and animal wastes were effectively composted to produce biofertilizers. Research in Holland (e.g. van Bruchem et al, 1999), and Shintani et al (2000) in Costa Rica highlight the potential of making compost with animal or crop wastes, this increasing yields of crops supplied with this material, over the productivity of traditional organic systems.

The use of EM in composting garbage developed in the mid 1990's and very successful projects have been undertaken in Asia. A good example is that of Hanoi Vietnam (Quang, 2000), under the purview of the Ministry of Science, Technology an Environment of that country. The city garbage is composted with EM and sold as fertilizers. A similar project is being undertaken in Yangon, Myanmar. The city of Pusan in Korea uses EM in over 500 apartments to compost kitchen wastes, which are recycled into home gardens, in a project undertaken by the Red Cross. The city of Christchurch in New Zealand is also undertaking a similar project, which will be a field site at the International Conference on EM in January 2002.

EM is also being used effectively in purifying water for reuse. The best example of this is in Okinawa the home of EM. The city library of Gushikawa uses EM very effectively in treating sewage water, which is recycled for the garden and in toilets. The COD and BOD of the water are reduced significantly when treated with EM (Okuda and Higa, 1999) and this water is reused, thus saving costs and energy.

A very recent project on using EM in water treatment is in the Gold Coast of Australia, in the city of Mc Kay. The city sewage system is treated with EM and oxygen and the quality of water enhanced prior to discharge. A resort island uses EM for its water treatment and this water is recycled into gardens with no smell. The quality of water is well within the stringent environmental laws of Australia, and this study will be presented in New Zealand next year.

Research in South Africa also highlight the potential of using EM for treating pig manure prior to feeding fish (Hanekon et al, 2001). Addition of EM to pig fed promoted growth of the animals. Application of EM to manure reduced faecal bacterial counts and feeding this manure to fish increase harvestable produce.

Although not recorded, there are many projects using EM for waste management in many countries. Amongst all the practitioners of EM, the best example is at the Nature farm in Sara Buri, Thailand, where EM is used for cropping, livestock, and waste management. Unfortunately these results have not been recorded as it is a practical farm used extensively for training people from Thailand and overseas on EM technology, at no cost to the trainees.

The most recent studies with EM on environmental management produced very interesting results. If repeatable, these would have a significant impact on the enhancement of environmental quality. The first is a study from Belarus, which illustrate the ability of EM to reduce radioactive contamination in affected soils (Konoplya, 1999). Application of EM increased uptake of Cs137 from contaminated soils of Chernobyl. The destruction of these crops would reduce the level of contamination in the soils. In addition, the use of EMx, a derivative of EM, which has antioxidant properties, was seen to act as a radioprotective agent.

The second and third studies relate to the reduction of dioxin production. A pilot study in the USA (Kozawa 2000) showed that the use of EM could reduce dioxin production. More importantly, a study by Miyajima et al (2001) in Okinawa, report that using EM in a commercial incinerator reduced the production of dioxin. These suggest valuable lines for research ad acceptance for the future.

CONCLUSIONS

The potential of EM in agriculture and environmental management is significant. The technology can be used easily and economically to enhance productivity of agricultural systems, especially organic systems and in mitigating environmental pollution.

While successful projects are being implements in many countries even at national scale as in Myanmar, D P R Korea, Vietnam and Thailand, and by non governmental organizations as in Sri Lanka, India and Indonesia or on a more localized scale by private organizations such as New Zealand nature farming Societies, Agriton of Holland, EMROSA of Africa, a setback has been the lack of proper exposure and recording of results. The users see the benefits of EM and there is a very growing demand for EM. This calls for the maintenance of good records of its success and effects, although the users often state – "We know its benefits – Why record it?"

In this story of success, one also needs to be cautious in using EM. It is not a means or answer to all problems, although it has a significant role to play in agriculture and environmental management. As in all techniques, EM must also be used diligently and with care, as per guidelines. Failure to do so would produce negative results as in some instances, which have also been given publicity. However, adoption of the technology of EM will ensure the achievement of the objective – Where all humans of this world strive for – Greater production of agricultural systems on a sustainable basis and a cleaner environment for humankind and its future generations.

REFERENCES

BRUGGENWERT, M. G. M. 2001. EM research in the Netherlands. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

CHAGAS, P R R, TOKESHI, H and ALVES, M. C. 2001 Effect of calcium on yield of papaya fruits on conventional and organic (Bokashi EM) systems. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

CHANTSAWANG, S and WATCHARANGUL, P. 1999. Influence of EM on quality of poultry production. In Proceedings of the 5th International Conference on Kyusei Nature Farming, Thailand, 1998 Senanayake, Y D A and Sangakkara U R (Ed) APNAN, Thailand: 133 – 150

DALY, M J and STEWART, D. P. C. 1999. Influence of Effective Microorganisms (EM) on vegetable production and carbon mineralization – A preliminary investigation. Journal of Sustainable Agriculture 14: 15 – 25

ELANGO, F, TABORA, P and VEGA, J M. 1999. Control of black sigatoka disease using Effective Microorganisms In Proceedings of the 5th International Conference on Kyusei Nature Farming, Thailand, 1998 Senanayake, Y D A and Sangakkara U R (Ed) APNAN, Thailand: 226 – 232

FUJITA, M. 2000. Nature farming practices for apple production in Japan. In Nature farming and microbial applications. H L Xu et al (Ed) Journal of Crop Production 3: 119 – 126

GUEST, D. 1999. Bokashi (EM) as a biocontrol agent to suppress the growth of *Phytopthora cinnamomi*. In Proceedings of the 5th International Conference on Kyusei Nature Farming, Thailand, 1998 Senanayake, Y D A and Sangakkara U R (Ed) APNAN, Thailand: 216 – 218

H R H THE PRINCE OF WALES 1998. Seeds of disaster. The Ecologist 28 (5): 252 - 253

HADER, U. 2001. Influence of EM on the quality of grass/hay for milk production. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

HANEKON D, PRINSLOO, J F and SCHOONBEE, H. J. 2001. A comparison of the effect of anolyte and EM on the faecal bacterial loads in the water and on fish produced in pig cum fish integrated production units. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)\

HO IN HO and JI HWAN, K. 2000. The study on the plant growth hormones in EM – A Case study. Paper presented at the International Conference on EM Technology and Nature Farming, October 2000, Pyongyang, DPR Korea.

HUSSEIN, T, JILANI, G M, ANJUM, S and ZIA, M H. 2000. Effect of EM application on soil properties. In Proceedings of the 13th International Scientific Conference of IFOAM. Alfoeldi, T et al (Ed). FiBL, Basel, Switzerland: 267

KONOPLYA, E. F. 1999. Prospects of using Effective microorganisms (EM and EMX) in the liquidation of nuclear accident consequences. In Proceedings of the 5th International Conference on Kyusei Nature Farming, Thailand, 1998 Senanayake, Y D A and Sangakkara U R (Ed) APNAN, Thailand: 372 – 378

KONOPLYA, E F and HIGA, T. 2000. EM application in animal husbandry – Poultry farming and its action mechanisms. Paper presented at the International Conference on EM Technology and Nature Farming, October 2000, Pyongyang, DPR Korea.

KONOPLYA, E F and HIGA, T. 2001. Mechanisms of EM 1. Effect on the growth and development of plants and its application in agricultural production. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

KOZAWA, G. 2000. Dioxin bioremediation. Paper presented at the International Conference on EM Technology and Nature Farming, October 2000, Pyongyang, DPR Korea.

KREMER, R J, ERVIN, E H, WOOD, M T and ABUCHAR, D. 2001. Control of *Sclerotinia homoeocarpa* in turf grass using Effective Microorganisms. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

LITTERICK, A, BRENMAN, S and LEIFERT, C. 2001. Organic farming –Its role in the new century. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

MIYAJIMA, M, NAGANO, N and HIGA, T. 2001. Suppression of Dioxin generation in the garbage incinerator using EM (Effective Microorganisms), EMX and EM Z ceramic powder. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

OKUDA, A and HIGA, T. 1999. Purification of wastewater with Effective Microorganisms and is utilization in agriculture. In Proceedings of the 5th International Conference on Kyusei Nature Farming, Thailand, 1998 Senanayake, Y D A and Sangakkara U R (Ed) APNAN, Thailand: 246 – 253

QUANG, L K. 2000. EM Technology in Vietnam and some results on environmental treatment. Paper presented at the International Conference on EM Technology and Nature Farming, October 2000, Pyongyang, DPR Korea.

SAFALAOH, A. C. L and SMITH, G A 2001. Effective Microorganisms (EM) as an alternative to antibiotics in broiler diets: Effects on broiler performance, feed utilization and serum cholesterol. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

SANGAKKARA, U. R. and HIGA, T. 2000. Kyusei Nature Farming and EM for enhanced smallholder production in organic systems. In Proceedings of the 13th International Scientific Conference of IFOAM. Alfoeldi, T et al (Ed). FiBL, Basel, Switzerland: 268

SANGAKKARA, U R and WEERASEKERA, P. 2001. Impact of EM on nitrogen utilization efficiency in food crops. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

SHINTANI, M. 2000. Organic fertilizer – Managing banana residues with Effective Microorganisms. In Proceedings of the 13th International Scientific Conference of IFOAM. Alfoeldi, T et al (Ed). FiBL, Basel, Switzerland: 269

Tisdal, J. M. 1994. Possible role of soil microorganisms in aggregation in soils. In Management of Mycorrhizae in agriculture. Robinson, A D et al (Ed). Kluwer Press, Holland: 45 – 121

VAN BRUCHEM, J, LANTINGA, E. L, OVERVEST, J. and JOVINK, J. P. M. 1999. Environmental tuning of agriculture in the Netherlands. In Proceedings of the 5th International Conference on Kyusei Nature Farming, Thailand, 1998 Senanayake, Y D A and Sangakkara U R (Ed) APNAN, Thailand: 233 – 245

WANG, R, XU, H L and MRIDHA, M. A. U. 2000. Phytopthora resistance of organic fertilized tomato. In Nature farming and microbial applications. H L Xu et al (Ed) Journal of Crop Production 3: 77 – 84

WOOD, M T, MILES, R and TABORA, P. 1999. Plant extracts and EM5 for controlling pickleworm *Diapharina nitidalis*. In Proceedings of the 5th International Conference on Kyusei Nature Farming, Thailand, 1998 Senanayake, Y D A and Sangakkara U R (Ed) APNAN, Thailand: 207 – 215

XU, H L. 2000. Effect of microbial inoculation, organic fertilization and chemical fertilization on water stress resistance of sweet corn. In Nature farming and microbial applications. H L Xu t al (Ed) Journal of Crop Production 3: 223 – 234

XU, H L, WANG, R, MRIDHA, M. A. U., KATO S., KATASE, K and UMEMURA, H. 2001. Effect of organic fertilization and EM inoculation on leaf photosynthesis and fruit yield and quality of tomato plants. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

ZARB, J, LEIFERT, C and LITTERICK, A. 2001. Opportunities and challenges for the use of microbial inoculants in agriculture. In Proceedings of the 6th International Conference on Kyusei Nature Farming, South Africa, 1999 Senanayake, Y D A and Sangakkara U R (Ed) (In Press)

BANANAS WITH EM (EFFECTIVE MICROORGANISMS) AND COMPATIBLE TECHNOLOGIES, AND ECONOMIC CONSEQUENCIES

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ABSTRACT

Effective Microorganisms (EM) were used as a tool to develop an organic banana farming technology at EARTH University in Costa Rica, Central America. The work was designed to deal with the black sigatoka disease (*Mycosphaerella fijiensis*), the nematode *Radopholus similis,* the nutritional requirements, the green life of the bananas at post-harvest and the cost of production with the EM regimen. Excellent results were obtained in quality and productivity. Black sigatoka and nematode infestation were minimized. The costs were slightly higher, the profitability motivates an organic banana production regimen in Central America.

Keywords: bananas, nematodes, fungus diseases, post-harvest, nutrition, profitability, effective microorganisms.

INTRODUCTION

Bananas have been a major economic base for Central American, Caribbean and some South American countries for the past century and this is expected to be so in this new millenium due to some special advantages of these countries such as a favorable climate and an added advantage of proximity to the growing markets for fruits in Europe and North America. These importing countries, however are demanding more organic bananas.

The market demand has not been met by the major banana growers whose existing technologies are oriented to synthetic fertilizers and pesticides and whose response to the demand has been to leave the organic market to the small operators, and to watch for substitute technologies to apply in massive/extensive monoculture.

Extensive monoculture has serious problems with biodiversity and needs strategies to restore natural equilibrium. We therefore designed our research project to use EM as an aide to restore microbial biodiversity, coupled with compatible cultural strategies and in-situ biodiversity.

Five major specific objectives were set: (1) management of the black sigatoka fungus disease *Mycosphaerella fijiensis*, (2) management of the toppling disease of bananas, *Radopholus similis*, (3) evaluating the dosages of bokashi, the fermented organic matter, (4) determining the green life of the bananas at post-harvest, and (5) evaluating the comparative cost of the bananas under an EM regimen.

REVIEW OF LITERATURE

Black sigatoka fungus disease, *Mycosphaerella fijiensis*, has ravaged the banana plantations in Latin America since it was detected in Honduras in the 1960’s (Stover, 1974, and Gauhl, 1992) and now it is present in all of the Americas (INIBAP, 1999) and the Caribbean region. At EARTH, and in general in Central America, the cost to control it with all the chemicals, the spraying and the manpower for attending operations ascends to some $1,250 per year per hectare, or about 50% of total production costs in the field and about 20-25% of total cost of bananas ready for export (Tabora, l997).

The toppling nematode, *Radopholus similis,* is another serious problem whose direct effect is not readily quantified, but it is estimated that its combined impact on reduction of yields and in the reduction in quality can mean a loss of as much as 55% of total productivity. In a study by Luc, *et al*. (1990), yields went up by 275% when nematicides were used, a clear demonstration of the impact of nematodes. Thus, the nematodes rival the black sigatoka in magnitude of its impact, and may in some cases be the major cause for reduced profitabilities of the banana producers.

Nutritional requirements of bananas have been well studied in many places (Soto, 1992; Lopez and Espinoza, 1995), and based on nutrient extraction of 45 tons of bananas produced and their stalks, it was determined that bananas will remove 80 kg N, 9.6 kg. P and 256 kg K. per hectare per year. This extraction means a replacement of the same quantities plus an additional amount to re-enrich the soil. Thus, most recommendations in Costa Rica range from an annual per hectare applications of 350-400 kg of N, 50 kg of P and 500-600 kg of K (Soto, 1992; Lopez and Espinoza, 1995).

It has been observed that premature ripening occurs during the transit period (13-18 days to Europe) especially if bananas with heavy black sigatoka infection are packed. This premature ripening has been attributed to the black sigatoka toxin, a phytotoxin that forms distinct elongated chlorotic zones surrounding the lesions on the leaves (Molina & Krausz, 1989). This means a triggering of ethylene production that causes chlorosis in the leaves and also fast ripening of the fruits in an enclosed container. Most plants with less than 5 green leaves at harvest time are considered to be heavily infected and therefore prone to have the toxins that cause premature ripening. Since toxins are oxidants, the application of EM and EM-products on the leaves were expected to inhibit oxidation. EM has anti-oxidation substances(Higa, l997) from its fermentation.

The price of organic bananas have been 2 to 2.5 times that of the conventional bananas in the retail markets (Sauvé, l998), and this has been attributed to its high cost of production. Recently, however, the prices have been going down due to aggressive competition for the same markets. Nevertheless, the prices are still higher than conventional bananas despite these competition.

Bananas continue to be criticized for its environmental problems (Dahlerus, 1995) such as soil and biodiversity erosion in clean culture and deforestation, massive applications of nematicides herbicides and other chemicals that have caused sterility and respiratory disease problems with its workers, and also the communities nearby. There is also a problem of waste disposal of banana rejects. While this is countered by banana professionals (Mirenda, 1998), there is also a tacit acceptance of the problems. Thus, the impetus for organic banana production.

MATERIALS AND METHODS

This work was undertaken at EARTH University in Costa Rica. The university owns and operates a 300 hectare banana farm used for income generation, student practice and for research. A 1-hectare plot formerly cultivated to bananas was selected. It had been abandoned due to low yields and poor quality, with a high population of nematodes, and of which the soils were sandy. This selection was made to have all the constraints of banana production be present. The commercial banana farm was about 100 meters in distance to minimize the drift due to chemical applications. Grand Naine Cavendish was the test variety, highly susceptible to black sigatoka and nematodes.

The selected plot was in fallow for one year before it was given to the project. At the start of 1997 the vegetation (principally grasses) was farrowed under and the area was planted to corn in order to build up organic matter. The corn was harrowed under at emergence of the tassels and immediately planted to field beans, *Phaseolus vulgaris*. This was also done as a way of determining the capability of the soil. Soil analysis was done during the initial phase of land preparation. Planting was done on January 1998.

Several student graduation projects (theses) were established for this project from 1997 to 1999: The EM related practices were: (1) EM dips after hot water treatment, (3) EM sprays on the vegetation before plowing under, (3) activated EM for sigatoka control, (4) use of banana latex as EM sticker, (5) EM bokashi (fermented organic fertiliser) for nematode control, (6) EM soil sprays, (7) EM-FPE fermented repellent plant extracts sprayed on the bunch, (8) EM foliar booster sprays (bokashi tea), (9) EM-5 sprayed on the bags, (10) drip irrigation with EM, (11) alternate planting with green manure plant, *Flemingia* sp., sprayed with EM at cutting, (12) EM dips during dehanding after harvest, (13) use of EM-X in post harvest treatment to control crown rot.

There were other EM-compatible technologies incorporated such as: (1) double row planting [1 m between rows and 1.5 m on the row, and 5 meters between doble rows] to give a population of 2,222 plants per hectare, (2) use of *Moringa oleifera* and *Glericidia sepium* as partial shade cover and aerial props, (3) cover cropping with squash, *Cucurbita moschata* right after plantingto keep down the weeds, (4) keeping the weeds as source of biodiversity when plants are higher, (5) weed cutting using a weed whacker every 8 weeks, (6) removal of lower hands to have only a 5 hand-bunch, (7) early harvesting on the 10th week instead of the regular 14-15 weeks of the bunch, at caliper grade of 38-42, (8) use of a special transluscent paper bags as bunch protection, (9) installation of drip irrigation to avoid water stress during the dry periods.

Bokashi was prepared from two sources, one from the cattle manure and the other from the crushed banana rejects. The cattle droppings were collected at the stables when the cattle were fed, during mid-days for 4 hours. The stables were covered with sawdust about 2 inches in thickness and this was sprayed with EM every day. The droppings and urine were trapped and mixed with the sawdust simply by the cattle feet trampling. After 2-3 weeks these were collected and put to ferment for another week (the high temperature kills all the seeds in the droppings). The banana rejects were crushed at the packaging house and put in windrows in the shed for bokashi, sprayed with EM and later covered with sawdust on the surface. After 5 days when the mass had fermented, a windrow-mixer was passed and this was repeated for another two times within a period of 15 days. The bokashi was ready between 15-21 days.

RESULTS AND DISCUSSION

For **black sigatoka**, the total number of leaves were observed 14 weeks from emergence of the plants after planting (June 7) up to the stage of flower bud appearance on the26th week (August 24, 1998). The treatments with EM and EMFPE at 1% and 10% and their mixtures all were bundled at about the same positions, having about 8.8 leaves at flower bud appearance. This contrasted with the control (using the conventional practices and with chemicals) whose number of leaves fell down to 6.5 leaves at flower bud appearance (Moino, 1998). The above results in 1998 echo the previous results of Elango (1997) and Tabora (1996) where the total number of leaves was close to 9 leaves at bud appearance. Figure 1 presents this phenomenon.

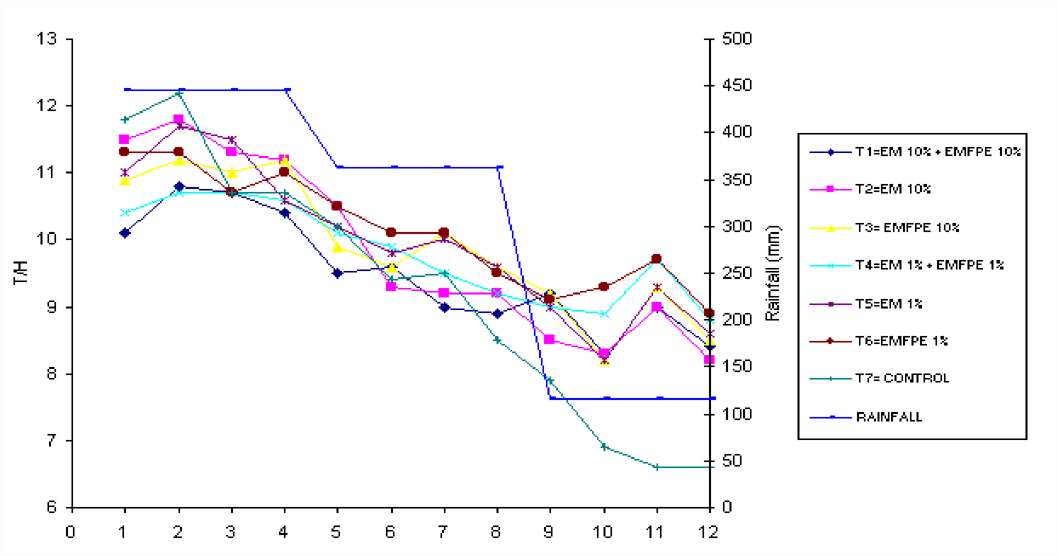


Figure 1. Total number of leaves from weeks 14 to 26 (critical period).

It is this number of leaves which allows us to determine the number of hands to retain on the bunch and to determine the quality of fruits (sizes) that would be harvestable some 10 weeks later. It was observed that upon harvest on the 10th week, the plants still had 3 green leaves intact.

There was a change in the forms coalescence of the lessions in the leaves. In the control, the lessions would coalesce and be joined to give a large dry area. In the treatments with EM the lessions would not coalesce and would present several independent spots all over the leaves. This signifies a possible effect on the growth of the black sigatoka fungus or some kind of an anti-toxin that prevented the growth and eventual coalesence of the lessions. This is presented in Figure 1 below:

In a simultaneous study in the laboratory, it was found that the ascospores in EM treated plates were deformed. One particular treatment with simple 1% EM had the least germination of ascospores (Bayro, 1998).

In **nematodes,** of the 6 treatments compared: (1) Furadan, (2) Nemout, (3) *Paecilomyces lilacinus*, (4) *P. lilacinus* + EM Bokashi, (5) EM Bokashi and (6) the control, it was the EM Bokashi and the combination P. lilacinus and EM Bokashi that had the best control (Dubón, 1998). This is seen in Figures 2, 3 and 4 below:

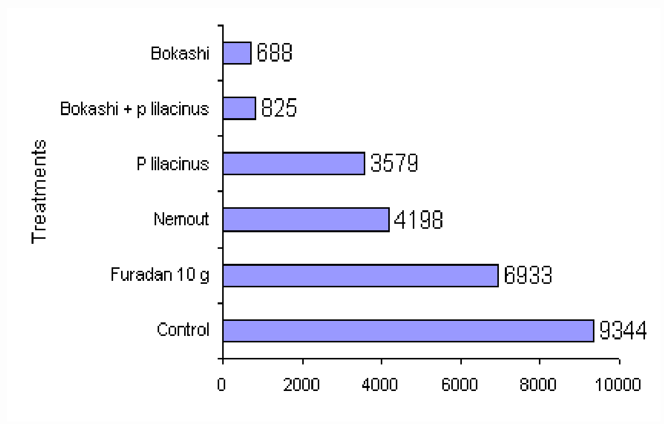
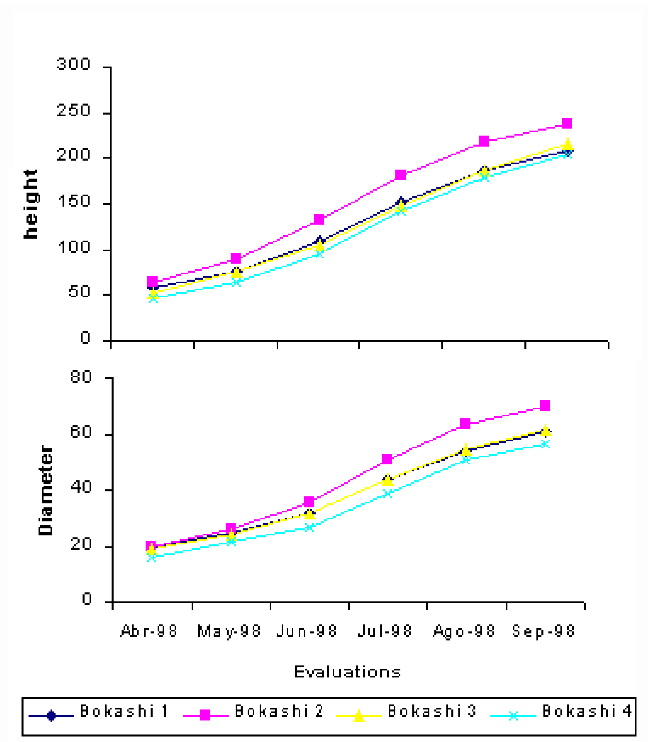


Figure 2. Averages of nematode population counts during 26 weeks of observation.

The success of just plain EM Bokashi was attributed to both biodiversity and anti-oxidation capability of the EM. When bokashi is applied on the soil, it hosts a myriad of organisms that is apparent in the mushrooms, the earthworms and the birds that follow them.

It was also noted when a windstorm occured just after the experiments that the treatments with bokashi withstood the winds and those of Furadan and the Control had the most plants blown down. This means that the organic bnana plants had very strong roots. This is explainable from the Figure 4 where the number of healthy roots of the bokashi treated plants definitely had more roots that those treated with Furadan and the control. This also means that savings can be obtained by eliminating the propping operation, now that the healthy roots themselves serve as the natural props.



In **nutrient supply** the application of 23 kg of bokashi per plant was slightly better than that with 15 kg (the recommended dosage based on requirements). The double application of 30 kg. of bokashi did not show any better result than that of the 23 kg. (Alvarado and Chaves, 1998). As expected, the half dosage of 7.5 kg. did poorly. This is seen in height and girth as in Fig. 5 and 6, below:

Figures 5 and 6. Height and girth of bananas pseudostems with the bokashi dosages.

This was also seen in the size and thickness of the leaves. Those treated with 23 kg of Bokashi had 5-18% longer and 7-20% wider leaves than those of the control. The thickness of the leaves registered was 15-25% more. On the whole, the volume of the leaves remained high. There was just as much volume of leaves as those from the conventional (chemically-treated) plants, indicating that even with only 9 leaves, these plants can support normal sized fruits and therefore the reduction in size of the bunches should not have to be that severe.

In **cost of production** the most limiting aspect was the cost of the bokashi which ended up ten times the cost of the chemical fertilizer at the time of the experiment. While this had the potential of being reduced in the future the high cost was retained to reflect the present conditions. The use of bokashi also meant that there was a reduction in nematicides, and even in the fungal disease control. Nevertheless, the costs still tended to be approximately 43%more per unit product on a cost analysis of 5 years. This is reflected in Table 1, below:

Table 1. Field costs (US$) of producing (up to cutting the bunches) of exportable bananas, based on a 5-year project from conventional and in transition to organic bananas.

Production system	Field costs	Number of boxes	Field costs/box
Conventional	22 278.70	9680	2.30
Transitional	34 193.28	10412.20	3.28

The sensitivity analysis on organic fertilizer costs indicates that major improvements in the supply of nutrients could be the key to making organic bananas a competitive enterprise to the conventional bananas (Alvarado and Chaves). At present, however, this 43% difference has been covered by the higher price of organic bananas in the market. Over time, efficiencies in production as well as in the operations should be worked out in order to bring down the prices of bananas.

The **green life of harvested bananas** from the project registered 18-23 days without any change in five successive trials, indicating that the bananas can be shipped successfully to Europe on the faster boats Bananas refrigerated at 13°C in the normal banavac bags, did not show any fungal growth.

During the harvesting of the bananas all the flesh was white and had no indication of the regular yellow flesh that indicates premature ripening. This, despite harvesting with only three green or functional leaves. During the ripening of the bananas from the stored samples after 18-23 days (afrter showing a slight change in color), the rate of ripening was the same as those of the bananas from the conventional production regimen. The ripened fruits appeared to be very similar between the organic and the conventional bananas.

In the field,, the bananas which were kept standing and had no more leaves, still remained green up to 18-20 weeks of age of the bunch. This is quite unusual because premature ripening under conventional banana production regimen usually occurs even before harvesting, on the 14-15 weeks of age of the bunch, or about the time of harvesting of the conventional bananas. The color of the flesh of the organic banana fruits were monitored during harvest and all were very white, without any discoloration indicating that there was no premature ripening.

The absence of premature ripening is an indication that the black sigatoka toxin had not proliferated and had not been transported to the fruits. This is an important development and could have been an effect of anti-oxidation of the EM.

CONCLUSIONS

This study on organic bananas shows that it is in organic fertilizers where is a serious limitation, not only because of its elevated quantity and the resulting high cost of production, but also because it has impacts on nutrition, nematodes, pre-mature ripening, quality of the fruit and even the black sigatoka.

It is also revealed that the serious problems of black sigatoka, nematodes and premature ripening at post-harvest can be readily overcome with the technologies with the use of EM. These indications have far-reaching impacts and therefore worth pursuing in-depth in order to assure a more perfect technology.

RECOMMENDATIONS

Production of organic bananas with EM is now feasible and should be pursued. There are still many refinements to make and these should be done as production goes along. Hand-in-hand with modest production, experience should be built based on the properties of anti-oxidation, increased volume of the leaves and in the stronger roots.

REFERENCES

ALVARADO LINARES, E. AND R. CHAVES. 1998. Evaluación económica y de desarrollo de una plantación en transición de producción de banano tradicional a banano orgánico bajo condiciones del trópico húmedo de Costa Rica. Graduation Project, EARTH University, Costa Rica. Unpublished.

BAYRO BOTELHO, A. M. 1998. Control biológico de sigatoka negra del banano en Invernadero mediante el uso de EM (Microorganismos Eficaces) Graduation Project, EARTH University, C. R. Unpub.

LEON MELGAR, L. A. 1998. Efecto de la aplicación de materia orgánica en la recuperación de suelos degradados por el cultivo intensivo del banano *(Musa* AAA). Graduation Project, EARTH University, Costa Rica. Unpublished.

DUBÓN GARCIA, H. R. 1998. Control biológico del nemátodo del volcamiento (*Radopholus similis*) en el cultivo del banano (*Musa* AAA). Graduation Project, EARTH University, Costa Rica. Unpub.
Dahlerus, A. 1995. Bananer. Glimtar fran bananproductionen.Natursskyddforeningen. Stockholm, Sweden.

ELANGO, F. 1999. Integrated management of black sigatoka (*Mycospherella fijiensis*) and the nematode toppling disease of plantains (*Radopholus similis*) in organic production systems. 6th Intrernational Conference on Kyusei Nature Farming. Pretoria, South Africa.

ELANGO, F., P TABORA, M. SHINTANI, C. UFER and J. VEGA. 1997. Control of black sigatoka disease (*Mycosphaerella fijiensis*) using EM (Effective Microorganisms). Proceedings of the Fifth

HIGA, T. 1995. Effective Micxroorganisms- A Holistic Technology for Humankind. Proceedings the Fifth International Conference on Kyusei Nature Farming. Bangkok, Thailand.

LOPEZ, A. and J. ESPINOZA. 1995. Manual de nutrición y fertilización del banano. Instituto de la Potasa y el Fósforo. Quito Ecuador.

LUC, M., R. SIKORA, and J. BRIDGE. 1990. Plant Parasitic Nematodes in Sub.Tropical and Tropical Agriculture. C. A. B.. 629 pp.

MIRANDA, J. 1998. Bananos y el ambiente. CORBANA, Corporación Bananera Nacional. San Jose, C. R.

MOINO, H. E. 1998. Control biológico de sigatoka negra en banano (*Musa* AAA) mediante el uso de EM (Microorganismos Eficaces). Graduation Project. EARTH University, C. R. . Unpublished.

MOLINA, G and J KRAUSZ. 1989. A phytotoxic activity in extracts of broth cultures of *M.fijiensis* v.difformis and its use to evaluate host resistance to black sigatoka. Plant Diseases: 73 (2). P. 142.

SOTO, M., E. Soto, P. Solis, and A. Lopez., in Soto M. (editor). 1992. Bananos, Cultivo y Comercialización. 2nd Edition. Litografia LIL, San Jose Costa Rica. Pp. 282-286.

ZAPATA, P., R. RODRIGUEZ, T. CUESTA, C. ARMIJOS, D. Abuchar and P. Tabora. 1998. Factibilidad en la producción orgánica de banano Gros Michel bajo sistemas de pequeños agricultores Memorias del taller internacional. EARTH, Julio1998.

EM APPLICATION MANUAL FOR APNAN COUNTRIES

http://www.agriton.nl/apnanman.html

The First Edition. 1995.

APNAN
ASIA-PACIFIC NATURAL AGRICULTURE NETWORK

CONTENTS

KYUSEI NATURE FARMING
WITH EFFECTIVE MICROORGANISMS
(EM TECHNOLOGY)

1.0 INTRODUCTION

Kyusei Nature Farming was developed in Japan with the objective of producing food that is safe and free of harmful chemicals and toxic materials. For many years the practitioners of Kyusei Nature Farming adopted the organic farming system, with little results to provide adequate food for the majority of the population.

In the 1980's, Prof. Dr. Teruo Higa introduced the concept of Effective Microorganisms(EM) to Kyusei Nature Farming. Thus, a group of beneficial microorganisms were cultured and used as a means of improving soil conditions, suppressing disease inducing microbes and improving the efficiency of organic matter utilization by crops. This technology proved to be highly successful, and thus an international conference was organized in November 1989 in Thailand to introduce this technology to the Asia Pacific region. At this conference, the Asia Pacific Natural Agriculture Network (APNAN) was formed.

The primary aim of APNAN is to establish an international network of scientists in the Asia Pacific region, in order to promote research, education practices and technologies.

These activities will be based on the principles of Kyusei Nature Farming and the technology of Effective Microorganisms (EM)

1.1 IDEAL AGRICULTURE

The main theme of Kyusei Nature Farming is to practice an IDEAL AGRICULTURE. The five principles of ideal agriculture as advocated by Kyusei Nature Farming are:

1. It produces safe and nutritious food to enhance human health.
2. It is economically and spiritually beneficial to both producers(farmers) and consumers.
3. It is sustainable and easily practiced by everyone.
4. It conserves our environment.
5. It produces sufficient food of high quality for an expanding world population.

1.2 USE OF BENEFICIAL MICROORGANISMS IN AGRICULTURE

Agricultural production begins with the process of photosynthesis by green plants, which requires solar energy, water, and carbon dioxide. These materials are freely available. Therefore, it can be defined that "Agriculture is to produce something from nothing". Althought it sounds good, when observed as an economic activity, present agriculture has an extremely low efficiency. This is due to the very low utilization efficiency of solar energy by plants

The potential utilization rate of solar energy by plants has been estimated theoretically to be between 10 and 20%. However, the actual utilization rate is less than 1%. Even the utilization rate of C4 plants, such as sugar cane which have a high photosynthetic efficiency, barely exceeds 6 or 7% during the maximum growth period. The utilization rate is normally less than 3% even for producing optimum crop yields.

Past studies have shown that photosynthetic efficiency of the chloroplasts of host crop can not be enhanced much further. This means that their biomass production capacity has reached a maximum. Therefore, the best opportunity for increasing biomass production is to utilize the visible light, which chloroplasts can not presently use, and the infrared radiation. These together account for about 80% of the total solar energy. We should also explore ways of recycling organic energy contained in plant and animal residues through direct utilization of organic molecules by plants.

In the presence of organic matter, photosynthetic bacteria and algae can utilize wavelengths ranging from 700 to 1200 nm. Green plants do not use these wavelengths. Fermenting microorganisms can also breakdown organic matter, thereby releasing complex compounds such as amino acids for plant use. This increases the efficiency of organic matter for crop production Thus a key factor for increasing crop production is the availability of organic matter, which has been developed by utilizing solar energy and the presence of efficient microbes to decompose these materials. This increases the utilization efficiency of solar energy.

2.0 EFFECTIVE MICROORGANISMS (EM)

Effective Microorganisms or EM is a mixed culture of beneficial microorganisms (primarily photosynthetic and lactic acid bacteria, yeast, actinomycetes, fermenting fungi) that can be applied as an inoculant to increase the microbial diversity of soils. This in turn, can improve soil quality and health, which enhances the growth, yield, and quality of crops.

The concept of inoculating soils and plants with beneficial microorganisms to create a more favorable microbiological environment for plant growth has been discussed for decades by agricultural scientists. However, the technology behind the concept of Effective Microorganisms and it's practical application was developed by Professor Teruo Higa at the University of the Ryukyus in Okinawa, Japan.

Professor Higa has devoted much of his scientific career to isolating and selecting different microorganisms for developing beneficial effects on soils and plants. He has found microorganisms that can coexist in mixed cultures and are physiologically compatible with one another. When these cultures are introduced into the natural environment, their individual beneficial effects are greatly magnified in a synergistic fashion.

EM cultures do not contain any genetically modified microorganisms. EM is made up of mixed cultures of microbial species that are found in natural environments worldwide.

2.1 EFFECTS OF EM

The following are some of the beneficial influences of EM.

(a) Promotes germination, flowering, fruiting and ripening in plants.
(b) Improves physical, chemical and biological environments of the soil and suppresses soil borne pathogens and pests.
(c) Enhances the photosynthetic capacity of crops.
(d) Ensures better germination and plant establishment
(e) Increases the efficacy of organic matter as fertilizers.

Due to the above stated beneficial effects of EM, yields and quality of crops are enhanced.

* EM is not a pesticide and thus does not contain chemicals that could be construed as such. EM is a microbial inoculant that functions as a biological control measure in suppressing and/or controlling pests through the introduction of beneficial microorganisms to the plant environment. Therefore, pests and pathogens are suppressed or controlled through natural processes by increasing the competitive and antagonistic activities of the microorganisms in EM inoculants.

2.2 PRINCIPAL MICROORGANISMS IN EM AND THEIR ACTION IN SOIL.

(1) Photosynthetic bacteria (Phototrophic bacteria)

Photosynthetic bacteria are independent self supporting microorganisms. These bacteria synthesize useful substances from secretions of roots, organic matter and/or harmful gases (e.g. hydrogen sulfide) by using sunlight and the heat of soil as sources of energy. The useful substances comprise of amino acids, nucleic acids, bioactive substances and sugars, all of which promote plant growth and development.

These metabolites are absorbed into plants directly and also act as substrates for increasing bacteria. Thus increasing Photosynthetic bacteria in the soil enhances other effective microorganisms. For example, VA (vesicular-arbuscular) mycorrhiza in the rhizosphere are 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 nitrogenfixing bacteria and enhance nitrogen fixing ability of legumes.

(2) Lactic acid bacteria

Lactic acid bacteria produces lactic acid from sugars, and other carbohydrates produced by Photosynthetic bacteria and Yeast. Thus, food and drinks such as yogurt and pickles have been made by using Lactic acid bacteria for a long period of time. 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 ferments these materials without causing harmful influences caused by undecomposed organic matter.

Lactic acid bacteria has the ability to suppress Fusarium propagation which is a harmful microorganism causing disease problems in continuous cropping. Generally, increased Fusarium populations weakens plants. This condition promotes diseases and also results in the sudden increase of harmful nematodes. The occurrence of nematodes disappear gradually, as Lactic acid bacteria suppresses the propagation and function of Fusarium.

(3) Yeasts

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.

(4) Actinomycetes

Actinomycetes, 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.

(5) Fermenting Fungi

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.

Each species of Effective Microorganisms (photosynthetic bacteria, lactic acid bacteria, yeasts, actinomycetes and fermenting fungi) has its own important function. However, photosynthetic bacteria is the pivot of EM activity.

Photosynthetic bacteria support the activities of other microorganisms. On the other hand, photosynthetic bacteria also utilizes substances produced by other microorganisms. This phenomenon is termed "coexistence and co-prosperity".

When Effective Microorganisms increase as a community in soils, populations of native effective microorganisms are also enhanced. Thus, the micro flora becomes rich and microbial ecosystems in the soil become well-balanced, where specific microorganisms (especially harmful microorganisms) do not increase. Thus, soil borne diseases are suppressed.

Plant roots secrete substances such as carbohydrates, amino and organic acids and active enzymes. Effective microorganisms use these secretions for growth. During this process, they also secrete and provide amino and nucleic acids, a variety of vitamins and hormones to plants. Furthermore, in such soils, effective microorganisms in the rooting zone(rhizosphere) co-exist (symbiosis) with plants. Hence, plants grow exceptionally well in such soils which are dominated by effective microorganisms.

The following chart shows the fuctions of Effective Microorgansims in the soil.

The following chart shows the functions of Effective Microorganisms in the soil.

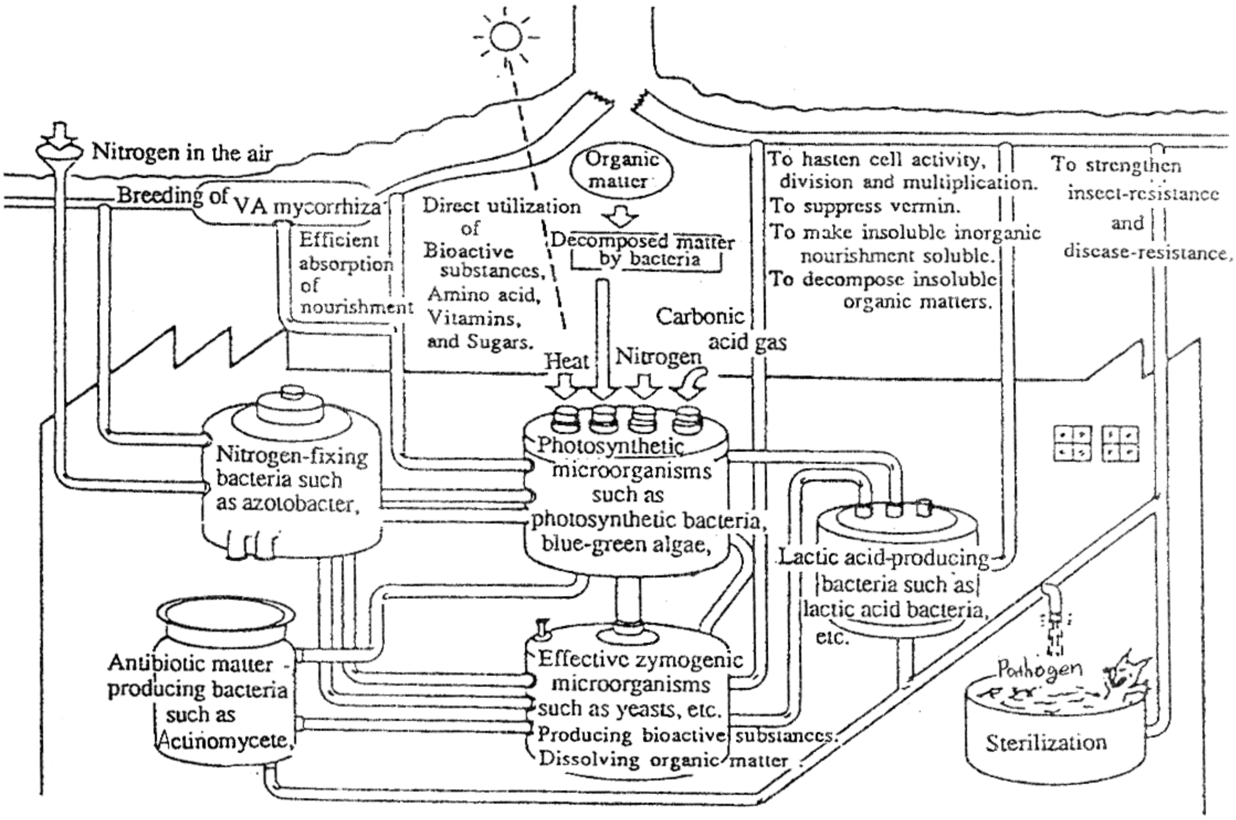


Figure 1: "Microorganisms for Agriculture and Environmental Preservation", Teruo Higa (1991) Nou-bun Kyo.(in Japanese)

Figure 1: "Microorganisms for Agriculture and Environmental Preservation", Teruo Higa (1991)Nou-bun Kyo. (in Japanese)

3.0 APPLICATION OF EM1

Basically, EM can be applied in four ways, namely as EM1 stock solution, EM5 solution, EM Bokashi and as EM fermented plant extract.

3.1 EM1 Stock Solution

EM1 stock solution can be applied by:

1) Watering into the soil (by watering cans, sprinklers or irrigation systems)
2) Spray onto plants (foliar spray) by sprayer or watering can

3.2 EM BOKASHI (EM fermented organic matters)

"Bokashi" is a Japanese word which means "Fermented organic matter". It is made by fermenting organic matter (rice bran, oil cake, fish meal etc.) with EM. Bokashi is normally found as a powder or as granules. Bokashi has been used by Japanese farmers as traditional soil amendments to increase the microbial diversity of soils and supply nutrients to crops. Traditionally Bokashi has been made by fermenting organic matter such as rice bran by soil from forests or mountains, which contain various microorganisms.

However, EM Bokashi is fermented organic matter using EM instead of forest or mountain soil. Thus, EM Bokashi is an important additive to increase effective microorganisms in the soil. (Details on the preparation of EM Bokashi is discussed later.)

3.3 EM5 (EM fermented solutions)

EM5 is a fermented mixture of vinegar, spirits(alcohol), molasses and EM 1.

It is used to spray the plant to suppress pathogens and keep away insect pests. (Details of EM5 preparation is discussed later.)

3.4 EM Fermented Plant Extract (EM-F.P.E.)

EM fermented plant extract is a mixture of fresh weeds fermented with molasses and EM 1. The main effect of this extract is to supply quality nutrients to crops, and also to suppress pathogens and keep away insects.

4.0 EM1 STOCK SOLUTION

Original EM 1 is yellow-brown liquid with a pleasant odor and sweet-sour taste. The pH of EM 1 should be below 3.5.

If it has a bad smell or foul odor or pH is more than 4.0, the EM1 has deteriorated. It should not be used.

4.1 USE OF EM1 STOCK SOLUTION.

Original EM1 is dormant. Thus EM1 needs to be activated by the provision of 'water' and 'food'. This is done by adding water and molasses. (Use EM diluted solution (0.1%) to apply to crops.)

1. 1 litre (1000 cc) of water
2. 1 cc of EM1
3. 1 cc of Molasses or 1g of any sugars

This solution is left for 2-24 hours and sprayed to plants, soil or organic matter.

5.0 BOKASHI

Bokashi is equivalent to compost, but it is prepared by fermenting organic matter with EM. It can be used 3 - 14 days after treatment (fermentation). Bokashi can be used for crop production even though the organic matter has not decomposed as in compost.

When bokashi is applied to soil, organic matter can be utilized as a feed for effective microorganisms to breed in the soil, as well as supplying nourishment to crops.

5.1 Aerobic Bokashi and Anaerobic Bokashi

Bokashi is classified as "Aerobic bokashi" and "Anaerobic bokashi" based on the manufacturing process. The advantages and disadvantages of aerobic and anaerobic bokashi are as follows:

Aerobic type
Advantage: Can be produced on a large scale. Fermentation period is shorter than in the anaerobic type.
Disadvantage: Energy of organic matter is lost, if temperatures during fermentation is uncontrolled.

Anaerobic type
Advantage: Maintains energy(nutrition) of organic matter. This condition is similar to silage.
Disadvantage: Mismanagement causes spoilage.

In Japan, the anaerobic type is popular, but in Thailand the aerobic type is widely used.

5.2 Materials of Bokashi.

EM can utilize any type of organic matter. For example, the following can be used as organic matter in preparing Bokashi

Rice bran, corn bran, wheatbran, maize flour, rice husk, bean husk, rice straw, oil cake cotton seed cake, pressmud, bagasse,chopped weeds, sawdust. coconut fiber and husks.

crop residues such as empty fruit bunches in oil palm, fish meal. bone meal. dung of any animals, kitchen garbage, sea weed. crab shells and similar material.

However, rice bran is recommended as an important ingredient of Bokashi, as it contains excellent nutrients for microorganisms. It is desirable to combine organic matter which have low and high C/N ratios. Generally the use of at least three types of organic matter is recommended in order to increase microbial diversity.

Adding wood or rice husk charcoal, zeolite, kelp, grass and wood ash to Bokashi is desirable. These porous materials improve soil physical conditions and nutrient holding capacity. They also act as harbouring points for effective microorganisms.

5.3 Preparing Bokashi

There are many type of Bokashi, depending on the organic matter used. The preparation of a typical Bokashi is as follows:

Materials:

(In Japan)		(In Thailand)
1. Rice bran	100 litres (volume)	Rice bran
2. Oil cake	25 litres	Rice husk
3. Fish meal	25 litres	Chicken dung
4. EM1	150 cc	
5. Molasses #1	150 cc	
6. Water #2	15 litres	

#1 If you do not have molasses, any kind of sugar can be used. Some materials that can be used are raw cane sugar, juice of any fruits and waste water of alcohol industries.

#2 The quantity of water is a guideline. The quantum of water that needs to be added will depend on the moisture content of the materials used. The ideal quantum of water is that required to moisten the material, without drainage.

Preparation

Anaerobic-type

1. Mix rice bran, oil cake and fish meal well.
2. Dissolve molasses in the water(1 :100). It is easily dissolved in warm water.
3. Add EM into the above prepared molasses solution
4. Pour the EM mixture onto the organic matter and mix well. Please pour the EM dilution gradually and mix well while checking the moisture content. There should be no drainage of excess water. The moisture content should be about 30-40%. You can check it by squeezing a handful. Once squeezed, it should remain as a single unit without crumbling. However, on touching it should crumble easily.

5. Put the mixture thus made into a bag that does not permit air movement (e.g. paper or polyethylene bag). This is placed within another polyethylene bag (black vinyl) to prevent movement of air. Close the bag tightly to maintain an anaerobic condition. This is placed away from direct sunlight.
6. The fermenting period is:
   In the temperate zone:

   In summer more than 3-4 days.
   In winter more than 7-8 days.

   In winter, put the container in a warm location to hasten fermentation.
   In the tropics: more than 3-4 days.

   The Bokashi is ready for use when it gives a sweet fermented smell. If it produces a sour and rotten smell, it is a failure.

7. Anaerobic Bokashi should be used soon after preparation.
   If storage is required, spread it on a concrete floor, dry well in the shade and then put into vinyl bag.
   Please prevent rodent or other pest attacks.

<u>Aerobic-type</u>

1. Mix rice bran, oil cake and fish meal well.
2. Dissolve molasses in the water(1 :100). It is easily dissolved in warm water.
3. Add EM into the above prepared molasses solution
4. Pour the EM mixture onto the organic matter and mix well. Please pour the EM dilution gradually and mix well while checking the moisture content. There should be no drainage of excess water. The moisture content should be about 30-40%. You can check it by squeezing a handful. Once squeezed, it should remain as a single unit without crumbling. However, on touching it should crumble easily.
5. Put the mixture made above on a concrete floor, and cover with gunny bag, straw mat or similar material. Avoid exposure of this material to rain.
6. Under aerobic conditions, bokashi ferments rapidly. Thus the temperature increases. Ideally, the temperature should be kept around 35-45 °C. Thus, please check temperature regularly using a normal thermometer. If the temperature rises beyond 50 °C, mix the Bokashi well to aerate it.
7. The fermenting period is:
   In the temperate zone:

   In summer more than 3-4 days.
   In winter more than 7-8 days.

   In the tropics: more than 2-4 days. It is ready for use when it gives a sweet fermented smell and white mold is observed. If it has a sour and rotten smell, it is failure.

8. This Bokashi is best used soon after preparation. If storage is required, spread it on a concrete floor, dry well in the shade and then put into vinyl bag. Please prevent rodent or other pest attacks.

The efficacy of Bokashi made at temperatures above 50 °C is 50% lower than that made at a lower temperature. This is due to the loss of heat energy at high temperatures.

*Please practice preparing bokashi several times. The key of preparing good bokashi is to know suitable moisture content and temperature of bokashi through practice.

It is recommended that you join the EM technology workshop to learn the process.

5.4 Using Bokashi

In general, apply Bokashi 200g per 1 square meter on the top soil, when enough organic matters has been applied.

You can apply more (maximum 1 kg per 1 square meter), when soil is poor or has little organic matter.

6.0 EM5 (Also known in Japan as Sutochu)

EM5 is a non-chemical insect repellent and is non toxic . EM5 is used to prevent disease and pest problems in crop plants. It is usually sprayed onto plants at a dilution of 1/500 - 1/1000 in water. It is mainly used to repel insects by creating a sort of barrier. EM5 could also control insect populations. EM5 carried by insects to places of food storage could "contaminate" the stored food. The process of fermentation that takes place in the food due to EM5 makes it non-edible to insects, thereby diminishing populations.

In making EM5, ingredients may vary. A standard set of ingredients is listed below. However, to make effective EM5 for more persistent pests, more organic materials should be added (organic materials that has a high quantum of antioxidants such as garlic, hot peppers, aloe, neem leaf, pruned green fruits, and grass) which are considered to be of medicinal value. When using such materials, they should be chopped or mashed in a mixer. Some or all of the materials may be used in making EM5.

6.1 Making EM5

The following is a standard set of ingredients for making EM5

Ingredients(Standard).

1. Water #1	600 cc
2. Molasses	100 cc
3. Vinegar #2	100 cc
4. Distilled spirit (30-50 %) #3	100 cc
5. EM1	100 cc

#1 Well water preferred since tap water is chlorinated.
#2: Natural vinegar is better than artificial acids
#3: Whiskey or Ethyl alcohol could be used.

Items needed in making of EM5
A large pot may be used to initially blend all of the ingredients. Plastic containers are required to store the EM5 along with a funnel to pour the EM into the containers.

Preparation

1. Blend the molasses with water, make certain that it has been completely dissolved. You may use warm water for quick dilution of molasses.
2. Add vinegar and distilled spirit, followed by EM1.
3. Pour the mixed solution into a plastic container which can be shut tightly (A glass container should not be used). Remove excess air in container to maintain anaerobic conditions.
4. Store the bottle in a warm place (20-35 °C), away from direct sunlight.
5. When container is expanded by the fermented gas, loosen the cap of the container to release gas. Shut it tightly again.

The EM5 is ready for use when the production of gas has subsided. The EM5 should have a sweet smell (Ester/alcohol).

Storage:

EM5 should be stored in a dark cool place, which has a uniform temperature. Do not store in the refrigerator or in direct sunlight. EM5 should be used within three months after preparation.

<u>6.2 Using EM5</u>

- Spray EM5 diluted in water 1/500-1/1000 to wet the crop.
- Start spraying after germination, before pests and diseases appear.
- Spray in the morning or after heavy rains.
- Apply EM5 regularly.

Since EM5 is not a pesticide, germicide or a harmful chemical, the application method is different from other agrochemicals. Chemicals are used to solve a problem forcefully and quickly and are applied at specific intervals. EM5, on the other hand, should be applied from the time of planting before the development of any disease or pests. If this is not done and diseases or pests appear, EM5 should be sprayed daily until the problem disappears.

Application can be done once - twice a week with a direct spray onto the plants. Direct spraying on harmful insects should reduce populations leading to eventual disappearance. A thorough spraying to the plant ensures good results. Continuous or regular sprayings ensure that harmful insects which may have escaped or are recent additions will be affected by the EM5.

EM5 works over time. Thus regular applications brings out the best results.

Although chemical applications may give rapid results, it may be harmful to plants and soil. The long term effects may be disastrous not only to the environment but also to the farmer's economic condition and health. EM5 has no adverse effect even with excessive applications. In contrast, EM5 may enhance the plant's strength through the absorption of EM and therefore increase the level of antioxidation (that is, the ability to suppress disease, pest infestation, and overcome any debilitating factors.). Although EM5 may take time to create the best condition depending on soil and type of crops grown, it will benefit the environment, the soil, the plant cultivated, and the economic status of the farmer.

The upliftment of the economic status occurs as EM5 can be made easily and cheaply. Over the long term, less EM5 (costs for the material to make EM5) is needed since the soil conditions change. This ensures a healthy and strong crop to protect itself from disease and pests. The post-harvest crop residues incorporated back to soil as a pre-treatment before the next season is recommended and, additionally, the use of EM5 would help in the suppression of diseases and pests that would be recycled back into the next crop. EM5 contains EM l - therefore it contributes to the beneficial effects that EM 1 increasing yield and quality of the crop. Thus, less expense is incurred on fertilizers and no cost would be expended on agricultural chemicals.

7.0 EM FERMENTED PLANT EXTRACT (EM-F.P.E.)

EM fermented plant extract is prepared by using fresh weeds and EM1.

EM-F.P.E. includes organic acids, bioactive substances, minerals and other useful substances from weeds. The production cost of EM-F.P.E.. is very low, because of the use of weeds.

7.1 Preparation of EM Fermented Plant Extract

The following is a standard set of ingredients for making EM-F.P.E.

Ingredients (for 20 litres bucket or drum)

1.Chopped fresh weeds#1	14 litres
2. Water #2	14 litres
3. Molasses #3	420 cc
4. EM1 #4	420 cc

#1 Use weeds, which have strong life such as mugwort, artemisia, clover and grass which are considered to be of medicinal value. Pruned green fruits and young shoots could be incorporated. The use of various types of weeds is recommended in order to increase bio-active substances and microbial diversity. The weeds should be cut in the morning.

#2 Well water is preferred since tap water is chlorinated. Adding a little amount of seawater (0.1%) is useful to supply minerals to crops.

#3 3% of water.

#4 3% of water.

Items needed in making of EM-F.P.E.
Large plastic bucket or drum, weight to press chopped weed, black vinyl bag, and wooden lid.

Preparation

1. Cut weeds and chop well (2-5cm).
2. Put chopped weeds into bucket.
3. Mix EM1 and molasses into water and pour the solution into bucket.
4. Cover the top of bucket with black vinyl bag.
5. Put lid on the vinyl, and then put weight on the lid. At the time, take care not to leave air in the bucket.
6. Store the bucket in a warm place (20 – 35 °C), away from direct sunlight.
7. Fermentation begins and gas is generated within 25 days. (depending on temperature).
8. Stir the weeds in the bucket regularly to release the gas.
9. The EM-F.P.E . is ready for use when pH of the solution is below 3.5. Put EM-F.P.E. into plastic bottle after removing the weeds by filtration (use gauze or cloth).

Storage:

EM-F.P.E. should be stored in a dark cool place, which has a uniform temperature. Do not store in the refrigerator or in direct sunlight. EM-F.P.E. should be used within one month after preparation.

<u>7.2 Using EM-F.P.E.</u>

- Watering into the soil (1:1000) by watering cans, sprinkler or irrigation system.
- Spray EM-F.P.E. diluted solution (1:500-1:1000) to wet the crop.
- Start spraying after germination, before pests and diseases appear.
- Spray in the morning or after heavy rains.
- Apply EM-F.P.E. regularly.
- The combination of EM-F.P.E. and EM5 is more effective.

8.0 EM1 IN CROP PRODUCTION

<u>8.1 RICE</u>

[Autumn treatment in temperate zones.]
(<u>After harvest in the tropics</u>)

After harvest, add all crop residues (rice straw and rice husk) to the field, and apply 30-150kg/ 10a of Bokashi and 500 - 5000L/10a of EM diluted solution (1 :1000) (1-10L/l0a of EM stock solution).

[Raising of seedling]

To hasten germination and prevent diseases, soak rice seeds into EM diluted solution (1:1000) until seeds are enlarged. It is preferable to change the solution daily. During raising of seedling, apply EM with water(1:1000) total 4-5 times. To prevent pest and disease, spray EM5(1:500) to seedlings several times.

[Spring treatment - for temperate zones.]

At plowing, apply 30-150kg/ba of Bokashi and 50 - 5000L/10a of EM diluted solution(1 :1000) (1 - 10 L/ 10a of EM stock solution).

[Before and after planting rice seedling]

At puddling, apply 1-10L/ 10a of EM. High concentration (1:50-1:100) can be acceptable, because the rice field is flooded.
10-15 days after transplanting, apply 500-1000L/10a of EM diluted solution(1:1000)(1-2L/10a of EM stock solution), before intercultivation and weeding.

[Growing period]

While observing growth, apply Bokashi(30-50 kg/ 10a) as supplementary fertilizer. Spray 500-5000L/ 10a of EM diluted solution(1:1000) (1-10L/10a of EM stock solution) every 1 or 2 month. Also spray EM5(1 :500) regularly.
A total of 3 - 6 applications of EM and EM5 is required up to harvest.

Weeding in Rice fields (without herbicides)

<u>1. The principle of suppressing weeds by EM</u>

Microorganisms (particularly lactic acid bacteria) in EM produces organic acids such as lactic acid and other bioactive substances when applied with organic mater to the soil. These organic acids and bioactive substances break the dormancy of seeds. They also act on perennial weeds like a rotary cultivator, and obstructs callus formation, which results in fermented decomposition of the tubers and roots. By this action weeds are sprouted by force after tilling in autumn or rough puddling. These weeds just sprouted can be suppressed at the final puddling, in order to cut down the number of weeding after planting.

Lactic acid bacteria begins activity at a ground temperature above 5 °C. The higher the ground temperature, the more vigorous the action. Weeds start sprouting at 10 – 15 °C. Their action becomes more vigorous with raised temperatures. A temperature greater than 18 °C is required to hasten germination. Therefore conditions are controlled to ensure that lactic acid bacteria works until the temperature rises.

2. EM treatment in autumn

Spray 1-10L/ 10a of EM stock solution after harvest. This treatment should be carried out as soon as possible after harvesting rice plants in order to have a higher ground temperature (over 18°C) for a longer time. Weeds which sprout in the year can not survive the coming winter, and they die. For a rice field that could be flooded in winter, a state of flooding gives a greater effect.

3. EM treatment in spring

Spray 1-1 0L/ 10a of EM stock solution with molasses at rough puddling(depth of 15-20cm). Let water into the field as soon as possible when the ground temperature is around 10 °C, and puddle roughly. Keep water from leaking to increase both the ground and water temperature. Then flood shallowly, and keep the ground temperature >15 °C for more than 20 days. A longer flooded period and higher ground temperature hastens germination of weeds. After confirming the emergence of main weeds, do the second puddling(final puddling). This time, puddle the outer side (around 5 cm deeps) to dig up both weeds just sprouted and seeds. Let water into newly puddled field and wash them out. To avoid pushing them out to the lower rice fields, pick them up at the water outlet by using cheese cloth or some nets.

The sprouting condition depends on species of weeds. It is important to know the characteristic of the weeds germinating in your rice field.

8.2 UPLAND FIELD CROPS

[Preparation of soil]

1-2 months before seeding or transplanting, apply 30-200kg/ 10a of Bokashi and EM diluted solution (1 :1000) (1-10L/10a of EM stock solution) and plow the field (In the tropics, bokashi can be applied 2-3 weeks before seeding). After plowing, mulch field with rice straw, hay or a vinyl sheet. The mulching is effective to keep soil moisture (i.e. help EM to increase), arid to control weeds.

[Raising of seedling]

Prepare a good soil for raising seedling with Soil Bokashi. (*See Page 27)
Soak seeds (such as seed potatoes) in an EM diluted solution (1 :1000) for approximately 30 minutes to coat seed with EM. This inoculates seed with EM.
After seeding, water with EM (1:1000-2000). Then spray EM5 (1:1000) to prevent pests and diseases 1-2 times a week. For seedlings purchased (pot seedlings), transplant after sprinkling a EM diluted solution (1:1000) 2-3 times instead of flooding.

[Before and after transplanting (seeding)]

At 3-7 days before planting (seeding), apply an EM diluted solution (1:1000) (1-10L/10a of EM stock solution). After transplanting, until roots develop, apply an EM diluted solution (1:1000 - 1:5000) until the field is flooded. The volume of EM stock solution you can use this time is not fixed. Dilute it appropriately according to the volume of water required for flooding.

*Bokashi should be applied at least 7-15 days before seeding or transplanting. Too much Bokashi might cause problems.

[Growing period]

Depending on the crop, apply an EM diluted solution (1:1000) (EM stock solution 1-10L/10a/one time) every 1 week for 1 month.
Increased applications will not cause any problem, but will be more effective. If it is expensive, effectual measures should be recommended.
At the beginning of the growth period, increase the number of times of application by shortening spray intervals. If the growth is favorable, apply at longer intervals.

For prevention of pests, EM5 should be sprayed on the leaves regularly at 7 - 14 days intervals. Addition of molasses or juice of Aloe(0.1%) as sticker into EM5 increases effectiveness. Please do not spray EM5 at a dilution less than 1: 500.
Apply Bokashi as additional manure, while observing crop growth. Do not apply too much Bokashi at a time. Pay attention not to put Bokashi over the crops directly, apply Bokashi around the crops.

Never use EM4 and 5 solutions diluted less than 1:500. Concentrated solution could cause a physiological problem or yellow spots on the leaves, especially in dry seasons, because of the pH of EM.

[Together agricultural chemicals] (We do not recommend to use these chemicals)

Agricultural chemicals, especially fungicides (soil disinfectant) reduce the effect of EM by half. After applying these chemicals, try to spray EM5 days later.

[Harvest]

Harvest only necessary parts, and return all crop residue to the soil. Damaged and diseased plants could also be added into the soil. EM is applied as a diluted solution(1 :1000) with Bokashi. Mulch with rice straw or other material.
Seeding or transplanting could be carried out 14 days - 1 month after this treatment.

In case of non-tillage culture, start seeding or transplanting between crops before harvest.

8.3 ORCHARD CROPS

[Raising of seedling]

It is very important to select suitable species for the environmental condition and management regimes of your orchard. It is also important to raise high quality and healthy seedlings using EM, as it costs to replant fruit trees.

[Before and after planting]

Make the planting hole and put Bokashi and organic matter.
After planting, mulch with rice straw or fallen leaf and water with EM (1:1000).

[Growth period]

Apply EM diluted solution (1:1000) (1-10L/10a of EM stock solution) and Bokashi (200g - 500g/a square meter) regularly.
Spray EM5 (1:500-1:1000) regularly to prevent pests and diseases.

[After harvest]

Apply EM diluted solution (1:1000) (1-1 0L/ 10a of EM stock solution) and Bokashi (200g - 1kg/a square meter).

[Sod culture system]

Cover ground with leguminous or graminaceous cover crops. Mow several times a year and use the cuttings as a mulch.
This system can prevent soil erosion, increase organic matter in soil and improve soil aggregate structure. Alternate row sod systems or mulch-sod Systems are recommended.

[Mulch with EM]

Grass Mulch is an important technique in nature farming. The good points of Mulch are as follows:
To prevent soil erosion, to keep soil moisture, soil temperature and maintain a good environment for EM, to suppress weed, improve soil physical conditions by providing organic matter. To provide nutrients (particularly water soluble potassium) to crops.
Always try to mulch and apply Bokashi or EM diluted with molasses on the mulch.

> This manual presents basic information. Application depends on soil and climate conditions, and culture such as green house or open air cultivation. The values on this manual should be used only as a basic reference.

9.0 EM1 IN ANIMAL PRODUCTION

9.1 Effects of EM1 on livestock

1. Suppresses the foul smell on livestock barns and septic tanks
2. Decreases numbers of flies and ticks.
3. Improves animal health
4. Decreases the stress of animals.

5. Improves meat quality.
6. Improves fecundity.
7. Improves animal dung quality. (produces good manure)

9.2 APPLICATION OF EM1

1. Add EM Bokashi into feed of animals.
2. Mix EM1 into drinking water.
3. Spray EM1 multiplied solution on to the livestock barn.
4. Sprinkle EM Bokashi on the bedding for animals.
5. Put EM1 into septic tanks.

1) Add EM Bokashi into feed of animals.

Prepare edible Bokashi and give to animal as additive feed. This Bokashi improves microflora in intestines. As the result, health of animals is improved and the bad smell of dung is suppressed.

Preparation

Materials

1. Rice bran	100 litres
2. Wheat bran #1	100 litres
3. Molasses	200 cc
4. EM1	200 cc
5. Water #2	20 - 30 litres

#1 Corn flour can also be used as a material.

#2 The quantity of water is a guideline. The quantum of water that needs to be added will depend on the moisture content of the materials used. The ideal quantum of water is that required to moisten the material, without drainage.

1. Mix rice bran and wheat bran well.
2. Dissolve molasses in the water (1:100). It is easy to dissolve molasses in warm water.
3. Add EM1 into the above prepared molasses solution
4. Pour the diluted EM mixture onto the organic matter and mix well. Please pour the EM dilution gradually and mix well while checking the moisture content. There should be no drainage of excess water.
   The moisture content should be about 30-40%. You can check it by squeezing a handful. Once squeezed, it should remain as a single unit without crumbling. However, on touching it should crumble easily.
5. Put the mixture thus made into a bag that does not permit air movement (e.g. paper or polyethylene bag). This is placed within another polyethylene bag (black vinyl) to

prevent movement of air. Close the bag tightly to maintain an anaerobic condition. This is placed away from direct sunlight.

6. The fermenting period is:
   In the temperate zone: In summer more than 3-4 days.
   In winter more than 7-8 days.

   In winter, put the container in a warm location to hasten fermentation.
   In the tropics: more than 3-4 days.

   If anaerobic conditions are not maintained, the temperature increases. Ideally, the temperature should be around 35-45 °C. Thus, please check temperature regularly using a normal thermometer. If the temperature rises beyond 50 °C, mix the Bokashi well to aerate it, and put into polyethylene bag (black vinyl) and close it to maintain anaerobic conditions.

   The Bokashi is ready for use when it gives a sweet fermented smell. If it produces a sour and rotten smell, it is a failure.

7. The Bokashi should be used soon after preparation. If storage is required, spread it on a concrete floor, dry well in the shade and then put into vinyl bag. Please prevent rodent or other pest attacks.

Application

Mix the bokashi (1-5% of feed) into feed, or sprinkle the bokashi on feed everyday.

2) Mix EM1 into drinking water.

EM improves microflora in intestines of animals. As the result, health of animals is improved and also the bad smell of dung is suppressed.

Application

Put EM 1 in the drinking water for animals (1:1000 - 1:5000).

3) Spray EM multiplied solution on livestock barns.

Bad smells in barns and animal diseases are caused by increasing harmful microorganisms. These produce harmful substances and toxins such as ammonia, hydrogen sulfide, tori-metiru-amin. EM suppresses the increase of harmful microorganisms. Thus, the environment of the barns and animal hygiene are improved

Preparation

Materials

1. Water #1	100 litres
2. Molasses	1 litre

3. EM1 1 litre

#1: Well water is preferred since tap water is chlorinated.

1. Blend the molasses with water, make certain that it has been completely dissolved. You may use warm water for quick dilution of molasses.
2. Pour the mixed solution into a plastic bucket or drum which can be shut tightly.
3. Store the bucket in a warm place (20-35 °C), away from direct sunlight. It is ready for use 1-2 days later. However, it should be used within 3 days, after mixing.

Application.

Spray on livestock barn by sprayer. (spray onto floor, walls, ceiling and drain.) or use as water for washing. Splashing EM solution on animals does not cause problems. However, in the winter do not spray animals with EM solutions.

Spray 1-2 litres per square meter every 3-7 days. When bad smell is suppressed, the number of spray can be decreased.

In case of treading style beds such as in cattle pens, applying this EM solution in rainy season or winter may cause excess humidity. In such case, use EM Bokashi (show following) instead of this EM multiplied solution.

4) Sprinkle Bokashi on the bedding for animals

Preparation

Materials

1. Rice bran	100 litres
2. Sawdust	100 litres
3. Molasses	200 cc
4. EM1	200 cc
5. Water	20 - 30 litres

Preparation is the same as for "EM Bokashi for animals"

Application

Sprinkle about 50g (a handful of bokashi) per 1 square meters on the bed every 3-7 days. Once the bad smell is lessened, sprinkle it at longer intervals (every 2 weeks - 1 month). Consumption of the sprinkled bokashi on the bed does not cause problems.

5) Put EM1 into septic tanks.

By adopting application methods 1 to 4, EM is fixed in excreta of animals (manure). Fixed EM utilizes excreta actively, and suppress the work of harmful microorganisms. As the result, the bad smells of septic tanks are reduced. The sludge and scam in septic tanks are decreased. Putting EM into septic tanks increases these effects much more.

Application

Put EM1 stock or EM1 multiplied solution into septic tank (1% of total water amount in tank) every 1-2 weeks. For example, put 10 litres of EM 1 multiplied solution into 1 ton tank.

10.0 EM1 IN FISH CULTURE

EM1 is useful for fish and prawn culture, because it improves water quality.

Application

Put EM1 into the pond. (0.01% of total water in the pond)(1:10000) every month. Please check the odor of water regularly. If the bad smell is not suppressed, put EM1 at shorter intervals.

Mixing "EM bokashi for animals" into feed for fish (1-5% of feed) is very effective in raising the productivity of fish farms.

11.0 IMPORTANT ASPECTS OF USING EM1

(1) EM is a living thing

EM is a living entity. Therefore, EM is completely different from chemical fertilizers or agrochemicals. EM does not work when applied in the same method as chemical fertilizers or agrochemicals. It is important to note that EM increases population of beneficial microbes in the soil.

(2) Use good quality water

It is important to use good quality water when watering crops, diluting EM 1, preparing Bokashi and EM5.

Using polluted water (high BOD, Low DO) causes infection of pests and diseases, reduction of yield and crop quality.

If you can not get good quality water, please filter it by charcoal or EM ceramics

(3) Storage of diluted solution

It is desirable to utilize diluted EM1 solutions within 3 days.

(4) Storage information

Store of EM1 - up to 6 months in a closed container, in a cool and dark place, (Please do not store in refrigerator).

Check smell if in doubt. EM 1 always has a sweet and sour smell. If smell is foul, do not use it. After the cap of bottle is opened and air comes in, a white membrane may be observed on the surface of EM1. This is yeast and does no cause a problem.

CONVERSION TABLE (Area)
1 are (1a) = 100m^2
1 hectare (1 ha) = 100are (100a) = 2.471 acres
1 km^2 = 100 hectares (100 ha)
1 acre = 0.4047 hectare

APPENDIX:1 EXAMPLES OF BOKASHI FOR YOUR INFORMATION

1. Manure Bokashi

(1) Materials

1. Dung of any animals	2 parts
2. Rice bran	1 part
3. Rice husk	1 part
4. EM1 and Molasses	

(2) Preparation

1. Mix dung, rice bran and husk well
2. Dissolve EM1 and molasses in the water(1:1:100)
3. Spray the EM1 diluted solution on the dry ingredients with a watering can.
4. The moisture content should be 30-40%.
5. Heap on a floor in flat shape to a height of about 15-20cm. Cover it with gunny bag.
6. During fermentation the temperature should be kept around 35-45 °C. Thus please check temperature regularly using a normal thermometer. If the temperature rises beyond 50°C, mix the Bokashi well to aerate it.
7. Bokashi is ready for use when it gives a sweet fermented smell and white mold is observed. If it has a sour and rotten smell, it is failure.

2. Rice and rice straw Bokashi

This bokashi can be prepared economically in the field.

(1) Materials (for 5a)

1. Rice straw	200 kg (preferably chopped)
2. Weed straw	50 kg

3. Rice bran	5 kg
4. Chicken dung	10 kg
5. EM1 and Molasses	

(2) Preparation

1. Dissolve EM 1 and molasses in the water (1:1:100).
2. Soak a part of rice straw into the diluted EM1 solution. Then drain the straw and place on the ground. Tread them well to remove air, and heap to a height of 30cm.
3. Soak a part of weeds in diluted EM1 solution and put them on the rice straw. Tread them to remove air, and heap to a height of 10 cm.
4. Mix rice bran and chicken dung, and sprinkle it on surface of weeds to a 1cm thickness. Mix with fork.
5. Repeat 1 to 4. till the height of heap becomes 1-1.5m.
6. Cover the top by gunny bag, and then by vinyl sheet to obtain anaerobic conditions and prevent infiltration of rainwater.
7. When temperature goes down after fermentation, turn it and leave 3-7days.

Thereafter, it is ready for use. (white mold will be observed.)

3. 24 HOURS COMPOST

(1) Materials

1. Any kinds of straw	10 parts (Dried and chopped)
2. Bokashi	1 part
3. Rice bran	1 part
4. EM1 and Molasses	

(2) Preparation

1. Dissolve EM1 and molasses in the water (1:1:100).
2. Soak rice straw in the above EM1 diluted solution.
3. Mix wet straws with bokashi and rice bran.
4. Put it on a floor to a height of 15-20cm height, and cover it with gunny bag.
5. Turn it over after 18 hours and continue to ferment for a further 6 hours. It is ready for application in the farm. If it is hot, spread and uncover it.

APPENDIX:2 SOIL FOR RAISING SEEDLINGS.

(1) Material

1. Soil	20 parts
2. Bokashi	1 part
3. Rice husk	1 part
4. EM1 and Molasses	

(2) Preparation

1. Mix soil, bokashi, and rice husk charcoal together.
2. Dissolve EM1 and molasses in water (1:1:100), and sprinkle the solution on the above mixture while mixing it. The moisture content should be about 30%.
3. Cover it with gunny bag and vinyl sheet.
4. Turn it several times to prevent the temperature rising above 50 °C.
5. Leave the soil for 3 weeks-covered with a vinyl sheet to avoid drying out.
6. It is ready for use when it gives a sweet fermented smell and white mold is observed. If it has a sour and rotten smell, it is failure.

(3) Application.

Use this soil when you raise seedlings of vegetable and fruit.

APPENDIX 3: PREPARATION OF EM1 SECONDARY STOCK SOLUTION.

If you can not get sufficient EM1 stock solution for your land, you can multiply available EM1 stock solutions. This secondary EM1 stock solution can be used instead of the original EM1 stock solution. However, this multiplied EM1 (EM1 secondary stock solution) is inferior to original EM1 (EM1 stock solution) in quality.

Storage period of EM1 secondary stock solution is obviously shorter than the original EM1 stock solution.

Material

1. Water	100 litres (pure water without chlorine.)
2. EM1	5 litre
3. Molasses	5 litres (or 5 kg of brown sugar)

(2) Preparation

1. Mix EM1 and Molasses well in the water.
2. Pour the mixture into a clean plastic container or drum, which can be shut tightly (A glass container is not applicable.) and store at the ambient temperature.
3. After 3-10 days, when pH is below 3.5, it is ready for use.

*It is desirable to use this secondary solution as soon as possible. It can be stored for 1 week under air tight and shady condition

*DO not multiply the third EM1 stock solution from EM1 secondary stock solution, because it is very difficult to prevent contamination. The balance of microorganisms is changed, and the efficacy is lost.

APPENDIX 4: SOIL CLASSIFICATION ON THE BASIS OF MICROBIAL ACTIVITY

(1) Disease-inducing soil

The percentage of Fusarium in all fungi is high (more than 15 - 20%) in this soil.
When raw organic matter containing high nitrogen is applied, this soil produces a foul odor. Maggots develop in the soil together with many harmful insects. Pest and disease infestation is high with significant damage to the crops.
Therefore, applying raw organic matter is harmful for crops in this soil. Application of raw organic matter hardens the soil. The soil physical conditions deteriorate. In case of rice fields, gas is generated. Application of high quantities of chemical fertilizer and/or agricultural chemicals leads to the development of this type of soil.

(2) Disease-suppressive soil

Microorganisms which produce antibiotic substances exist in this soil. Thus, soil borne diseases do not develop easily. As Microorganisms such as Penicilium, Tricoderma, Streptamyces are active, the percentage of Fusarium in all fungi is low (less than 5%) in this soil.
When raw organic matter containing high nitrogen is applied to such soil, foul odors do not develop. The soil has the fresh sweet smell of mountain soil after decomposition. Soil aggregation and permeability are improved. On cultivation, pest and disease infestation is very low, but the yield is not so good. If this soil links up with a "Synthetic soil", productivity is enhanced.

(3) Zymogenic soil

This soil primarily contains zymogenic microorganisms such as lactic acid bacteria and yeasts. When raw organic matter containing high nitrogen is applied, this soil develops an aromatic fermented smell. The populations of fermentable fungi such as Aspergillus and Rhizopus are increased. The percentage of Fusarium in all fungi is low (less than 5%) in this soil.
The water-stable soil aggregate is high, and the soil becomes soft. Thus the solubility of inorganic nutrients enhances. The presence of amino acid, sugars, vitamins and other bioactive substances is increased in this soil, thereby promoting growth of crops.

(4) Synthetic soil

This soil contains microorganisms such as photosynthetic, nitrogen fixing bacteria.
Under stable soil moisture conditions, the soil quality is enhanced by addition of small volume of organic matter. The percentage of Fusarium in all fungi is low in this soil. This soil often links up with a "disease-suppressive soil"

Zymogenic-synthetic soil

When "Zymogenic-soil" and "Synthetic soil" are linked, it becomes an ideal soil for crop production. Such as soil is termed "Zymogenic-synthetic soil".

1) Teruo Higa (1991) "Microorganisms for Agriculture and Environmental Preservation", P33-34, Nou-bun Kyo. (In Japanese)

EM•1 Products

EM･1 Microbial Inoculant
EM･1 Microbial Inoculant: Soil Amendment

For application to soils, turf, and cover crop.

EM･1 Waste Treatment

Wastewater, wastewater treatment plants, sewer systems, lagoons, pond systems, solid waste, food waste, livestock holding facilities, and odor treatment. Not For Septic Use.

EM･1 Waste Treatment: For Septic Systems

For septic systems applications, on-site systems, holding tanks, recreational vehicles, boats, and portable restrooms.

EM•1 products are not recommended for animal or human consumption.

All products are available only in the continental United States.
In Hawaii, contact EM Hawaii, Inc. at 808-548-0396, or visit www.emhawaii.com
In Canada, Mexico, and the Caribbean countries, contact EMRO USA.

The authenticity and quality of our products are indicated by the EM logo and our company name, EMRO USA Effective Microorganisms.
(See also: About EMRO USA)

EFFECTIVE AS OF NOVEMBER 1, 2002

Manufacturer's Suggested Retail Price (MSRP)

Unit	**MSRP**	
liter bottle	**US$18.00**	**/Liter**
1-gallon container	**US$45.00**	**/Gallon**
5-gallon container	**US$200.00**	**/5-Gallon**
55-gallon drum	**US$1,650.00**	**/Drum**
tote (275-gal.)	**US$6,875.00**	**/Tote**

All prices are subject to change without notice.

Resource Directory

Please make the appropriate contact according to your needs:

For other EM related products, such as EM•X, EM•X ceramics, etc.,

- In Hawaii, contact EM Hawaii, Inc. for a list of authorized resellers.
- In the U.S./North America, contact Sustainable Community Development, LLC at 913-541-9299, fax 913-541-0380, or scd@emtrading.com.

For EM•1 products:

- Contact your Certified EM Provider (CEMP) for:
  - Purchase orders
  - Tech support, including application methods, rates, etc.
  - General information

- Contact EMRO USA for:
  - Product quality issues
  - Product shipment issues
  - Distributor contacts in Canada, Mexico and the Caribbean countries

- Contact EM Hawaii, Inc. for all matters relating to EM in Hawaii.

Contact our office for product quality and shipping issues:

EMRO USA Effective Microorganisms
2440 N. Coyote Dr., Suite 126
Tucson, AZ 85745-1256

Tel 520 792 3143
eFax 928 563 1037
Email info@emrousa.com

For EM activities and information, EM•1 products and other EM related products in Hawaii:

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