Effect of EM on Growth and Yield of Corn

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Abstract

Crop yields in Northeast Thailand are often limited by unproductive marginal soils, and erratic and insufficient rainfall. The soil factors that limit yields, such as low fertility, low water retention, low organic content, and soil crusting, can be largely overcome by regular additions of organic amendments which offer the best means of improving soil productivity. To further enhance the rehabilitation of these soils, there is a growing interest in the principles of nature farming and the use of effective microorganisms (EM).

Greenhouse and field experiments were conducted to determine the effect of EM cultures, organic waste materials, and chemical fertilizer on the growth and yield of corn. In the greenhouse study, corn yields were highest where soils were amended with composts that had been prepared by inoculation with EM 1 and EM 4. There was no significant yield increase from adding chemical fertilizers to these treatments. The field experiment showed no significant difference in corn stover yields from soils amended with animal manure and chemical fertilizer, either singly or combined, and sugarcane bagasse applied with EM 2, EM 3, and EM 4.

Northeast Thailand is the largest region of the country, comprising about 170,000 kn^2 (106 million rai), or one-third of the country. Its population is about 17 million which is one-third of the total population. Agricultural production in the Northeast is only 25 percent of the national average, and annual per capita income is the lowest in the country, or about 40 percent of the national average. This is mainly due to unproductive and infertile soils, and erratic and insufficient rainfall.

Most of the agricultural soils in the Northeast have moderate to severe limitations to crop production, including salinity, acidity, low fertility, and coarse-textured, sandy soils with low water-holding capacity. Saline soils occupy about 17.8 million rai, and are classified as slightly, moderately, and heavily salt-affected. Sandy soils comprise more than 17 million rai.

Most of the low fertile to moderately fertile soils in this region are sandy loams and loamy sands. They are very low in their clay (mostly kaolinite) and organic matter content. Consequently, these soils are low in their plant nutrient holding capacity and buffering capacity. Sandy soils with only a small amount of low activity clay cannot provide stable organo-mineral complexes. Uncombined forms of organic matter are often more susceptible to microbial attack and more dispersible into runoff water.

Infertile and unproductive soils can result from infertile parent material such as sandstone; excessive soil erosion and nutrient runoff losses; intensive tillage and cropping patterns; and insufficient use of chemical fertilizer and biofertilizers. Sandy soils derived from sandstone are generally coarse-textured, high in bulk density, low in cation exchange capacity, low in water-holding capacity, and subject to compaction and surface crusting. These poor physical properties are often associated with a very low soil organic matter content.

The best means of improving the productivity of these very marginal and infertile soils is through regular additions of organic wastes and residues supplemented with judicious amounts of chemical fertilizers. Organic amendments help to improve soil physical properties and the retention of plant nutrients in the soil-root zone where they can be used more efficiently by plants. Most farmers have traditionally applied animal manures to their soils to enhance and maintain their productivity, especially for rice and vegetable crops.

However, animal manure is not as available as it once was, due to smaller numbers of cattle. Consequently, farmers have had to look elsewhere for other sources of organic waste materials.

Last year Thai farmers imported about two million Mg of chemical fertilizers. While these materials are rather expensive, they can be very effective in increasing crop yields. However, there are certain disadvantages in using them since they can increase soil acidity, degrade soil structure, and pollute surface and ground water through runoff and leaching.

The Prospect of Nature Farming in Northeast Thailand

Nature farming may offer the means of overcoming many of the problems and constraints that farmers face in Northeast Thailand. The aim of nature farming is to enhance agricultural production without interrupting the natural ecosystem and without the use of chemical fertilizers and pesticides. Nature farming seeks to develop agricultural production systems that utilize the natural ecosystems to ensure pollution-free food products, and that conserve energy, reduce production costs, utilize resources efficiently, and revitalize agriculture in rural areas. The application of effective microorganisms (EM) to soil, particularly those which can enhance the release and availability of nutrients to plants, while reducing the incidence and destructive effects of plant pathogens, is a promising new research initiative.

Reasons for using EM in nature farming include:

1) To produce sufficient good quality food that is free of toxic chemicals and beneficial to human health.
2) To conserve soil, water, and energy in agroecosystems and prevent environmental pollution.
3) To develop productive and healthy soils through the proper utilization of organic amendments and other waste materials (OWM).
4) To reduce the dependence of farmers on chemical fertilizers and pesticides.

Properties and descriptions of the various EM formulations follow.

EM 1 has predominately filamentous fungi that are heat resistant and hasten the decomposition of organic amendments; is often more effective if applied with EM 4; and works best under aerobic conditions.

EM 2 is a mixture of more than 10 genera and 80 species of coexisting microorganisms (photosynthetic bacteria, ray fungi, yeasts, molds, etc.) that have been cultured in a liquid medium with a controlled pH of 7.0 and stored at pH of 8.5. [Number in saturated culture solution was 10^9 g^{-1}.] The mixture is predominately *Streptomyces* and can prevent diseases in plants; can enhance the effectiveness of *Azotobacter* and *mycorrhizae*; can transform a disease-inducing soil (e .g., one with high populations of *Fusarium*) into a disease-suppressive soil.

In EM 3, more than 95 percent of the microorganisms consist of photosynthetic bacteria which promote the transformation of soils into synthetic soils. It is effective for improving the quality of crops and for enhancing the effect of EM 2. The mixture is liquid at a pH of 8.5 and at a concentration of 10^9 organisms g^{-1}. EM 3 can make chemical fertilizers unnecessary and can effectively fix nitrogen, existing symbiotically with *Azotobacter spp*.

The EM 4 formulation has more than 90 percent of microorganisms such as lactobacilli that produce lactic acid. It can enhance the fermentation of organic materials and make them more soluble even under aerobic conditions. The mixture is liquid at a pH of 4.5 and at a concentration of 10^9 microorganisms g^{-1}. EM 4 accelerates the production of humus and can abate malodors of some organic materials in paddy fields.

Materials and Methods

What is needed to optimize the beneficial effects of effective microorganisms? All soil microorganisms, whether bacteria, fungi, or actinomycetes, require energy, nutrients, water, and optimum conditions of temperature, pH, and oxygen. Organic amendments are the principal sources of nutrients and energy and, thus, must be added to soils on a regular basis. The many beneficial effects of organic materials on soil productivity, fertility, and tilth are widely known.

We recently conducted two preliminary experiments with EM. One was a greenhouse study to determine the effect of EM in combination with different types of locally-available organic waste matter (OWM). The other was a field study to compare the effect of EM with different chemical fertilizers and biofertilizers, as well as lime. Both experiments used corn as an indicator crop.

Greenhouse Experiment

The objective of this experiment is to determine the effect of EM in combination with different types of locally-available OWM on the growth of corn.

Three kinds of OWM were used: corn cobs, peanut shells, and bagasse. Each waste material was mixed with cow manure, rice bran meal, rice husks, and rice husk ash. The mixtures were then divided into two parts, with EM and without EM, respectively. EM l was mixed into the compost pile, while EM 4 was diluted 1,000 times and watered into the heap at weekly intervals. After two months of curing for moisture, aeration, and temperature, each compost pile was sampled, weighed into three parts, and mixed (10% by weight) with the air-dried, sieved Korat soils (Oxic Paleustults). This provided the treatments for OWM alone, OWM with chemical fertilizer, and OWM with EM. The chemical fertilizer (15-15-15) was applied at a rate of 25 kg rai^{-1}, and EM 2.3.4 were diluted 1,000 times and applied to the EM-treated pots instead of water. Sweet corn was seeded into the pots on August 31 and later thinned to four plants per pot. Plants were grown for five weeks. Soil water content was kept between 60 to 80 percent of field capacity. No insecticides or pesticides were applied. The experimental design was a randomized complete block with three replications for a total of 60 pots, including fertilized and unfertilized controls. Plant height and weight were measured, and observations were made for growth. Soil samples were analyzed before and after the experiment. Plants also were analyzed for their nutrient content. The effects of EM, chemical fertilizer, and OWM were determined statistically. The experiment will be repeated under the same conditions to verify the initial results.

Field Experiment

The purpose of this experiment was to compare the effect of EM with other conventional types of fertilizer (both chemical and organic) and lime on the growth and yield of corn under field conditions. The Yasothon soil series (oxic paleustults) was used. Treatments included the control; manure (4 Mg rai^{-1}); lime (l00 kg $Ca(OH)_2$ rai^{-1}); chemical fertilizer (50 kg rai^{-1} of 15-15-15); a combination of manure + chemical fertilizer; and bagasse (4 Mg rai^{-1}) with EM. Plot size was 6x10 m with 75x50 cm spacing. All materials (except EM) were applied to the soil before planting. Sweet corn was planted on July 11, 1989 and later was thinned to two plants per hill. For the EM with bagasse treatment, EM 2.3.4 solutions were diluted 1,000 times with water and applied to the bagasse-amended soil at two week intervals. No insecticides or pesticides were applied. Soils were sampled and analyzed before and after the experiment. Plants were measured for height and weight, and were analyzed for their plant nutrient contents. When fully mature, the corn ears were collected twice and the numbers of ears and their weights recorded. The experimental design was a randomized complete block design with three replications for a total of 18 plots. The effects of different treatments were statistically compared.

Results

Greenhouse Experiment

The properties of Korat soils shown in Table 1 indicate that they are typically sandy loams, often highly acidic, and very low in organic matter, CEC, plant nutrients, and water-holding capacity.

Table 1. Chemical and Physical Properties of Korat Soils Used in the Greenhouse Study and Yasothon Soils Used in the Field Study.

Soil Type	Particle Size Distribution				pH	Bulk Density	Particle Density	Field Cap.	Wilting Point	Org. Matter	CEC	K	Ca	Mg	P
	Sand %	Silt %	Clay %	Texture		$g\ cm^{-3}$	$g\ cm^{-3}$	%	%	%	me 100 g^{-1}				ppm
Korat				Sandy loam	4.7	1.51	2.61	9.4	2.4	0.64	2.40	0.08	1.6	0.32	7
Yasothon	75	18	7	Sandy loam	4.9	1.50	2.60	7.2	2.8	0.46	3.25	0.09	0.45	0.20	10

Table 2 shows the chemical properties of composts after two months and just prior to their incorporation into soils, and also properties of the original OWM. Peanut shell compost has a considerably higher nitrogen content than either the corn cob or bagasse compost. However, the phosphorus and potassium contents were highest in the corn cob compost. Treatments of the organic waste materials with EM 1.4 tended to narrow the C : N ratio of the composts.

Table 2. Chemical Analysis of the Compost and Original Organic Waste Materials.

Organic Waste Material	OC %	N %	C:N %	P %	K %	Ca %	Mg %
Composts*							
CC	14.6	0.71	20.5	0.32	0.57	0.52	0.29
CC+EM 1.4	13.6	0.71	19.2	0.30	0.51	0.44	0.26
PS	24.8	0.97	25.5	0.12	0.25	1.21	0.71
PS+EM 1.4	18.4	0.80	22.9	0.25	0.31	1.23	0.21
B	16.7	0.61	27.3	0.18	0.27	0.24	0.17
B+EM 1.4	20.6	0.88	23.4	0.42	0.49	0.37	0.31
Uncomposted							
B	37.5	1.13	33.0	0.16	0.32	1.81	0.11
CC	39.9	1.04	39.0	0.14	1.40	0.37	0.11
PS	37.7	1.27	30.0	0.08	1.00	0.31	0.12

* Composts included specific amounts of manure, rice bran meal, rice husks, and rice husk ash. Composts were produced primarily from corn cobs (CO, peanut shells (PS), and bagasse (B).

Analysis of variance shows that there were significant differences between sources of OWM and fertilizer with and without EM 2.3.4, based on F values. However, the treatments involving EM 1.4 were not significantly different. For the OWM treatments plant dry weight means in grams were as follows:

Organic Waste	*Plant Dry Weight*
Peanut shells	10.3g a
Corn cobs	9.48g a
Bagasse	6.29g b

LSD (.05) = 0.81

The sources of OWM from peanut shells and corn cobs resulted in significantly greater dry weights of corn than from bagasse.

The OWM treated with and without EM 1.4 were not significantly different.

The so-called fertilizer treatment which included a fertilized and unfertilized control compared with EM 2.3.4 also were significantly different. Plant dry weight means in grams were as follows:

Treatment	*Plant Dry Weight*
With fertilizer	9.83g a
With EM 2.3.4	8.28g b
Control (without fertilizer)	7.93g b

LSD (.05) = 0.8

The fertilizer treatment gave the highest plant dry weight and was significantly higher than the EM treatment and the unfertilized control.

The four highest dry weight yields in grams were obtained from the following treatments, although there were no significant differences among them.

Treatment	*Plant Dry Weight*
Corn cob + EM 1.4 + F	12.1g a
Peanut shell + EM 1.4	10.4g ab
Peanut shell + EM 1.4 + EM 2.3.4	10.8g abc
Peanut shell + EM 1.4 + F	10.7g abc

LSD (.05) = 2.0

Interestingly, the unfertilized and fertilized controls produced mean dry weights of only l.5 and 2.8 g, respectively.

Field Experiment

Table 1 shows the chemical and physical properties of Yasothon soils. These soils are sandy loams in texture, acidic, low in organic matter, low in CEC, and moderate to low in their plant nutrient content. The bulk density is rather high and the water retention capacity is low.

The chemical properties of bagasse and manure used in the field experiment are reported in Table 3. Manure has a narrower C : N ratio due to its lower organic carbon but higher nitrogen content. Manure also contains higher amounts of most plant nutrients, a higher pH, and a higher CEC.

Table 3. Chemical Analysis of Bagasse and Manure Used in the Field Experiment.

Organic Amendment	C:N	OC *%*	N *%*	P *%*	K *%*	C *%*	Mg *%*	pH	CEC *me 100 g⁻¹*
Bagasse	33	37.5	1.13	0.16	0.32	1.81	0.11	-	17.5
Manure	23	28.7	1.22	0.30	0.61	1.30	0.21	7.9	26.1

Table 4 shows the plant height, stover weight, and pod fresh weight from the different treatments. The treatment combination of organic plus chemical fertilizer ranked first for all parameters, followed by organic fertilizer or chemical fertilizer alone. For stover and pod weight, the bagasse plus EM ranked fourth, followed by the control and lime treatments, respectively. For stover, the bagasse plus EM treatment was not significantly different from any of the fertilized treatments. However, the pod weight was significantly higher for the combination of organic plus chemical fertilizer than for the other treatments.

Table 4. Plant Height, Stover Weight and Pod Fresh Weight of Corn from the Different Treatments.

Treatments	Height *cm*	Stover *kg pot^{-1}*	Pod *kg pot^{-1}*
OF + CF	161 a*	36 a	19 a
CF	154 a	28 a, b, c,	10 b
OF	150 a	29 a, b	11 b
Control	128 a	14 b, c	4 b
B + EM	123 a	26 a, b, c	8 b
L	80 b	11 c	4 b
LSD (.05)	36	16	7
CV. (%)	15	30	40

* Column values followed by the same letter are not significantly different at the 5% probability level.

Summary and Conclusions

The low level of agricultural production in Northeast Thailand is due mainly to unproductive, marginal soils and erratic rainfall patterns. Many of the problems and constraints which limit production can be overcome by regular additions of organic waste materials to soil. This approach offers the best means of improving soil productivity. However, there is a growing shortage of good quality organic wastes that are available to farmers as soil amendments. Increasing concerns about the adverse effects of chemical fertilizers and pesticides on soil properties and the environment have generated considerable interest in the principles of nature farming and the use of effective microorganisms (EM) for developing more productive, stable, and efficient farming systems in the Northeast.

Greenhouse and field experiments were conducted to determine the effect of different combinations of EM formulations, OWM, and chemical fertilizer on the growth and yield of corn. In preparing experimental composts for a greenhouse pot study, it was noted that inoculation of the composting biomass with EM 1.4 narrowed the C : N ratio of the finished compost. The highest corn yields were obtained from soils amended with corn cob and peanut shell composts that had received EM 1.4. Interestingly, there was no significant yield increase from adding chemical fertilizer to these treatments, indicating that maximum yields were obtained from compost plus EM combinations.

The results of a field study indicated that a combination of animal manure and chemical fertilizer gave the highest values for plant height (corn), and the highest yields of stover and pod fresh weight.

Of considerable interest is the fact that there was no significant difference in stover yields among treatments, including organic fertilizer and chemical fertilizer applied either singly or combined, and bagasse applied with EM 2.3.4. This suggests that the EM treatment enhanced the decomposition of bagasse and released available plant nutrients at a rate that could sustain the growth and yield of corn. Additional experiments are needed to verify these results.

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