Imperatives for Re-orienting Agricultural Production System with Effective Microorganisms (EM) Technology………….
Technology of the 21st Century

VEGETABLE & FRUIT PRODUCTION

Self Reliance
NFRDF-PAKISTAN

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EFFECTIVE MICROORGANISMS (EM) FOR A SUSTAINABLE AGRICULTURE AND ENVIRONMENT

INTRODUCTION

The technology of Green Revolution transplanted intact from abroad into our agro-ecological situations, began to look increasingly out of place and inappropriate. The current agriculture of Pakistan, like other Asian countries is confronted with, low and stagnant crop yields, high cost of chemical fertilizers, pesticides and herbicides, high cost of energy, machines, irrigation, dams, tube wells, subsistence farming and low access to technology adaptation insecurity of produce benefits, and lack of Agri- business management facilities.
The potential utilization of solar energy by plants has been estimated to be between 10-20%. However, the actual utilization rate is less than 1%. Even e4 plants such as corn and sugar cane which have higher rates of carbon fixation fix approximately 6-7% of solar energy during their maximum growth period. However in general, the utilization rate of photosynthesis is lower than 3% even under conditions that produce optional yields.

Research has shown that photosynthetic efficiency of chloroplasts of most crops cannot be enhanced much further. This indicates that the biomass productivity of these crops have reached a maximum. The best opportunity for increasing biomass production is to utilize the visible light which cannot be used by chloroplasts, and also the infra red radiation which together account for approximately 80% of total solar energy. Efforts should be made to explore methods of recycling organic energy contained in plant and animal residue through direct utilization of organic molecules.

In the presence of organic matter, photosynthetic bacteria and algae can utilize wavelengths ranging from 700-1200mm. Green plants do not use there wavelengths. Fermenting microbes could also breakdown organic matter, thereby releasing complex compounds such as amino acids for utilization by plants. This enhances the efficiency of organic matter in crop production. Therefor, a key factor for increasing crop production is the availability of organic matter, which has been developed by using solar energy , and the presence of efficient microbes to decompose the organic material. This increases the utilization efficiency of solar energy,

Effective microorganisms (EM) in Agriculture

Effective Microorganisms (EM) was developed at the University of the Ryukyus, Okinawa, Japan in early 1980 by a distinguished professor Dr. Teruo Higa. He developed a mixture of beneficial microorganisms, first by accident and there after by diligent research, to enhance productivity of conventional organic farming system.

The use of EM in agriculture has many significant beneficial such as:

1. EM promotes germination, growth, flowering, fruiting and ripening in crop plants.
2. EM enhances the photosynthetic capacity of plants.
3. EM increases the efficiency of organic matter as fertilizers.
4. EM develops resistance of plants to pests and diseases.
5. EM improves the physical, chemical and biological environments of the soil.
6. EM suppresses soil borne pathogens and pests.

Due to the above stated benefit, EM enhances crop yields in organic system in most environments. It also develops the soil, to improve its ability to sustain crops. Therefore, the use of EM culminate in the following economic benefit to the user:

1. The requirement of EM declines with time as the microbes are self propagating.
2. The use of EM requires lower quantities of organic matter.
3. Use of EM reduces the labor requirements by reducing tillage and weeding.
4. Use of EM enhance the soil biota and develops the physical structure.
5. EM ferments organic matter as opposed to deterioration.
6. EM breakdown organic matter rapidly once incorporated into the soil.
7. EM facilitates the release of grater quantities of nutrients to plants.
8. EM destroys harmful insects and pests but not beneficial organisms.
9. EM develops internal immunity of plants and animals, thus enhancing natural resistance.
10. EM has the capacity to convert wastes into useful non toxic products.
11. EM retards the process of rusting in metals, reducing the replacement costs of machinery.

PRINCIPAL MICRO-ORGANISMS IN EM AND THEIR ACTION

Photosynthetic bacteria (Rhodopseudomonas spp)

The photosynthetic or phototropic bacteria are a group of independent, self supporting microbes. These bacteria synthesise useful substances from secretions of roots, organic matter and / or harmful gases (e.g hydrogen sulphide), by using sunlight and the heat of soil as sources of energy. The useful substances developed by these microbes include amino acids, nucleic acids, bioactive substance and sugars, all of which promote plant growth and development. The metabolites developed by these microorganisms are absorbed directly into plants and act as substrate for increasing beneficial microbial populations. For example, Vesicular Arbuscular (VA) mycorrhizae in the rhizosphere are increased due to the abailability of nitrogenous compounds (amino acids) which are secreted by the phototropic bacteria. The BA mycorrhizae in turn enhance the solubility of phosphates in soils, thereby supplying unaailable phosphouus to plants. VA mycorrhizae can also coexist with Azotobactor and Rhizobium, thereby increasing the capacity of plants to fix atmospheric nitrogen.

Lactc acid bacteria (Lactobacillus spp)

Lactic acid bacteria produce lactic acid from sugars and other carbohydrates, developed by photosynthetic bacteria and yeast. Therefore, food and drinks such as yoghurt and pickles have been made with Lactic acid bacteria from ancient times. However, Lactic acid is a strong sterilising compound, and suppresses harmful microorganisms and enhances decomposition of organic matter. Moreover, Lactic acid bacteria promotes the fermentation and decomposition if material such as lignin and cellulose, thereby removing undesirable effect of undecomposed organic matter. Lactic acid bacteria has the ability to suppress disease inducing microorganisms such as Fusarium, which occur in continuous cropping programmes. Under normal circumstances, species such as Fusarium weakens crop plants, thereby exposing them to diseases and increased pest populations such as nematodes. The use of lactic acid bacteria reduces nematode populations and controls propagation and spread of Fusarfum, thereby inducing a better environment for crop growth.

Yeast (Saccharomyces spp)

Yeasts synthesise antimicrobial and other useful substances required for plant growth from amino acids and sugars secreted by photosynthetic bacteria, organic matter and plant roots.
The bioactive substances such as hormones and enzymes produced by yeasts promote active cell and root division. These secretions are also useful substrates for Effective Microorganisms such as Lactic acid bacteria and Actinomycetes.

The different species of Effective Microorganisms (Photosynthetic and Lactic acid bacteria and Yeast) have their respective functions. However, Photosynthetic bacteria could be considered the pivot of EM activity. Photosynthetic bacteria support the activities of other microorganisms in EM. However, the photosynthetic bacteria also utilise substances produced by other microbes. This phenomenon is termed “Co existence and Co prosperity”. The enhancement of populations of EM in soils by application promotes the development of existing beneficial soil microorganisms. Thus, the microflora of the soil becomes abundant, thereby the soil develops a well balanced microbial system. In this process soil specific microbes (especially harmful species) are suppressed, thereby reducing microbial diseases that cause soil borne diseases. In contrast, in these developed soils, the Effective Microorganisms maintain a symbiotic process with the roots of plants within the rhizosphere.
Plant roots also secrete substances such as carbohydrates, amino and organic acids and active enzymes. Effective Micro-organisms 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, EM in the rhizosphere co exist with plants.

The Green Revolution was based on the assumption that technology is a superior substitute for nature, and hence a means of producing growth, unconstrained by nature's limits. However the ecological destruction due to monoculturism and indiscriminate use of pesticides, herbicides and chemical fertilizers without integrating with organic matters, have not only produced scarcity but was also responsible for destruction of soil fertility, micro-nutrient deficiency, soil toxicity, waterlogging and salinization, bio mass reduction for fodder and organic manure, nutritional imbalances with reduction of pulses, oil seeds and millet, pesticide contamination of food, soil, water, human and animal life and greenhouse effect with atmospheric pollution. Infact revolution options were built on neglecting the other avenues for increasing food production that are more ecological, such as improving mixed cropping system, improving indigenous seeds, improving the efficiency of the use of local resources, enhancing the process of organic intensification of agriculture, "involution", conversion of crop residues, manure, municipal solid and liquid and industrial wastes, practicing diversity for seed breeding strategies, increasing the utilization efficiency of solar energy for maximum crop production.

VEGETABLE PRODUCTION

There was 20% increase in vegetable yield where EM was applied along with organic sources of nutrients like Farmyard manure (FYM), Poultry manure, Sugarcane filter cake (SFC), and crop residues, Naseem (1994). Data appear in table 1.

Table 1: Effect of EM, Inorganic Fertilizer and Organic Amendments on Yield of Vegetable Beans in two Wet Seasons.

Treatment	**Season 1**	**Season 2**
	-----Yield (g/m^2)-----	
Inorg. Fert.	985	1031
Gliricidia Leaves (GL)	649	674
Rice straw (RS)	498	521
EM	414	483
EM+GL	931	996
EM+RS	519	558
EM+Fert.	991	1068
Control	315	341
LSD (P=0.05)	62	51

Addition of EM produced higher yield during the second season, which demonstrated the long term benefits of EM; While this could be the result of the ability of EM culture to transform the soil into more zymogenic state.

Javaid (1995) studied the effect of EM for pea production. Results showed that statistically similar yield of peas were achieved by fertilizer and EM treatments. Data are given in Table 2.

Table 2: Yield of Peas as effected by fertilizer of EM Treatments in (kg/ha)

Treatment	**Replication**			**Mean**
	R1	R2	R3	
Control	731.25	879.25	835.62	815.4 C
Fertilizer	1129.37	1139.37	1097.50	1122.0 A
(120-90-60)kg/ha FYM @20 t/ha + EM_4	1081.87	1041.25	1038.75	1054.0 AB
HAS @ 250 kg/ha + EM_4 @ 15 l/ha	1023.75	998.12	1028.75	1017.0 B
HAL @ 12.5 l/ha + EM_4 @ 15 l/ha	915.00	934.37	814.37	887.9 C
DIAZ @ 2 kg/ha + EM_4 @ 15 l/ha	1134.37	1085.62	1090.00	1103.0 AB

Ayub et al., (1993) conducted a comparative study of Nature Farming proftability and sustainable development in vegetable production. He concluded that EM-Technology for potato production resulted in higher yield than the normal doze of NPK or FYM alone. Moreover, the use of EM proved more economical, generating a profit of Rs.59640/ha followed by NPK as Rs.46198/ha. The yield data are given in Table 3.

Table 3: Effect of EM application on Potato tuber yield (t/ha)

Treatment	Yield (t/ha)
Control	8.04 c
Fertilizer	13.41 ab
Farmyard Manure	12.68 ab
EM4	10.44 bc
EM4 + FYM	15.86 a

Riaz et al.,(1994) found statistically equal production of Radish in fertilizer and EM treatments. Data appear in Table 4.

Table 4: Radish yields in (t/ha)

Treatment	Yield in 1991-92	Yield in 1992-93	Means
Control	6.02^{NS}	3.74	4.88 D
NPK	10.93	9.55	10.23 A
EM4 only	4.01	5.67	4.84 D
FYM + EM4	8.77	7.33	8.05 B
PM + EM4	10.83	8.51	9.67 A
City waste + EM4	6.31	6.16	6.23 C
GM + EM4	5.38	3.46	4.37 D
Rice straw + EM4	3.19	2.08	2.63 F

Naseem (1994) studied the effect of organic amendments and EM on Radish production and found that the maximum oven dry weight of Radish in EM + PM (Poultry manure) was statistically alike with NPK treatment. The yield of Radish was statistically equal in Poultry Manure fermented with EM and fertilizer. Data are given in Table 5.

Table 5: Radish yields (t/ha)

Treatment	Years		Mean
	1992	1993	
Control	231.66	172.04	201.85 CD
NPK @ 120-90-60 kg/ha	351.43	372.75	362.09 A
EM4 alone	198.44	251.43	224.93 CD
EM4 + FYM @20 t/ha	321.00	296.24	308.62 B
EM4 + PM @ 20 t/ha	426.85	339.17	383.01 A
EM4 + CW @ 20 t/ha	237.97	259.41	248.61 C
EM4 + GM @ 20 t/ha	214.51	152.38	183.44 DE
EM4 + WS @ 20 t/ha	155.397	99.96	127.68 E

WS = Wheat straw CW = City waste GM = Green manure

Arakawa (1989) concluded that nature farming using EM gave comparatively high yield of peanut and carrot. Data appear in table 6.

Table 6: Yield of peanut and carrot growth in three different farming systems.

Crop	Conventional Nature farming	Conventional Agriculture	Nature farming with EM	% increase in yield with CNF
Peanut	500	2,000	3,500	700
Carrot	10,000	25,000	28,000	280

Imai and Higa (1991) studied that the yield of spinach growth in pot cultures of the two soils, highest yield was obtained by fertilizer followed by compost+EM, which indicates that highest yield can be obtained by utilizing EM in Kyusei Nature Farming Practices i.e. organic Farming. Data appear in table 7.

Table 7: Yield of Spinach Growth in Pot Cultures of Two Different Soils Treated with compost, EM and chemical fertilizer.

Yield parameters	**Series A**		**Series B**			
	Compost only	Compost + EM	Compost only	Compost +EM	Fert. only	Fert. +EM
Number of plants	30	28	30	30	30	30
Total fresh weight (g)	135	345	37	92	436	402
Average weight/plant(g)	4.5	12.3	1.2	3.1	14.5	13.4
Relative yield (%)	100	273	27	69	322	298

U. R. Sangakkara (1991), studied the effect of EM on Tomato and capsicum and said that they produced similar responses to the addition of organic matter. Application of EM also increased yield over the control. The increment varied form 14 percent to26 percent for egg plant in the first season. Application of EM increased in yield of egg plant, capsicum & tomato by 38.33 and 18 percent, respectively over the control in second season. This result suggests a long-term benefit from the use of EM. Data are given in table 8.

Table 8: Yield of Solanaceous crops as affect by EM, in organic fertilizer and organic amendments in the wet season.

Treatment	Capsicum		Egg plant		Tomato	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
	----- yield (g/m2) -----					
Inorg. Fert.	1461	1506	5242	5315	1524	1585
Gliricidia leaves	956	905	2109	2191	829	858
Rice straw	760	691	1545	1506	588	641
EM	595	601	959	1080	640	525
EM+GL	1045	1061	2459	2704	949	1011
EM+RS	799	645	1684	1724	632	714
EM+Fert.	1480	1548	5606	5799	1604	1683
Control	484	451	759	781	408	443
LSD(p=0.05)	127	98	104	148	67	60

Sangakkara (1991) explored that EM and OM promote the growth of soyabean, cucumber and cowpea. The data appear in table 9.

Table 9: Effect of EM on soyabean, cucumber and cowpea yield.

Treatment	Soyabean	Cucumber	Compare
	Yield increase %		
CF	-	-	0.3
OM	6.9	5.7	-
OM+CF	13.7	13.2	9.0

*CF = chemical fertilizer

Jiong et al., (1994) conducted tests in the greenhouse and protective ground showed that the spraying of EM increased yield of cucumber and tomato for both crops higher yields were obtained with higher EM concentration (Table 10).

Table 10: The effect of EM on vegetable yields.

EM concentration	**Cucumber**	**Tomata**
	(%) increase in Yield	
0.2	13.8	2.6
0.1	7.8	1.2
0.05	4.4	0.8
Control	-	-

Wididana & Higa (1995) studied the effect of EM dilution for the production of vegetable on fields. They said that percentage increase in the field is due to the fact that when EM is applied to the soil they stimulate the decomposition of organic waste and residues thereby releasing inorganic nutrients for plant uptake. Foliar application of EM appears to suppress the occurrence of plant diseases and facilitate the uptake of simple organic molecules that can increase plant growth and yield. They recorded the percent increase as follows: Data appear in table 11.

Table 11: Effect of EM concentration and frequency of application on the percentage increase in yield of crops compared with control.

Treatment		Yield increase from EM		
EM	Interval	Garlic	Onion	Tomato
(%)	(weeks)	(% increase compared with control)		
Control		Unity	Unity	Unity
0.1	1	12.5	4.3	0.6
0.5	1	8.1	9.7	1.3
1.0	1	1.7	11.5	19.5
.01	2	7.9	0.3	2.3
0.5	2	1.3	10.9	0.7
1.0	2	-1.7	6.1	12.6

*EM solutions were formulated with water on v/v basis.

Red Pepper

Sangakkara (1991) observed that the application of EM alone does not produce high yield, however, when added with organic matter, yield of both species increased significantly. Data appear in table 12.

Table 12: Effect of treatment on yield per plant of vegetable bean & Mung bean.

Treatment	Vegetable bean (yield g)	Mung bean (yield g)
O.M. 1	22.2	2.9
O.M. 2	26.1	5.2
O.M. 1+EM	25.2	3.3
O.M. 2+EM	35.2	7.0
EM (alone)	21.1	2.9
Fertilizer	60.8	8.6
Fert.+EM	64.1	9.1
Control	12.8	2.1
LSD(P=0.05)	5.0	0.2

Lee et al., (1993) further studied the effect of EM and EM-fermented compost on yield and disease incidence in Red Pepper. Yields progressively increased as increased rates of EM-fermented compost were applied to soil. Data are presented in table 13.

Table 13: Effect of EM & EM-fermented compost on yield and disease incidence in Red pepper.

Treatment	Yield (kg/10a)	Yield index (%)	Damping off (%)
Recommended NPK	481	100	50
EM-fermented compost @ 100kg/10a + EM spray	860	179	2
EM-fermented compost @ 200kg/10a +EM spray	971	202	2

Further information about the use of EM-Technology for Agriculture, Livestock, Poultry and Environment can be had from the following address. Email: naturef@paknet4.ptc.pk

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FRUIT PRODUCTION WITH EM

Disease control:

Jonglackha et al., 1993, studied the Root Rot of strawberry in normal and inoculated soil with EM. They concluded that application of EM solution (1:1000) for 4-6 times at weekly intervals gave considerable control of the disease. The data appear in table 1 and 2.

Table 1: Comparison of growth of *Rhizoctonia fragaria* causing rot of strawberry on PDA and PDA mixed with EM solution at four different concentrations.

Treatment	**With colony (cm)**				
	12 hr.	**24 hr.**	**36 hr.**	**48 hr.**	**60 hr.**
PDA+ster. Dist. Water	2.49	3.49	5.53	7.30	8.44 a
PDA+ster. EM	2.11	3.34	5.28	7.36	8.50 a
PDA+EM 1:100	2.17	2.60	3.75	4.47	4.68 d
PDA+EM 1:200	1.84	2.65	3.69	4.98	6.35 c
PDA+EM 1:500	2.67	3.59	4.72	6.04	6.95 b
PDA+EM 1:1000	2.64	3.45	4.29	5.81	6.80 b
LSD (p 0.05)					0.346

Table 2: Comparison of growth of strawberry cultivated in soil. Soil mixed with inoculum (*Rhizoctonia Fragariae*), inoculated soil treated with EM solution (1:1000) at weekly intervals of 3 various applications.

Treatment	**Stem weight (g)**		**Root weight (g)**	
	Fresh wt.	Dry wt.	Fresh wt.	Dry wt.
Soil	5.83 abc	2.05 a	4.84 ab	1.49 ab
Soil+Inoculum (IS)	4.89 bc	1.79 ab	4.45 b	1.45 ab
IS+1 EM appl.	4.60 c	1.47 b	3.95 b	1.18 b
IS+4 EM appl.	6.11 ab	1.73 ab	3.97 b	1.36 ab
IS+6 EM appl.	7.11 a	2.08 bc	6.14 a	1.70 a
LSD (p 0.05)	1.50	0.45	2.04	0.57

Orange

Hussain et al., (1995) studied the effect of EM on increasing the total soluble sugars, juice contents and fruit weight for two varieties of oranges. They concluded that fruit weight was considerably increased by application of EM. Similar result was obtained from Waluyo (1993) on water apple ston fruit and acerola by the use of EM-Bokashi. Data appear in table 3.

Table 3: Effect of EM on the quality and fruit weight of two citrus (orange) varieties.

Treatment	Total soluble sugar (%)	Fruit juice content (%)	Single Fruit weight(g)
Valencia-late variety			
Control	10.2	46.5	187.4
EM (40ml/plant)	10.3	49.3	189.9
EM (80ml/plant)	10.7	51.5	191.2
Kinno Variety			
Control	10.2	46.2	172.5
EM (40ml/plant)	10.3	48.4	172.5
EM (80ml/plant)	10.7	50.0	181.7

Paschoal et al., 1995 conducted experiment on citrus to study the effect f Effective Microorganisms on soil quality and control of Citrus Rust Mite (CRT). Results indicated that soil organic matter contents increased, pH of the soil decreased with the passage of time. Juice contents of fruit increased by 17% with the application of EM treatment compared with control.

Foliar application of EM increased rust mite population on the citrus leaves, however, soil applied EM decreased the leaf surface population. Data is given in table 4.

Table 4: Yield and Quality of oranges

Characteristic	**Control**	**EMS (soil)**	**EMP (plant)**	**EMPS (soil-plant)**
Yield (kg/10plants)	502.97 a	575.62 b	526.50 ba	580.00 b
Weight of juice (g)	573.11 a	639.94 b	638.74 b	672.83 b
Weight of peel (g)	597.28 b	525.96 ba	454.83 a	442.67 a

Paschoal et al., (1996) studied the effect of EM on soil properties and nutrient cycling in citrus agroecosystem.

After analysis of the chemical characteristic of the soil, they concluded that:

1) The organic matter content (OM) of the treated soil (with EM) was increased to significant levels.
2) The CEC (Cation Exchange Capacity) of the soil reached to significant level.

They also concluded that higher CEC level can be co-related to the OM contents which was enhanced by the activity of EM. Data is shown in table 5.

Table 5: Effect of EM on soil chemical properties at a Depth of 20-40 cm, after five application of EM in soil (EMS) to Citrus plants (EMP), and to Both plants and soil (EMPS).

Soil Properties	Control	EMS (Soil)	EMP (Plant)	EMPS (Plant-Soil)
OM (g kg^{-1})	16.8	20.4	19.4	19.9
pH ($CaCl_2$)	3.3	5.2	5.1	5.8
P (resion) mg dm^{-3}	1.8	1.7	1.7	1.5
K ($Cmol_c$ kg^{-1})	0.3	0.3	0.3	0.3
Ca ($Cmol_c$ kg^{-1})	1.0	0.9	1.0	1.1
Mg ($Cmol_c$ kg^{-1})	0.5	0.5	0.6	0.6
H+Al ($Cmol_c$ kg^{-1})	4.4	5.7	5.7	6.0
SB ($Cmol_c$ kg^{-1})	1.8	1.7	1.9	2.0
CEC ($Cmol_c$ kg^{-1})	6.2	7.2	7.4	8.0
V (%)	29.0	23.6	25.7	25.0

SB = Sum of Bases

V = 100 SB/CEC (Soil Base Saturation)

MAXIMUM PRODUCTION OF GARDENS WITH EM- TECHNOLOGY

Yields of gardens are decline due to several kinds of diseases and disorders in soil quality. The promising ones are malformation in mangoes, fruit fall and kanker in citrus and dieback in guava.

Mulching: EM research shows that it is extremely useful to mulch garden trees which improve plant-health and quality of fruits. Compete instruction for mulching are available from the office Nature Farming Research Center, University of Agriculture, Fisalabad.
E-Mail: naturef@paknet4.ptc.pk

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