Nature Farming With EM Technology for Sustainable Crop Production in Pakistan

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Abstract

A large number of field and greenhouse experiments have been conducted in Pakistan since 1990 to evaluate the use of Effective Microorganisms (EM) as an alternative to chemical fertilizers in crop production. One such study was a long-term field experiment conducted for five years on a rice-wheat rotation with the following treatments: control, chemical fertilizer (NPK), green manure (GM), and farmyard manure (FYM), all with and without the application of Effective Microorganisms (EM). Results showed that EM increased crop yields and improved soil physical properties, especially when applied with organic amendments. On-farm trials comparing EM-Biokasht (a mixed organic amendment inoculated and fermented with EM) with chemical fertilizer were conducted on rice. The average paddy yield for nine sites was essentially the same for both treatments.

A lysimeter study on wheat under controlled conditions showed that the yield from EM-Biokasht plus one-half the recommended rate of NPK fertilizer was essentially the same as obtained with the full rate of chemical fertilizer. In another study, EM applied with VA mycorrhizae produced a higher yield of maize fodder compared with each inoculant applied alone. An experiment on citrus showed that EM applied in irrigation water increased the total soluble sugar concentration, juice content and average weight of fruit. The feasibility of EM technology in poultry production was also evaluated. Results indicated that EM provided to broiler chicks in drinking water significantly increased the live weight of chicks.

In addition to these experiments, there has been considerable time and effort devoted to promote EM technology in Pakistan. For example, the Nature Farming Research Center (NFRC) was established in 1993 followed by founding of the Nature Farming Research and Development Foundation (NFRDF). A series of annual national seminars on nature farming began in 1993, and a research and development farm was established for studies on EM technology. The government of Pakistan has provided invaluable assistance in establishing a pilot plant for the production of EM cultures to ensure that our farmers can receive the benefits of EM technology.

Introduction

Prior to the introduction of chemical fertilizers, agricultural production was solely dependent on the use of various organic amendments, including farmyard manure, green manure, crop residues and composts, as sources of plant nutrients. Farmers in Pakistan continue to rely on organic amendments to maintain soil fertility and productivity, and conserve/protect the natural resource base (i.e., soil and water) for a more sustainable agriculture. Sustainable agricultural systems must be productive, profitable, conserve natural resources, protect the environment, produce safe and nutritious food, and protect human health. However, all of this requires that we address the issues of economic, environmental and social sustainability in our agricultural systems (Hussain et al., 1992).

The intensive use of chemical fertilizers which began in the 1950's as part of the Green Revolution soon gained widespread acceptance because they could elicit dramatic increases in crop yields compared with the traditional organic amendments (Braun and Roy, 1983). However, following the transition to high yielding crop cultivars and intensive methods of farming, farmers have experienced a substantial depletion of plant nutrients from the soil. This has often resulted in a critical decline in soil fertility and productivity. Furthermore, the economic and environmental costs associated with heavy use of chemical fertilizers have become major constraints to developing a more sustainable agriculture.

Today, Pakistan is experiencing a dramatic population explosion. The annual rate of population increase is 3.1 percent and among the highest in the world. Consequently, there is an urgent need to increase agricultural production, but with less dependence on agri-chemical inputs, and to make our agriculture more sustainable. While interest in organic farming has been increasing worldwide, the application of most organic amendments alone is not sufficient to sustain the level of soil fertility needed for maximum economic yields. Although animal manures are often returned to soils in many developing countries, their overall nutrient content of N-P-K is low, with a percentage ratio (elemental dry weight basis) of little more than 2-2-1 (Parr and Colacicco, 1987). Moreover, some nutrients in animal manures are either volatile or water soluble and may be lost during the process of storage and application (Smith, 1988; U.S. Department of Agriculture, 1978).

As an alternative to agrichemicals (i.e., chemical fertilizers and pesticides), Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan, developed the concept and technology of Effective Microorganisms (EM). EM has been shown to be effective in replacing agrichemicals, especially when applied in combination with organic amendments. EM is a mixed culture of beneficial, naturally-occurring, microorganisms that can be applied as inoculants to enhance the microbial diversity of soils and plants which, in turn, can improve soil health and the growth, yield and quality of crops (Higa and Wididana, 1991a). EM contains predominant populations of lactic acid bacteria, yeasts, actinomycetes, photosynthetic bacteria and other organisms that are mutually compatible and can co-exist in liquid cultures (Higa and Parr, 1994).

Experiments on nature farming with EM technology in Pakistan began in 1990. Numerous field and greenhouse trials have proven the benefits of EM technology for crop production (i.e., increased yields); as a probiotic in poultry and livestock rations; and to enhance the composting and recycling of municipal / industrial wastes and effluents.

Studies reported by Japanese scientists showed excellent results from the use of EM-Bokashi (a mixture of organic materials inoculated and fermented with EM) in both crop and livestock production. A similar product called EM-Biokasht has been produced and tested in Pakistan the results of which are reported herein along with other selected experiments using EM.

Materials and Methods

The methodologies for the experiments reported in this paper are briefly described as follows:

Effect of EM on Crop Yields in a Rice-Wheat Rotation

A long-term field experiment (5-year duration) on a rice-wheat cropping systems was initiated in 1990 using a split-plot design with three replications. The sub-plot treatments were: control; fertilizer N-P-K applied at 1 20-90-60 kg ha^{-1}, respectively; *Sesbania aculeata* green manure (GM) at 20 t ha^{-1}; and farmyard manure (FYM) at 20 t ha^{-1}. The effect of these treatments was studied with and without the application of EM. Each year, the yield of both rice and wheat crops was recorded; changes in soil physical properties were determined at the end of five years.

Effect of EM-Biokasht on Rice Production

On-farm trials were conducted in 1994 at 16 sites in Punjab Province to determine the effect of EM-Biokasht (organic amendments inoculated and fermented with EM) on paddy rice production. Treatments were: EM-Biokasht applied at 1,000 kg ha^{-1} and the farmer's fertilizer practice of N-P_2O_5-$ZnSO_4$ applied at 80-57-12.5 kg ha^{-1}, respectively. Rice was planted in 0.2 ha plots and treated with either chemical fertilizer or EM-Biokasht. Rice yields were recorded from 9 of the 16 sites.

Effect of EM-Biokasht on Wheat Production in a Lysimeter Study

A controlled experiment was conducted in 1 x 2 m lysimeters to determine the effect of EM-Biokasht on wheat production. The study utilized a randomized complete block design (RCBD) with three replications. The treatments were: control; fertilizer N-P-K applied at 120-90-60 kg ha^{-1}, respectively; EM-Biokasht at 500 kg ha^{-1}; EM-Biokasht at 1,000 kg ha^{-1}; and half fertilizer plus EM-Biokasht at 500 kg ha^{-1}. At crop maturity grain yield was recorded.

Effect of EM and V-A Mycorrhizae on Maize Fodder Production

A pot experiment utilizing a completely randomized design (CRD) with three replications was conducted to determine the interaction of EM and V-A mycorrhizae on maize fodder production.

The treatments were: control; EM 4 alone; mycorrhizae alone; and EM 4 plus mycorrhizae. EM 4 was applied weekly in irrigation water, whereas, the mycorrhizae treatment was applied prior to sowing. The fresh weight of maize fodder was recorded at 15, 30, 45 and 60 days after sowing.

Effect of EM on Citrus Production

A field study was conducted in 1994 to determine the effect of EM 4 on the growth, yield and quality of two varieties of oranges. The treatments were: control; EM 4 applied at 40 ml per plant; and EM 4 applied at 80 ml per plant. EM 4 was applied in irrigation water at regular intervals from the flowering stage through fruit maturity. Yield and quality parameters determined included soluble sugars, juice content, and average single fruit weight.

Effect of EM on Poultry Production

A study was conducted during 1994-95 to determine the usefulness of EM in poultry production. In two experiments, broiler chicks were given EM 4 in their drinking water from the third through the sixth week of growth. Treatments in the first experiment (Trial A) Conducted by the Animal Nutrition Department were: control and EM 4 at EM:water dilutions of 1:250, 1:500 and 1:750. Treatments in the second experiment (Trial B) conducted by the Poultry Husbandry Department were: control and EM 4 at EM:water dilutions of 1:400, 1:800 and 1:1,200. In both experiments, the live weight gain of broilers was recorded at six weeks of growth and the percentage weight increase over the controls (no EM) was calculated.

The data obtained in all of the aforementioned experiments were subjected to statistical analysis by standard procedures (Steel and Torrie, 1980) and the treatment means were compared using Duncan's Multiple Range Test (Duncan, 1955).

Results and Discussion

Effect of EM on Crop Yields in a Rice-Wheat Rotation

The effect of EM, chemical fertilizer (NPK), green manure (GM). and farmyard manure (FYM) on the yield of rice and wheat is shown in Table 1. These data are based on the average yields obtained during the five year duration of the study (1990-94). In all cases, EM increased the yields of both crops compared with the treatments that did not receive EM. The maximum percent increase in yield was obtained with rice (16.0%) and wheat (24.8%) when EM was applied alone, i.e., as a control. The chemical fertilizer plus EM treatment gave the lowest percent yield increase for rice (6.4%) and wheat (5.6%); however, this treatment gave the highest yields for both crops. The relatively low response to microbial inoculation with N fertilizer may have been due to the inhibition of nitrogen fixation (National Research Council, 1989). Poonyarit et al. (1993) reported the highest yield of paddy rice where EM+chemical fertilizer were applied. The percent increase in wheat yields due to EM application was higher than rice yields for all treatments except chemical fertilizer. Karim et al. (1993) also reported that wheat yields were increased from addition of EM, farmyard manure and chemical fertilizer. They observed a higher yield increase with EM+organic amendments compared with EM+N fertilizer.

Table 1. Effect of EM on the Percentage Increase in the Yield of Rice and Wheat Grown in Rotation with Different Treatments from 1990 to 1994.

Treatments	% yield increase due to EM	
	Rice	**Wheat**
Control	16.0	24.8
Chemical fertilizer	6.4	5.6
Green manure	9.5	19.7
Farmyard manure	7.2	19.5

Data are based on the average yields obtained for both crops during the study period.

In this long-term study, the effect of organic amendments and EM application on soil physical properties was also determined. The saturation percentage of soil was increased significantly when

EM was applied with GM and FYM. The soil bulk density was decreased marginally from the application of EM with GM and FYM. Green manure had very little effect on soil bulk density probably because the fresh biomass was difficult to incorporate into the soil and remained largely at the soil surface during the growing season. Higa and Wididana (1991b) and Karim et al. (1993) reported a significant decrease in soil bulk density from EM application.

Effect of EM-Biokasht on Rice Production

The effect of chemical fertilizer and EM-Biokasht on rice yields from on-farm trials in Punjab Province is shown in Table 2. The average yield data from these trials show little difference between chemical fertilizer and EM-Biokasht. Minami and Higa (1994) reported similar results on farmer's fields in Japan. They concluded that in most cases, the yield of paddy rice was higher in the years following EM application than in the initial year of application. This could help to explain the results of the present study.

Table 2. Effect of Chemical Fertilizer and EM-Biokasht on Rice Yields from On-Farm Trials in Punjab Province in 1994.

Farmer participant	Chemical fertilizer (kg ha^{-1})	EM Biokasht (kg ha^{-1})
1	4360	4670
2	3240	5330
3	2920	2200
4	4100	3330
5	4990	4360
6	3480	3660
7	3380	2960
8	3900	3670
9	2370	2830
Average	3638	3634

Effect of EM-Biokasht on Wheat Production in a Lysimeter Study

The effect of chemical fertilizer and EM-Biokasht on the yield of wheat grown in lysimeters is reported in Table 3. Yields for all treatments were significantly higher than the control. The highest yield was obtained with the full recommended rate of chemical fertilizer followed by one-half the recommended rate applied with EM-Biokasht. Grain yield was higher for EM-Biokasht when applied at a rate of 1,000 kg ha^{-1} compared with the lower rate of 500 kg ha^{-1}. Poonyarit et al. (1993) reported similar results for a rice experiment in Thailand. They observed that one-half the recommended rate of chemical fertilizer (NPK) applied with EM produced a rice yield statistically equal to that obtained with a full rate of chemical fertilizer. Karim et al. (1993) also reported similar results in Bangladesh where EM + one-half the recommended rate of chemical fertilizer was applied compared with the full recommended fertilizer rate alone.

Table 3. Effect of Chemical Fertilizer and EM-Biokasht on the Yield of Wheat Grown in Lysimeters.

Treatments	Wheat grain yield (kg ha^{-1})
Control	1775
Chemical fertilizer (NPK)	3125
EM Biokasht (500kg ha^{-1})	2075
EM Biokasht (1,000kg ha^{-1})	2375
1/2 NPK+EM Biokasht (500kg ha^{-1})	2735

Effect of EM and V-A Mycorrhizae on Maize Fodder Production

Results of this study (data not shown) showed that a combination of EM and V-A mycorrhizae gave the highest yield of maize fodder. The order of descending yields was: EM + mycorrhizae >

mycorrhizae alone > EM alone. The beneficial effect of combining two types of microbial inoculants can likely be attributed to enhancing the release, availability and uptake of nutrients by plants. Mycorrhizal "root" fungi are important in the uptake of nutrients from soil by plants and in the establishment and development of vigorous seedling growth by many crop and nursery species (Gerdeman, 1976). Mycorrhizae increase the surface area of the plant root system and enhance the nutrient uptake efficiency by plants, especially in the case of soil phosphorus (Subba Rao, 1993). EM contributes to this apparent synergy by solubilizing inorganic nutrients and, thus, increasing their availability to plants (Higa and Wididana, 1991a,b).

Effect of EM on Citrus Production

The effect of EM on increasing the total soluble sugars, juice content and fruit weight for two varieties of oranges (Valencia and Kinnow varieties) is reported in Table 4. The best results for both varieties were obtained when EM was applied at a rate of 80 ml/ plant compared with the lower rate of 40 ml/plant. Waluyo (1993) also reported that the fruit weight of water apple, starfruit and acerola was significantly increased with the application of EM-Bokashi. The total ascorbic acid (Vitamin C) content of these fruits was also statistically higher due to EM application.

Table 4. Effect of EM on the Quality and Fruit Weight of Two Citrus (Orange) Varieties.

Treatments	Total soluble sugars (%)	Fruit juice content (%)	Single fruit weight (g)
Valencia-late variety			
Control	10.2	46.5	187.4
EM (40ml plant^{-1})	10.3	49.3	189.9
EM (80ml plant^{-1})	10.7	51.5	191.2
Kinnow variety			
Control	10.2	46.2	172.5
EM (40ml plant^{-1})	10.3	48.4	172.5
EM (80ml plant^{-1})	10.7	50.0	181.7

Effect of EM on Poultry Production

The results of this study (Table 5) showed that all EM dilutions gave higher broiler weights compared with the controls. The highest percentage weight increase in Trial A occurred with EM at a dilution of 1:500 added to drinking water (25%). In trial B, the highest weight increase was obtained with EM at a dilution of 1:1,200. Zhao (1994) also studied the effect of EM as a feed additive for poultry in China and reported that EM increased the live weight of birds and decreased their feed : weight ratio.

Table 5. Effect of EM on the Percentage Increase in the Weight of Broiler Chicks over the Control in Experiments Conducted by the Animal Nutrition Department (Trial A) and the Poultry Husbandry Department (Trial B).

Treatments (EM dilution)	Weight of Broiler chicks (% weight increase)
Trial A	
1:250	2.5
1:500	25.0
1:750	15.9
Trial B	
1:400	11.3
1:800	13.3
1:1200	16.2

Conclusions

Numerous field, laboratory and greenhouse studies conducted in Pakistan have demonstrated the wide range of beneficial effects that can be derived from the use of Effective Microorganisms (EM). These include a) increased crop yields from (EM) in a rice-wheat rotation; b) increased fertilizer use efficiency from EM; c) improved soil physical properties from EM; d) enhanced synergistic effect of EM on V-A mycorrhizae resulting in increased maize yield and nutrient uptake; e) increased yield and quality of oranges from EM application; and f) increased market weights of poultry broilers from EM applied to drinking water.

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