Mechanism of EM

(Effective microorganisms)

In

Reclamation of saline-sodic soils

Abstract

A field experiment was undertaken to study the mechanism of EM in reclamation of saline-sodic loamy soil with the application of EM in all possible forms (soaking of seeds, 4.4 tons / acre composted FYM + PM, 130 Kg / acre EM Bokashi, EM irrigations and sprays) compared with conventional method of reclamation, which generally takes 2-3 years to fully reclaim such lands. EM Technology played a pivotal role in the reclamation of saline-sodic land and helped to obtain good yield of rice grain in the 1st year as compared to conventional method of reclamation. In the presence of easily decomposable organic matter the effective microorganisms (phototrophic bacteria, lactic acid bacteria and yeast) became in overwhelming majority and co-existed with other bacteria, fungi, actinomycetes and soil fauna and flora. During the decomposition of organic matter they synthesized and released useful substances such as organic acids (amino acids, nucleic acid, citric acids, acetic acids, lactic acids), alcohols, ethers, aldehydes, bioactive substances (vitamins, enzymes, hormones), sugars, polysaccharides, enhanced release of phosphates, fixed atmospheric N forming NH_4 and NO_3, broke down highly complex and resistant compounds (cellulose, starch, gums, lignins), released antibiotic (streptomycin, actinomycin, neomycin), produced humus (fluvic acid, humic acids, humic) and released macro-and micro nutrients (N, P, K, S, Ca, Mg, Fe, Mn, Zn, Cu etc) and other products (fatty acids, chelates) into the soil solution.

The level of reclamation achieved was reflected by the reduction in pH from 9.8 to 6.8, ECe from 67 to 5 dSm^{-1} and SAR from 79 to 11. This means that harmful soluble salts present in the saline-sodic soil and Na^+ present on the clay complex had been removed from the upper part of the active zone of the rhizosphere with the application of EM in all possible forms. The NH_4^+ and Ca^{++} released by the

decomposition of organic matter and Bokashi, which contained 1442 ppm Ca, have replaced Na^+ from the clay complex and thus Na^+ became a part of the soil solution, where it formed soluble salts NaCl and Na_2SO_4, which leached down to the lower layers of the loamy soil, the permeability of which is said to be moderate. This is the mechanism of EM in the reclamation of saline-sodic soils.

The reclamation and amelioration of saline-sodic soils as well as production of good crop is possible in the 1^{st} year using EM Technology, whereas in the conventional method of reclamation not only leaching of soluble salts as in case of saline soils with excessive irrigations is required but also the removal of exchangeable Na^+ from the clay complex with the application of soil amendments such as gypsum and H_2SO_4 as in case of alkali soils, is needed. EM Technology is effective, easy to prepare and use and leaves behind enhanced bacterial population increasing soil fertility for all times to come.

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1. INTRODUCTION

Pakistan represents a fairly broad spectrum of land resources. Agricultural potential has been explored for 43.69 million hectares (m ha) out of the total geographical area of 79.61 m ha of the country (Syal, N. M, 1985). Of the total area about 46.8 m ha forms the mountain terrain and valleys land and 32.8 m ha comprises a level plain and of which 20.54 m ha are presently cultivated (Hussain, T. et al 1991). Of the mountain terrain and valleys' area about 25 m ha, the non-arable resource, have very severe soil or site limitations. About 3.7 m ha are rainfed lands of moderate to marginal quality (Syal, N. M, 1985).

The major part of Pakistan experiences dry climate and agriculturally important area receives less than 250mm rainfall. Thus, agriculture is only possible with artificial irrigation with canals and tube wells in the level plan. Of the total area 16.84 m ha is the gross canal commanded area (GCCA; Irrigated agriculture of Pakistan by S. Nazir, 1988) and 11.79 m ha land is still lying as culturable waste for want of irrigation water (National Agriculture Commission Report, Govt. of Pakistan, 1988). Of the GCCA about 6.7 m ha have saline ground water, whereas in the Punjab Province 70 % of ground water pumped with tube wells is not fit for irrigation (Management of salt affected soils, Rapid Soil Fertility Survey, 1988). One cusec of canal water is available for 142 ha compared to 28.3 ha in USA. The extent of lands affected by salinity and sodicity ranges from 4.85 to 7.91 m ha.

The agricultural productivity even on prime lands (11.6 m ha; Syal, N. M, 1985) shows a decline trend because of deterioration of soils due to accumulation of salts in the rhizosphere in the absence of sufficient quantity of irrigation water to meet evaporation and consumptive use of various crops. For the amelioration of sodic soils application of gypsum and increased quantity of irrigation water is generally recommended and practiced, even sulphuric acid is also being used to accelerate the reclamation. The fertility of such reclaimed lands is tried to be stored within 2 to 3 years by adopting such methods with which organic matter contents and with that soil fauna and flora are increased.

To augment the cannel water a lot of research has been carried out to make it possible to use brackish ground water by adopting various cultural practices, use of sulphuric acid and their dilution; in spite of this the salinization and alkalization have not exhibited a declining trend. Actually continuous, unbalanced use and low efficiency of inorganic fertilizers combined with mechanized cultivation, reduced replenishment of macro-and micro-nutrients mined by crops, low organic matter contents and almost no fallow period have shown a detrimental effect not only on the chemical and physical properties but also on the biological properties of the soil.

Keeping in view the successful work done on the use of effective microorganisms (EM) in the field of agriculture in many countries of the world this piece of research work was undertaken to explore how EM Technology with all its components (manures treated with EM, EM Bokashi and EM irrigations and EM sprays) compared to conventional method of reclamation helps to reclaim saline-sodic lands by removing soluble salts and exchanging adsorbed sodium present in the upper part of soil profile and simultaneously by increasing the biological activity of the soil to maintain sustained production of crops, and to understand the EM mechanism .of ameliorating salt affected soils.

2. Material and Methods

The experiment was conducted during the year 2000. Before the start of the experiment in the field a lot of preparations were made. For example, selection of a suitable site having saline-sodic lands and irrigation source, enough space and storage facilities for EM products, plastic tanks, drums, buckets, scoops, weighing balance, rice bran, farm yard manures, poultry manure, preparation of EM solution and composts. Such a site was found in the premises of Himont Chemicals, Raiwind, about 30 kilometers form Lahore. One acre (0.4047 ha) measuring 220 ft x 198 ft saline-sodic field was demarcated for conducting the experiment. To manage the preparation of EM solutions, composting of manures, preparation of land, application of EM solutions, EM irrigation and EM sprays following procedures was adopted.

2.1 Preparation of EM extended solution for composting farmyard manure (FYM) and poultry manure (PM)

Total volume of the extended solution required is generally 30% of the total quantity of the material to be composted. EM extended solution was prepared with EM-1, sugar cane molasses and water in a ratio of 1:5:14. For composting 2 tons manure (1 ton FYM and 1 ton PM) for the treatment of experimental area a quantity of 600 liters EM extended solution containing 30 lit EM –1, 150 lit sugar cane molasses and 420 lit clear water was needed. First of all 150 Lit sugarcane molasses were mixed well with 420 Lit water in installments and then 30 Lit EM –1,which is already in liquid form, was mixed thoroughly with molasses solution. The container was made airtight and kept in a room for 7 days for fermentation and multiplication of useful microorganisms. On 8th day it was ready giving a nice fermenting smell with pH 3.5.

2.2 Making of compost from FYM & PM

One-ton air-dried FYM & one ton PM was taken, thoroughly mixed, transformed into a heap and about 500 Lit EM extended solution was mixed with the manure by sprinkling with a small fountain in installments manually. At the end the heap was covered with a plastic sheet to ferment it anaerobically for 6 weeks. After every 10 days it was reopened and moisture contents were kept at 30% with the remaining EM extended solution and again made anaerobic. The compost was ready after 6 weeks period and stored in a room

2.3 Making of Bokashi from rice bran.

50 Kg rice bran was taken, mixed well manually with 15 Lit EM extended solution containing 2.5 grams EM powder, packed in plastic bags, made airtight and kept in a room for 4 weeks to ferment. It was ready in the 5^{th} week giving a peculiar fermented smell having pH 6.0. It is called Bokashi (a Japanese word meaning organic matter).

2.4 Preparation of EM extended solution for irrigations and sprays.

EM extended solution for irrigation and sprays was prepared with EM-1, molasses and water in a ratio of 3:5:12. A total quantity of 133 Lit was made by mixing 20 Lit EM-1, 34 Lit molasses and about 80 lit water. It was fermented for 7 days. Four irrigations each with 32.5 Lit to EM plots were given and the remaining 3 Lit after dilution with water (1:1000) was used for spraying and soaking of rice seed.

2.5 Soil sampling of original soil and after EM treatment

From the whole acre 16 soil samples from 16 plots (Fig.-1) were taken with long-blade spade from 0-15 cm depth. All the samples were put together on a plastic sheet, thoroughly mixed and dried in the sunshine. 10 Kg soil was taken, ground and sieved with a 2 mm sieve. Of which 2 Kg soil was taken and stored in a plastic jar for further analyses. This was the original soil.

At the maturity of the rice crop the second soil sampling was made from 0-15 cm depth from the plots of conventional method of reclamation (CR-soil) as used by the farmers of the area and EM treated plots (EM soil, Fig.-1). Composite samples for CR-plots and EM plots were prepared, crushed, ground, dried in the sunshine, sieved with 2 mm sieve and 2 Kg soil sample of each was stored in plastic jars for further use

2.6 Lay out the experiment

One acre (220 ft x 198 ft) was got well cultivated with a tractor before layout. It was well demarcated all around with earthen bund of 16 inches at the base. A watercourse with earthen bund (5 ft 4 inches) was made in the middle of 198 ft side, thus leaving net plot length of 95 ft. The other side (220 ft) was equally divided into 8 plots with 9 earthen bunds each of 16 inches at the base, thus leaving net plot width of 26 ft. The plots for the CR and EM treatment were fully randomized (Fig.-1)

2.6 Preparation of land and application of inorganic and EM material.

In the plots of conventional method of reclamation (CR) the total quantity of P & K and ½ N (calculated on N=54 Kg, P=27 Kg and K=25Kg per acre) was applied in the first week of June and irrigated with tube well water. At proper moisture condition the land was ploughed with bullocks. The remaining N was applied just at the start of emergence of panicles. NPK was applied through urea, single super phosphate and potassium sulphate respectively.

In each EM treated plot 240 Kg composted manure and 6 Kg Bokashi was mixed thoroughly and evenly spread. In each plot a quantity of 16.5 Lit EM extended solution was dripped into the tube-well water at the entry point during irrigation. At suitable moisture content the land was ploughed with bullocks.

2.8 Growing of Nursery and Transplantation

5 Kg rice seed of variety Basmati 385 was soaked for 24 hours in 1000 times diluted EM extended solution (prepared under iv) and then sown on 11th May 2000 in a small plot prepared for nursery. It was ready after 7 weeks. It was transplanted into CR plots and EM plots during first week of July 2000. Before transplantation the plots were irrigated with tube-well water and nursery was transplanted in standing water manually. The irrigations were given with tube well water to CR-plots and EM plots. EM extended solution of 16.5 lit was dripped with (3rd, 5th and 7th irrigation in EM plots). EM spraying with 1000 times diluted EM extended solution was done before 2nd, 4th and 6th irrigation.

2.9 Harvesting of Rice Crop.

The rice crop was harvested during 10-20 November 2000.

2.10 Characteristics of original soil, tube-well water and other materials used in the experiment.

The properties of the original saline-sodic soil and reclaimed land with CR and EM are given in table-2. The soil is loam in texture. Tube-well water was having pH 8.1, EC x 10^6 1446, CO_3 nil, HCO_3 9.16 meq/L, Na 11.62 meq/L, Cl meq/L, Ca+Mg 2.84 meq/L, SAR 9.8 and RSC 6.32. The water is having higher RSC, the water is classified as hazardous if RSC is > 1.25 by the Water and Power Development Authority (WAPDA /WASID) & by Agriculture Department of Government of the Punjab Province, Pakistan. The EC x 10^6 1446 also comes under hazardous.

Animals' dung + urine (cow, bull, buffalo, goat, sheep, and poultry) contain on an average N 3.62%, $P_2 O_5$ 1.33% and $K_2 O$ 2.67%. EM Bokashi prepared from rice bran has pH 4.6, N 1.8%, P 210 ppm, K 960 meq/L, Mg 40 meq/L, Ca 72 meq/L, S 251 ppm, Cu 10 ppm, Zn 55 ppm, Mn 80 ppm, B 41 ppm, Fe 45 ppm, and organic matter 84.54%.

2.11 EM (effective microorganisms):

Prof. Dr. Teruo Higa, the University of Ryukyus, Okinawa Japan with sustained and diligent research produced the first batch of effective microorganisms, which eventually called EM in 1980. EM is a liquid concentrate. EM is a combination of various beneficial naturally occurring microorganisms mostly used for or found in food. It is produced in vats from cultivations of over 80 varieties of microorganisms. The microorganisms are drawn from 10 genera belonging to 5 different families. The most outstanding characteristic of EM is this that it includes both aerobic and anaerobic species coexisting symbiotically in a most beneficially productive manner. EM contains beneficial tiny anabiotic microorganisms from 3 main genera phototrophic bacteria, photosynthetic bacteria, lactic acid bacteria, yeast, fungi and effective actinomycetes. A positive feature of effective microorganisms is that they secrete large amounts of nutrients such as amino acids, organic acids, chelated minerals, antioxidants, polysaccharides and vitamins when in contact with organic matter.

2.12 EM Powder:

It is an extract of all types of useful beneficial bacteria in powder form.

2.13 Investigations:

Special investigations such as analysis of minor elements and heavy metals, ICP-MS analysis, soil structure with electron microscope, aggregate stability, microbial population indicating beneficial and non-beneficial micro-organisms and enzymes were made to study the mechanisms of EM in the reclamation of salt affected soils.

Fig –1. Layout plan for conventional method of reclamation (CR) and EM Technology (EM)

EM	CR
CR	EM
EM	CR
CR	EM
EM	CR
CR	EM
EM	CR
CR	EM

Watercourse

3. Results and Discussion

3.1 Soil reaction - pH

The pH value of an aqueous solution is the negative logarithm of the hydrogen ion activity. The pH value of the original (saline-sodic) soil was 9.8. At the completion of the experiment the soil reclaimed by conventional method of reclamation (CR-soil) had pH 8.8, and the soil reclaimed with the application of EM and organic manures and Bokashi (EM-soil) showed pH 6.8 (table-1).

The pH values of 8.5 or greater almost invariably indicate an exchangeable-sodium-percentage of 15 or more and the presence of alkaline earth carbonates (Agriculture Handbook # 60, United States Department of Agriculture, February 1954, pp18). The pH values of CR-soil and EM-soil have decreased as compared to the original soil value but the application of EM with organic manures and Bokashi had decreased the pH drastically indicating that EM had reduced the salts significantly and the nutrients uptake were also enhanced as reflected in the crop performance.

The application of EM with organic manures (FYM, PM, green manure, filter cake of sugar industry etc) reduced pH of brackish water after 15 days incubation period (Hussain, T. # 19). Soil pH was reduced with EM treatment (Jillani, G. # 32). Compost amendments alleviated some effects of pH of saline soil (Pairintra, C. & Pakdee # 39).

3.2 Electrical Conductivity of the Saturated Paste of the Soil (EC_e):

EC_e of the original, CR-soil and EM soil is 67.0, 54.0 and 5.0dSm^{-1} respectively. Conventional method of reclamation (CR method) has not shown considerable effect on the EC_e; on the other hand EM has lowered it significantly. (Table-1).

The application of EM reduced EC of wastewater of a cheese plant by 20% and of wastewater of a Hog Farm in California significantly (Aries Tek Ltd 2000 & 1999 # 4 & 5). EC of brackish water (2.25 dSm^{-1}) was reduced by applying FYM, green manure (GM), filter cake of sugar industry, PM with EM after incubation period of 15 days (Hussain, T. # 19). The N requirement of crops decreased with an increase in soil salinity (Hussain, T., et al # 20). The growing of GM crops and their burying under the soil (biological treatment) helped to grow rice crop successfully even with brackish water. The cyclic use of brackish water of drains and canal water for crop production is to be undertaken with a little risk. The application of saline sodic water increased the ECe (Hussain, T. et al # 21). The application of FYM increased the exchange of Ca with Na; thus, decreased the exchangeable sodium and soluble salts in the soil (Hussain, T. et al # 22). ECe of the soil decreased with GM application as compared to control (Hussain, T. et al # 26). ECe of the soil was reduced with the EM treatment (Jillani, G. # 32). Compost amendments alleviated some effects on ECe of saline soil (Pairintra, C. & Pakdee # 39).

3.3 Sodium Adsorption Ratio (SAR):

SAR of the original, CR-soil and EM soil is 79.0, 36.9 and 10.7 respectively. SAR has been calculated with the formula given in the Agriculture Hand book # 60. The Na is the minimum in the EM (25 meq/L) and the highest in the original soil (485 meq/L; table-1). The application of EM reduced the SAR of wastewater of a cheese plant by 54% and that of a Hog Farm significantly (Aries Tek Ltd 2000 & 1999 # 4 & 5). SAR of the soil decreased with GM as compared to the control (Hussain, T. et al # 26).

Table – 1: **Chemical Analyses of original, CR- and EM Soil.**

Parameters		Original Soil*	CR Soil**	EM soil**
pH		9.8	8.8	6.8
EC_e	dSm^{-1}	67.0	53.0	5.0
OM	%	0.41	0.48	2.10
Na	meq/L	485	335	25
Ca+Mg	meq/L	75	165	11
N	%	0.02	0.02	0.45
Zn	mg/Kg	0.65	0.97	30.6
Cu	mg/Kg	0.3	1.01	1.58
Fe	mg/Kg	6.4	19.1	22.5
Mn	mg/Kg	9.3	10.0	12.5
SAR		79.1	36.9	10.7
Texture		Loam	Loam	Loam

- Samples taken during first week of April 2000

** Samples taken during last week of October 2000 at the maturity of the rice crop.

Table-2: Contents of trace elements, heavy metals and Na in the original and EM Treated soil

Name of the elements	Methods	Original Untreated soil (ppb)	EM treated Soil (ppb)
Na	0.1 N HCl leaching	3200	
	ICP –MS	2900	1600
Cl	0.1 N HCl leaching	5560	2800
	ICP –MS	5500	2100
Al	0.1 N HCl leaching	130	95
	ICP –MS	130	70
Cr	0.1 N HCl leaching	25	26
	ICP –MS	35	19
Cd	0.1 N HCl leaching	35	18
	ICP –MS	28	18
Fe	0.1 N HCl leaching	520	300
	ICP –MS	520	270
B	0.1 N HCl leaching	2000	1000
	ICP –MS	1900	980

3.4 Determination of Micronutrients (trace elements), heavy metals and Na in the CR-soil and EM-soil.

The plants take thirteen mineral elements from the soil. Six elements {N, P, S (anion) and K, Ca, Mg (cation)} are classified as macronutrients, and 7 {Cl, B, Mo (anion) and Fe, Mn, Zn, Cu (cation)} are termed as micronutrients. This classification has been made according to the quantity of the elements taken by the plants. According to the chemical characters Fe, Mn, Zn, Cu, Mo are heavy metals. The heavy metals were determined to see the effect of EM on the bio remediation of these metals as the soil on which the experiment was carried out contained some quantity of waste material of Himont chemicals pharmaceuticals.

Heavy metals and trace elements were determined with two methods i.e. 0.1 N HCl leaching and inductively coupled plasma mass spectrometry (ICP-MS) and the results are given in table-2. The results of the two methods are almost identical. The perusal of the data indicates that the EM treated soil have less contents indicating that the EM with all its products have reduced the elements in the soil. The effect on the reduction of Na 49.2% and Cl 55.7% is specifically to be noted indicating that NaCl has been eliminated up to 50%. Al, Cr, Cd, and Fe have been reduced by 36%, 25%, 43%, and 45 % respectively. Boron has been reduced by 50%.

EM treated compost is recommended as an efficient soil amendment in ameliorating a saline soil (Pairintra, C. and Pakdee # 39). The solution of EM –4 extracted a significantly greater proportion of all nutrients from all organic fertilizers (Piyadasa, E. R., et al # 40).

3.5 Detection of anions, cations, and C & O in CR-soil and EM-soil.

Anions were determined with neutral salt leaching method using leaching solutions M NaOH and 0.01 M Na_2 HPO_4. The measured values were expressed in $CgKg^{-1}$. Five typical kinds of negative ions that were found in the soil solution were Cl, SO_4, HCO_3, H_2 PO_4 and NO_3. The measured value for the Cr-soil and EM treated soil was 80 $CgKg^{-1}$ and 210 $CgKg^{-1}$ respectively indicating that eliminations / removal effect was higher (2.625 times) in EM treated soil compared to CR-soil.

The cations were determined with surface scanning of the soil (XPS-X ray photo electron spectrometer) with which quantitative analysis and chemical bonding phase analysis of the specimen were conducted. As a result of wide scan Na, Fe, Ca, Si, Al, C and O were detected. The results in atomic % for CR-soil and EM treated soil are given in table –3. The perusal of the data indicates that Na, Ca, Fe is removed / reduced more in the EM treated soil compare to CR-soil. Both the cations and anions were removed more in EM treated soil as compared to the CR-soil. The presence of C & O in greater quantities in EM treated soil as compared to CR-soil (Table –3) suggests that the decomposition of applied materials (FYM, PM- compost, Bokashi) was faster and with that the increased bacterial activity secreted more beneficial substances such as vitamins, organic acids, chelated minerals and anti oxidants into the soil solution.

From the data of research work carried out on "recycling of municipal liquid waste using EM Technology for domestic use" it was reported that EM has the potential to deoxidize the heavy metals and convert these into organo-metallic compounds, which are not harmful for human and animal health (Hussain, T, 2001 # 24). Both EM solution and EM compost increased the level of available P_2O_5, Ca and Mg in the soil (Lee, K. H. # 33).

Table –3 Detection of cations and C & O in atomic % in the CR-soil and EM-soil.

Type of Soil	Na	Fe	Ca	Si	Al	C	O
CR-soil	1.0	0.1	0.1	14.6	15.6	10.5	48.0
EM-soil	2.5	1.7	5.5	14.2	16.6	17.0	56.8

Table –4. Enzymes activity (U/L) in the CR-soil and EM-soil.

Type of soil	1st reading	2nd reading	3rd reading	Average
CR-soil	230	229	228	229
EM-soil	2643	2650	2456	2583

Table –5. Measurement of bacteria in 10YG culture media.

Type of soil	1st reading	2nd reading	3rd reading	Average
CR-soil	16×10^4	12×10^4	12×10^4	13.3×10^4
EM- soil	20×10^4	18×10^4	18×10^4	18.6×10^4

3.6 Determination of Enzymes in CR-soil and EM-soil.

Enzymes activity in the CR-soil and EM-soil was examined. The enzymes extract in the respective soil was extracted with phosphoric acid buffer solution and the enzymes were estimated by an oxygen electro method. Enzymes activity was the least (on an average 229 U/L) in the CR-soil as compared to 2583 U/L on an average in the EM-soil (table 4).

EM –1 introduction into the soil before and after sowing plants leads to the activation of photosynthetical processes, which increase the formation of chlorophyll, protein and activity of number of enzymes in particular the increase of peroxidase activity in plants (Minsk, 1998 # 36 & 37). The addition of organic manure (12 tons / ha) caused approximately three times increase in the activity of enzymes (L-glutaminase and L-asperginase) in the microbes than NPK as chemical fertilizer (Sikandar, A. # 48).

3.7 Determination of bacterial population in the CR-soil and EM-soil.

The bacterial population in the CR-soil and EM-soil was determined by "YG-culture-media method" and bacteriological analysis by "dilution incubation of bacteria" (table –5 and fig –2 & 3). The data in table –5 indicate that the bacteria in the EM-soil are abundant than in the Cr-soil, on an average the bacteria are more by 5.3×10^4. The bacteriological analysis (fig 2 & 3) showed that in EM-soil small colonies were of lactic acid bacteria as confirmed by the formation of air bubbles with the drops of hydrogen peroxide solution, and larger gray colonies were of bacillus group as presumed from the observations made on characteristics of colonies and identification of colors. The identification of various types of bacteria was made by ribo-printer system applying molecular biology technology and the bacteria identified are tabulated in table –6.

EM treatment has increased the number and types of bacteria significantly. In Cr-soil only 7 types of bacteria were found whereas in EM-soil 27 types of bacteria had been found. In CR-soil E.coli group and Fungi are harmful and these nourish if favorable environments are available. The application of EM has increased the beneficial types of microorganisms such as Rhodobacter, Pseudomonas, Lactobacillus, Furabacterum, and Gluconobacter etc, which have the ability to produce proteins, minerals and antioxidant in the soil. According to Dr. Harwood Caroline, Prof. of Microbiology (Harwood Caroline, # 14) bacteria are the most primitive form of microorganisms but are composed of a great variety of simple and complex molecules and are able to carry out wide range of chemical transformations. Their optimum growth occurs at a temperature ranging between $25^{o}C$ and $40^{o}C$ (mesophiles). Rhodospirillum, Rhodopseudomonas and Rhodobacter microorganisms use Sulfide in their metabolism and can utilize a variety of carbon sources from carbon dioxide through simple sugars to aromatic compounds. They derive their energy from light (phototrophic). According to Prof. Dr. Teruo Higa, University of Ryukyus, Okinawa, Japan (Higa, Teruo 1993 # 15 & Higa, T. & G.N. Wididana, 1999 # 17) the Rhodopseudomonas-sp synthesize useful substances such as amino acids, nucleic acid, bioactive substances and sugars. The Azotobacter can fix atmospheric nitrogen. The Lactobacillus species suppress harmful microorganisms and promotes the fermentation and decomposition of lignin and cellulose and enhances decomposition of organic matter. Lactic acid bacteria have the ability to suppress Fusarium (disease inducing microorganisms). The combination of beneficial microorganisms in EM is such that it develops a well balanced microbial system in the soil. The effective microorganisms in EM Technology maintain a symbiotic process with the roots of plants in the rhizosphere and favorably interact with soil microbial communities and promote beneficial relationships between biotic and biotic factors, which enhance the health of soil, and growth of plants. Bacteria also synthesize cementing agents in the form of gums and polysaccharides that also help to promote to good aggregation. Lynch, 1981 found that Azotobacter Chroococcum, Lipomyces starkeyi, and Pesudomonas spp can promote the stablization of soil aggregates.

The application of organic matter to soil encourages microbial activity. The importance of azolla, N-fixing rhizobia and P-dissolving bacteria were recognized (Abd El-Hameid Nofal, M & Attiat Abo-Bakar Aly # 1). Various institutions in Pakistan have carried out work on biological fertilization. These have isolated strains rhizospheric bacteria, which have potential for mobilizing atmospheric N, both on legumes and non-legumes. These are sold under the name Biozot, Bio Power. Strains of Aspergillus niger and Penicillium spp. have properties of solubilizing P from soil as well as from rock phosphate (Ahmad, N # 2). EM application generally inhibited the growth of phytopathogenic fungi and bacteria (Castro, C.M. et al # 8). The application of microbial inoculant produce growth promoting substances (hormones) in the rhizosphere of the plant (Fauzia Y. Hafeez # 11). The soil organic matter is being depleted continuously and it must be supplied through organic resource (crop residue, organic manures, green manures, wastes recycling, filter cake of sugar industries and biogas slurry) to maintain the biological the activity of the soil (Gill, H. K. # 13). Rhodopseudomonas palustris, a bacterium, can convert atmospheric N into ammonia, a critical biological building block, which only bacteria can perform this transformation. Bacteria are the most primitive form of microorganisms but are composed of great variety of simple and complex molecules and are able to carryout wide range of chemical transformations (Harwood Caroline, # 14). EM is source of enhancing soil fertility and reducing the problems of agriculture (Hong-Gon, R. # 18). RDX is widely used military explosive. It is a synthetic compound. Even biodegradation of RDX occurs anaerobically by a mixed population of purple photosynthetic bacteria of the genera Chromatium, Rhodospirillum, and Rhodopseudomonas, and possible others. It was hypothesized that RDX was not actually metabolized, but rather was reduced and modified as a result of active electron transfer brought about by the anaerobic photosynthetic activity of the organisms. Yeasts extracts acclimated RDX-utilizing organisms (Jackson, P. J. # 27). Application of EM Bokashi increased the number of Azotobacter, Azossprillium, Bacillus and Lactobacillus in the soil. The application of EM –3 significantly improve the counts of beneficial bacteria in rhizosphere (Jamil, M., et al # 30). Rhizobium and AM-mycorrhizal inocula are now widely used in specific crops to improve nutrient supply (Leifert, C. et al # 34). The soil hyphae of mycorrhizal fungi effectively increase the rhizosphere around plant root (Milliner, P.D. and D. D.

Kaufman, # 35). The proper and regular addition of organic amendments tends to increase the numbers and diversity of beneficial soil microorganisms, which are vital to the growth, nutrition and protection of plant. The use of EM as microbial inoculant in agriculture was found to be a promising new technology that can improve soil quality and health (Paar, J. F. and S. B. Hornic # 38). EM treated compost gave the highest overall microbial population (Pairintra, C. and Pakdee # 39). The organic materials release CO_2 on decomposition and forms carbonic acid and promote bioactivity by providing energy sources (Sadiq, M. # 43). EM applied with organic matter changed the plant rhizosphere into more conducive conditions (Sangakkara, U.R. # 46). The addition of organic matter to soil serves as substrate to microbes and increase microbial biomass in soil. The microbial number in the top soil (3-8 cm) may be 12 million / gm comprising live biomass of bacteria 100-4000 Kg / ha, while double of this biomass for all the microbes (bacteria, actinomycetes, fungi and algae) forming 0.02 – 0.8 % of total soil biomass. The bacterial count was more than double for FYM than urea (Saikandar, A. # 48). Soil microbial populations (bacteria, fungi, actinomycetes and N fixing microorganisms) were 1.5 times higher in the organic matter treated with EM than for organic matter alone (Zhao, Q. # 57). The organic matter contents are low in agricultural soils of Pakistan (0.3 to 1.2 % in the soil of 4 rice zones). It has been advocated for integrated plant nutrients management strategy that all possible sources (FYM, green manure, compost, crop straw, bio fertilizers etc) to increase the organic matter be adopted. Soil organic matter is key material resource, which acts as a source and sink of key nutrients and modifies the structural properties of the soil (Zia, M. S., et al # 58).

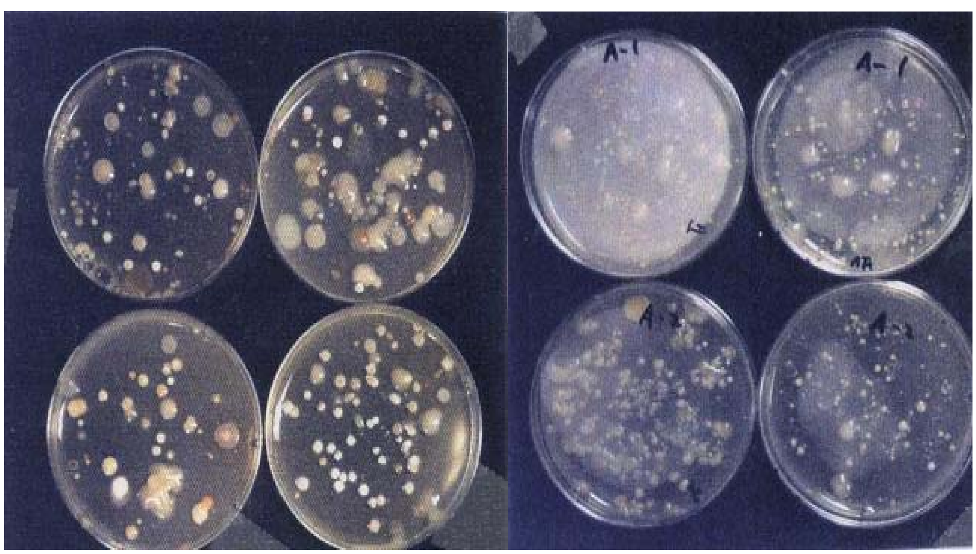
Table –6. Types of bacteria in CR-soil and EM-soil

Sr. No	Salt affected soil (control)	Sr. No	EM treated soil
1	Bacillus-sp	1	Azotobacter-sp
2	Entrobacter-sp	2	Bacillus -sp1
3	E. coli group	3	Bacillus-subtile
4	Fungi	4	Clostridium-treponema
5	Pseudomonas-sp	5	Corymebacerium-sp
6	Streptococcus-sp	6	Furabacterum
7	Seratia-sp	7	Gluconobacter-sp
		8	Lactobacillus- cassei
		9	Lactobacillus-sake
		10	Lactobacillus-sp
		11	Lactobacillus-sp1
		12	Lactobacillus-sp2
		13	Micrococcus-sp
		14	Micrococcus-sp1
		15	Micrococcus-sp2
		16	Pseudomonas- aeruginosa
		17	Pseudomonas- fluorescens
		18	Pseudomonas- putida
		19	Pseudomonas- Q1
		20	Pseudomonas- type –1
		21	Pseudomonas- type –2
		22	Pseudomonas-sp
		23	Rhodobacter-capsulatus
		24	Rhodoseubodomonas-sp
		25	Rhodospirillum-sp
		26	Streptococcus-sp
		27	Treponema-sp

Fig –2. Dilution incubation of CR-soil and EM-soil

Conventional Method of Reclamation Soil.　　**EM Soil**

Fig –3. Isolation of colony of bacteria in CR-soil and EM-soil



Conventional Method of Reclamation Soil.　　**EM Soil**

3.8 Determination of chemical bonding of elements especially Si & Al

The photoelectrons energy emitted from a very shallow depth (10^{-9}mm) of soil is dependent on the peculiar bonding of elements. This can be measured by XPS (X-ray Photoelectron Spectrometry) techniques. Si & Al were observed at each waves-peek. The values for Al_2O_3 and SiO_2, and Al-O-Si and Si-O-Al are given in table –7.

The study on C-bonding revealed that C is better bonded with H & O in the EM treated soil than in the CR-soil. This means that the absorption and elimination of salts in the CR lands is easy by using EM Technology in which abundant organic matter is used.

The perusal of the data show that the concentration of Al_2O_3 and SiO_2 in CR-salt is abundant than in the EM-soil. On the other hand the Al-O-Si and Si-O-Al is more in the EM treated soil. The presence of oxides of Al & Si is considered to be not favorable for bacterial nourishment and growth. The complexes / chelates formed by Al & Si are not harmful to the microorganisms. More complexes were formed in EM treated soil as compared to the CR-soil (table –8). The formation of complexes / chelates helps to increase aggregation of soil particles and enhance the soil structures.

The CO_2 production in the organic matter + EM treated soil was the highest as compared to chemical fertilizer and organic fertilizer [4545, 316, 4158 mg {Filho, S.Z. et al # 12}]. This indicates the rapid decomposition of organic matter and maximum release of C & O for further utilization in the soil. Most species can utilize a variety of C sources from CO_2 through simple sugars to aromatic compounds, and are phototrophic (Harwood Caroline # 14).

Table –7: Elements waves-peek separation analysis

i) Al2p

Peak position (eV)		Intensity (CPS)		Belonging to	Persistence (%)	
CR-soil	EM-soil	CR-soil	EM-soil		CR-soil	EM-soil
75.64	7528	418.1	419.9	Al (OH)	24.4	25.7
74.95	74.69	865.8	595.9	Al_2O_3	50.5	36.4
74.10	73.97	358.6	507.9	Al-O-Si	20.9	31.0

ii) Si2p

Peak position (eV)		Intensity (CPS)		Belonging to	Persistence (%)	
CR-soil	EM-soil	CR-soil	EM-soil		CR-soil	EM-soil
103.60	103.60	1346.3	380.6	SiO_2	49.8	16.7
102.85	102.85	1110.7	1482.6	Si-O-Al	36.4	65.8
101.81	101.79	1521.8	151.8	Si-O-Na	31.0	12.8
100.50	100.60	113.5	94.1	SiC	6.9	4.4

Table –8: Complexes / chelates formed in CR-soil land and EM-soil

CR-soil	EM-soil
SiO_2	$KalSi_2O_8$
$(NaK)\ (Si_2Al)O_8$	$r\text{-}Al_2O_3$
$KalSiO_3O_8$	$PbTiO_3$
$KalSiO_3O_8$	$(SiO_2)X$
$(Ca.Na)\ (Si.Al)_4O_8$	$C_4.4H_{12}.85Al_2Nil.150_8$.
$(NaK)\ (Si.Al)_4O_8$	(Hoshimura et al.1999
(Al_2O_3)	$05P1.80.22H_2O$
$(Ca.Na)\ (Al.Si)_2SiO_8C$	55C(C4H9)2NH
$SiO_2)X$	$0.3(NH_4)20.Al_2O_3$
	$0.95P_2O_8.O.20.Al_2O_3$
	SiO_2
	$KalSi_3O_8$
	$KalSi_3O_8$
	$(Fe_2O_3)100M$
	$(NaK)AlSi_3O_4.1/2(NaK)_3O$.
	$Al_2O_3.6SiO_2$
	$NaO.61KO.39AlSi_3O_8$
	$(Na.Ca)Al.Si)_4O_8$
	$Ca7Na_3Al_1.7Si_2.3O_8$
	Al_2O_3
	$1/2(N,K)_2O.Al_2O_3.6SiO_2$
	Ca.7Na.3Al.Si2.3O8

3.9 Determination of organic acids in the CR-soil and EM-soil

The organic acids from the CR-soil and EM-soil were determined using solvent-extraction liquid with a high-speed liquid chromatograph (table –9).

The perusal of the data show that the acetic acid and citric acid are abundant in the EM-soil while it could not be detected in the CR-soil. The lactic acid is more in the EM-soil 1.12 % as compared to the CR-soil where it is only 0.39 %. The decay related butyric acid was not detected in the EM-soil while it was 0.45 % in the CR-soil.

The organic acid are said to couple soil particles to form aggregates especially the citric acid acts like a paste for joining the soil particles together. This phenomenon suggests that aggregates structure is formed in the EM-soil as compared to the CR-soil. The same was confirmed with surface scanning of the soil using an electron microscope (Fig –2 & Fig –3).

The application of EM accelerated the decomposition rate of organic amendments applied to soils, improved certain chemical and physical properties and enhanced the mineralization and availability of nutrients. It resulted in the higher concentration of soluble sugars (poly saccharides), which are "binding materials" to promotes aggregation of soil particles (Filho, S. Z. et al # 12). The organic matter is depleted by 0.02 % annually in the soils of the Punjab Province of Pakistan. Therefore, for maintenance of soil fertility organic manures be applied with commercial fertilizer sustainable agriculture (Gill, H. K. # 13). Often during bacterial growth, organic acids are released into the medium (Harwood Caroline # 14) The effective microorganisms develop amino acids, nucleic acids, bioactive substances (hormones and enzymes) and sugars. The lactic acid promotes decomposition of lignin and cellulose (Higa, Teruo. 1993 # 15). Lynch 1981 found that Azotobacter Chroococcum, Lopomyces and Pseudomonas spp could promote the stablization of soil aggregates. Fungi can bind soil particles into more stable aggregates. Bacteria can synthesize cementing agents in the form of gums and polysaccharides that also help to promote good aggregation (Higa, T. and G. N. Wididana 1989 # 17). EM Technology is a powerful tool to convert all types of crop residues, farm manure and biodegradable municipal and industrial wastes into a high quality biofertilizer in just 10 to 22 days depending upon the type of material and temperature. The microorganisms contained in EM through anaerobic fermentation convert the organic carbon into amino acids and polysaccharides, which can be assimilated with very low energy by the roots (Hussain, T. and A. Haq # 25). The microorganisms convert organic material such as manure, sludge, leaves, paper and food wastes into a soil like material called compost. The composting process produced heat with drives off moisture and kills pathogens and weed seeds. During composting many organic acids are produced (Jacobson, L. et al # 28). Changes in soil physical soil properties namely bulk density, soil moisture retention and aggregate stability were studied by adding EM to an acid soil (Ultisols) at different fertilization (inorganic, organic and mixture of organic and inorganic fertilizer each with EM and without EM). Fertilization improved soil aggregate stability and EM inoculation further enhanced this property. The increase in aggregate stability was greatest with EM and organic fertilizer, and lowest without EM in inorganic fertilizer (Jamal, T., et al # 29). EM application increases the release of nutrient from organic matter, enhanced photosynthesis and protein activity (Sangakkara, U.R. # 45). Fungi and bacteria (phosphate solubilizers) secrete organic acid and help in solubilization of insoluble P-compound in soil. Fungi, bacteria and actinomycetes (decomposers) break down the organic material, form humus and unlock the useful nutrients (NPK, S, trace elements). Mycorrhizal fungi have been reported to mobilize P and other nutrients in normal as well as saline soil. Some microbes liberate antibiotic and other compound and act as biological control of pathogens. The fungi and algae help in aggregate formation in soil. The formation of organic acids during the decomposition act as chelating agents. Decomposition of organic materials under anoxic conditions proceeds in two stages. Organic acids are formed at first stage and their conversion to water and gases (CO_2, CH_4, N_2, HPO_2, NH_3 etc) takes place in the second stage. Volatile fatty acid is formed during decomposition of organic materials. Some of the microbes (Clostridium) utilize only amino acid as energy sources for production of acetic acid, butyric acid and other fatty acid. The use of EM was more useful for increasing rice grain yield with green manure, which provided energy and nutrients requirements to microbes in a better way. During decomposition proteins are broken down into amino acids, then into ammonium and nitrate by microorganisms (Sikandar, A. # 48). Lactobacilli and yeasts were present in higher concentration for a longer period when organic matter was mixed with EM rather than with water alone and similarly in Bokashi. EM produce growth promoter (Yamada, K., et al # 53 & 54).

Table –9: Organic acids in the CR-soil and in the EM-soil

Organic acids (%)		1st rdg*	2nd rdg	3rd rdg	4th rdg	5th rdg	Average (%)
Acetic acid	EM soil	0.75	0.87	0.79	0.80	0.89	0.82
	Control	ND**	ND	ND	ND	ND	-
Butyric acid	EM Soil	ND	ND	ND	ND	ND	-
	Control	0.36	0.56	0.50	0.40	0.46	0.45
Lactic acid	EM Soil	0.60	1.08	0.96	1.39	1.56	1.12
	Control	0.45	0.70	0.54	0.14	0.14	0.39
Citric acid	EM Soil	1.70	1.75	1.75	1.90	1.78	1.78
	Control	ND	ND	ND	ND	ND	-

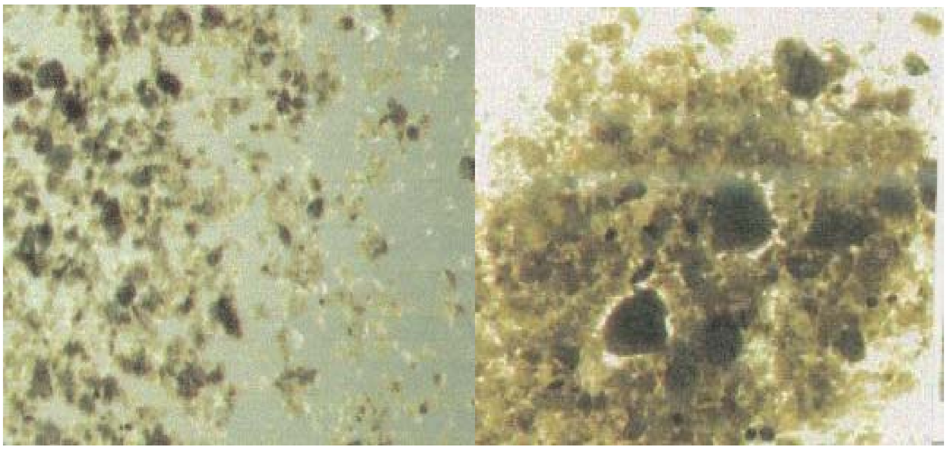
- **rdg = reading**

** **ND = not detected**

Fig –3. The image showing the aggregate structure in EM-soil

Conventional method of reclamation soil. EM soil

Fig –4. Presence of crystals of salt surrounded by black decayed substances in the CR-soil.



Conventional method of reclamation soil. EM soil

3.10 Crop performance

Rice crop was grown in the CR-soil and EM-soil. Observations made on mortality showed that it was 30.9 % more in the CR-soil as compared to EM-soil. This affected also the number of tillers per plant, which were 10 in case of EM-soil and 6 in case of CR-soil. There were on an average 55 – 64 grains more per rice plant in the EM-soil. The plants were on an average 10 –15 cm higher in the EM-soil than CR-soil. The crop was harvested during 10 – 20 November 2000. The yield per acre was 1490 Kg in the EM-soil while it was 1120 Kg in the CR-soil.

The contents of protein were 8.7 % in the EM-soil while it was 8.4 % in the CR-soil. Similarly the fats were 0.8 % in the EM soils and 0.7 % in the CR-soil. Carbohydrates were 77.5 % in the CR-soil while it was 77. % in the EM-soil. There was no difference in the contents of crude fiber, which was 0.4 % in both the cases.

The occurring of diseases and attack of insects was more in the CR-soil than in the EM-soil. The regular spraying of EM extended diluted by 1000 times helped to control insects attack and occurring of diseases in the EM treated plots.

The experiments on blue green algae on paddy field were started in 1955 and algalization in combination with N produced higher yields of paddy (Abd El-Hameid Nofal, M & Attiat Abo-Bakar Aly # 1). The rhizospheric bacteria in combination with NPK, green manure and FYM increased yield of rice by 18.3 % (Ahmad, N. # 2). EM caused 9.5 % increase in yield of paddy (Ahmad, R. et al # 3). With the application of rhizospheric bacteria the yield of legume was increased by 20 – 100 % (Aslam, M. # 6). The application of press mud (filter cake of sugar industry increased yield of sugar cane by 25 – 50 % (Chattha, AA., et al # 7). The application of bacterial inoculum (Bio Power) to rice crop provided N and growth hormones, made the plants healthy and less susceptible to pathogens. With the use of 1 pack of bio power for 1 acre, half doze of chemical N-fertilizer can be saved with atleast 200 Kg / acre increase in paddy yield. The use of Azolla increased the N efficiency and rice yield significantly. The use of biofertilizers increased the yield of wheat by 15 % and rice yield significantly. The replacement of 10 % inorganic fertilizer requirements on 2 million ha paddy area with biofertilizers a saving of Rs. 1.7 billion can be made annually in Pakistan (Fauzia

Y. Hafeez # 11). EM in the rhizospheric co exist with plant roots and secrete amino acids and nucleic acids, a variety of vitamins and hormones to plants, thus, plants grow exceptionally well in the soil which is dominated by effective microorganisms (Higa, Teruo. 1993 # 15). The EM accelerated the decomposition of organic matter in the soil and increases the release of nutrients for plant growth (Higa, T. and S. Kinjo, 1989 # 16). Biological treatments such as green manure with cyamopsis tetragonoloba were found to be the best with respect to improve growth and yield of rice crop. Even saline water having EC less than 5.0 dSm^{-1} can safely be used for irrigating rice crop after burying green manure (Hussain, T. et al # 20). Maximum yield of paddy and straw was obtained with the application of poultry manure and prilled urea and plant nutrient uptake was enhanced. Soil salinity due to the application of brackish water can be reduced to some extent by organic amendments (Hussain, T. et al # 22). EM increased crop yield and improved soil physical property, especially when applied with organic amendment (Hussain, T., G. Jillani, and T. Javaid. # 23). EM in combination with organic manures enhanced the yield of rice and wheat (Piyadassa, E.R. et al # 40). Use of EM as microbial inoculants in agriculture increased the growth, yield and quality of crop (Paar, J. F., and S. B. Hornic # 38). The main factors for low efficiency of fertilizers (40 – 50 % N, 15 – 25 % P & 50 – 70 % K) is imbalance in the use of N & P but low organic matter of the soil. It is an important factor and needs special attention. Vigorous efforts are needed to include legumes, green manure, crop residues and biofertilizers into the integrated plant nutrients system (Rasheed, M. # 41). The yield data of rice, wheat and potato crop showed that the compost (neem cake, cotton meal, sugar pressmud and activated sludge of house hold water wastes) had reduced the chemical fertilizers use by 50 % (Rehman, F. and Bajwa M. I. # 42). EM enhanced germination, plant growth and leaf area indices, and increased yield components (Sangakkara, U.R. # 44). The application of EM in combination with organic amendments (chicken dung) significantly increased the yield of sweet corn and leaf mustard (Sharifuddin, H. A, H. et al # 47). Agricultural productivity and profitability can be maintained by practicing sustainable agriculture with green manure and effective microorganisms (EM). EM application helped to control erosion, reduce number of irrigation and suppress attack of soil pathogens (sclerotina) without using agricultural chemicals (Tokeshi, H. et al # 50 & 51). EM increased the productivity of sugar beat significantly by enhancing photosynthetic capacity of plants, which resulted in higher yields (Van den Ham, F. # 52). Yield of rice, corn and wheat was increased by over 100 % when EM was used with 200 M tons of organic matter per hector (Yong Chol, Ko # 55). Available N & P contents was found to be more in the plants treated with EM –4 + FYM when compared to control (Zacharia, P. P. # 56).

4.Mechanism of EM (Effective Microorganisms)

The application of EM in all possible forms (soaking of seeds, 4.4 tons / acres composted FYM + PM, 130 Kg / acre EM Bokashi, and irrigations and sprays with EM) played a pivotal role in the reclamation of saline-sodic land, in the formation of aggregates soil structure of the upper most soil layer, in the enhancement and maintenance of useful and beneficial microorganisms, release of essential plant nutrients through rapid decomposition of organic matter and in the production of good yield of rice grain as compared to conventional method of reclamation, which generally takes about 2-3 years to fully reclaim and resuscitate the soil fauna and flora. In the presence of easily decomposable organic matter the overwhelming majority of effective microorganisms (phototrophic bacteria, lactic acid bacteria and yeast) used in EM comprises among others photosynthetic bacteria, fungi and effective actinomycetes, aerobic and anaerobic in nature, coexist symbiotically with other soil microorganisms.

The soil microorganisms act also as decomposers of organic matter particularly polysaccharides, lignin and chitin with the production of humus, initiators of C & N cycles and producers of antibiotics and killers of pathogens. The distribution and multiplication of microorganisms in the soil is determined largely by the presence of food supply in the surface soil. They, therefore, occur in the greatest number in the upper soil horizon and had teeming mass of biological activity in the presence of optimum food, moisture and temperature. Generally bacteria are present in numbers of 10^8 to 10^9 organisms per gram of soil (300 to 3000 grams of biomass per m^3 of soil), actinomycetes are 10^7 to 10^8 organisms per gram of soil (300 to 3000 grams of biomass per m^3 of soil) and fungi are 10^5 to 10^6 propagules per gram of soil [600 to 10 000 grams of biomass per m^3 of soil (Cinklin, Jr. A. R. 2002 # 9)]. The number of groups of microorganisms that commonly occur in top 0-15cm i.e. per hectare-furrow slice may be for bacteria 10^{17}-10^{18} with fresh biomass 450-4500 Kg, for actinomycetes 10^{16}-10^{17} with fresh biomass 450-4500 Kg, for fungi 10^{14}-10^{15} with fresh biomass 112-1120 Kg, for algae 10^{13}-10^{14} with fresh biomass 56-500 Kg and for protozoa 10^{13}-10^{14} with fresh biomass 17-170 Kg. The microflora (bacteria, actinomycetes, fungi and algae together form 2076 to 20760 Kg fresh biomass and 415-5190 Kg dry biomass (20-25% of fresh biomass) per HFS (Brady 1994). According to Alexander 1977 (introduction to soil microbiology. John Willey & Sons. NY. 467p.) the microbial number in the top soil (3-8 cm) may be 12 million/g, comprising live biomass of bacteria 100-4000 Kg/ha; while double of this biomass for all the microbes (bacteria, actinomycetes, fungi and algae) forming 0.02-0.8% of total soil biomass (Sikandar, A. # 48).

The photosynthetic bacteria (rhodopseudomonas spp) synthesize useful substances such as amino acid, nucleic acid, bioactive substances (vitamins, enzymes and hormones) and sugar. These are released into the soil solution. The presence of amino acids (a nitrogenous compound) increase the population of Vesicular Arbuscular micorrhiza in the rhizosphere, which in turn enhance the solubility of phosphates in the soil and can coexist with Azotobacter and Rhizobium, thus, increasing the capacity of plants to fix atmospheric N. the photosynthetic bacter is considered the pivot of EM Technology (Higa, Teruo 1993 # 15).

Lactic acid bacteria (lactobacillus spp) produce lactic acid using sugars and carbohydrates. Lactic acid is a strong sterilizing compound, suppresses harmful microorganisms (Fusarium) thus reducing nematode population, enhances decomposition of organic matter, promotes fermentation and decomposition of material such as lignin and cellulose (Higa, Teruo 1993 # 15).

The yeast (saccharomyces spp) synthesizes anti microbial and other useful bioactive substances such as hormones and enzymes, which are useful substrates for effective microorganisms (Higa, Teruo 1993 # 15).

The fungi break down highly complex and resistant compounds such as cellulose, starch, gums and lignin (Cinklin, Jr. A. R. 2002 # 9).

Actinomycetes produce and release in the soil solution antibiotics such as streptomycin, actinomycin and neomycin, and are involved in the decomposition of complex organic compounds such as phospholipids (Cinklin, Jr. A. R. 2002 # 9).

Chemistry and biology in soil environment (solids, liquids & gases) are significantly different and more complex. Microorganisms produce a large variety of byproducts, some of which are quite surprising. N containing compounds are decomposed and ammonia (NH_3) and ammonium (NH_4) are released into the soil solution. This in turn is oxidized for energy by other bacteria producing nitrite and nitrate. The rate of nitrate production is faster than nitrite production. Some free-living and some symbiotic bacteria can take N from the air and combine it with organic compound to produce amino acids. Humus is the material remaining after decomposition of organic matter. It is made of three components: fluvic acid, humic acid and humic. Its particles are colloidal in size. It has high sorptive capacity for water and organic compound as well as high cation exchange capacity (CEC). At basic pH, CEC increases, thus, both organic molecules and cations, but not anions, are attracted to humus (Cinklin, Jr. A. R. 2002 # 9 & 10).

The decomposition of organic matter means that a diversity of bio- and organic molecules (acid, alcohol, ether and aldehyde) is constantly being released into the soil solution. Under aerobic soil the decomposition of organic matter / molecules the main products are CO_2 and H_2O, e.g. (Cinklin, Jr. A. R. 2002 # 10):

$$R\text{-}CH_2CH_3 + O_2 \; \underline{\text{aerobic microorganisms}} \; CO_2 + H_2O + \text{Energy} + \text{mineral} + \text{humus}$$

Under anaerobic soil the microorganisms break down organic (C-containing) compounds for energy and final products are:

$$R\text{-}CH_2CH_3 + O_2 \; \underline{\text{anaerobic microorganisms}} \; CH_4 + H_2O + \text{Energy} + \text{mineral} + \text{humus}$$

Methane is the simplest and reduced form of organic compounds in soil. It is considered the basic unit from which all organic molecules are built (Cinklin, Jr. A. R. 2002 # 10).

Summarizing it can be concluded that decomposition processes in soil release minerals, macro-and-micro nutrients (N, P, K, S, Ca, Mg, K, Fe, Mn, Zn, Cu, etc) and other byproducts such as amino acid, sugars, fatty acids, organic acids, chelates, NH_3, NH_4, NO_3, organic molecules (acid, alcohol, ether, aldehyde), humus (fluvic acid, humic acid and humin), vitamins, hormones, enzymes and antibiotic etc.
The results obtained have already been discussed in detail. These results confirm the multiplication of useful bacterial population, the production of enzymes and their activity, production of organic acids (lactic acid, acetic acid, citric acid), formation of aggregates and chelates, removal of NaCl and elimination of exchangeable Na^+ and higher germination, less attack of insects, minimum occurrence of diseases and higher yield of rice grain.

Now the question arises how EM has ameliorated saline-sodic land and what is the possible mechanism of effective microorganisms (EM) to reclaim such lands. According to Agriculture Handbook No. 60, United States Department of Agriculture a saline-Alkali Soils are characterized by their appreciable contents of soluble salts (ECe > 4 mmhos/ cm) and exchangeable sodium percentage (> 15). The pH may vary considerably. Cl & SO_4 are the principal soluble anions, HCO_3 content is relatively low, and CO3 is absent. The soluble Na contents exceed those of Ca + Mg. This means that the problematic zone was the rhizosphere, being saline-alkali in nature and have higher contents of Na in the soil solution and exchangeable Na > 15. This is of major concern. If these are controlled and brought to acceptable level, then the soils are said to be reclaimed and agricultural crop can be grown. Now coming to the level of reclamation achieved, which is reflected by the reduction in pH from 9.8 to 6.8, ECe from 67 to 5 dSm^{-1} and SAR from 79 to 11. The formation of aggregate structure by the release of organic acid and humus by the effective microorganisms in combination with organic manure and Bokashi improved the structure of the upper soil and with that the permeability of the rhizosphere. The EM, applied along with composted FYM + PM and Bokashi, released many byproducts inclusive of NH_4+ and Ca++ oins (Bokashi contained 72 meq/L or 1442 ppm Ca) into the soil solution have acted upon the exchangeable Na on the clay complex and taken the place of Na with which Na became a part of the soil solution. The Na released from the clay complex and Na present already in the solution formed NaCl and $NaSO_4$, being soluble in water, leached from the upper most soil horizon (plough layer) to the lower layers of the soil profile, the texture of which was loam, the permeability of which is already said to be moderate. This is the possible mechanism of EM in soil reclamation.

5. Conclusions

From the results of the field experiment carried out on “mechanisms of Effective Microorganisms (EM) in reclamation of saline-sodic soil” it can be concluded that the reclamation and amelioration of saline-sodic soil can be achieved most effectively with the application of EM Technology, which comprises of soaking of seeds in EM solutions, field applications in the form of irrigations and sprays with EM Extended solutions, compost prepared from farmyard manure + poultry manure with EM solutions and Bokashi prepared from rice bran with EM solution. The overwhelming majority of effective microorganisms in the presence of easily decomposable organic matter co-exist symbiotically with other bacteria, fungi, actinomycetes and soil fauna and flora, synthesize and release useful substances [organic acids (amino acids, nucleic acids, citric acids, acetic acids, lactic acids), alcohols, ethers, aldehydes, bio active substances (vitamins, enzymes, hormones), sugars, polysaccharides, enhance solubility of phosphates, fix atmospheric N forming NH_4 and NO_3, break down highly complex and resistant compounds (cellulose, starch, gums, lignins), release antibiotics (streptomycin, actinomycin, neomycin), producing humus (fluvic acid, humic acid, humic) and macro- and micro nutrients (N, P, K, S, Ca, Mg, Fe, Mn, Zn, Cu, etc) and other products, fatty acids, chelates etc) into the soil solution. The NH_4 and Ca replace the Na^+ from the clay complex. The exchanged Na form NaCl and $Na_2\ SO_4$ in the soil solution and these salts leach down to the lower layers of the soil profile, making the upper zone of the rhizosphere free from harmful salts. This part of the root zone becomes biologically very active releasing all types of essential nutrients to the roots for uptake by the plants. The saline-sodic soil is not only reclaimed in the 1st year without using any soil amendment such as gypsum or sulphuric acid etc but it gives also good production. In short EM Technology is effective, easy to prepare and use and leaves behind enhanced bacteria population increasing soil fertility for all times to come.

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