Net Journal of Agricultural Science
Vol. 5(3), pp. 114-120, September 2017
ISSN: 2315-9766
Full Length Research Paper

Reducing water salinity using effective microorganisms

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Accepted 3 August, 2017

ABSTRACT

Effective Microorganisms (EM) have been used as a commercial biofertilizer since they contain a mixture of co-existing beneficial microorganisms collected from natural environments. They mainly consist of photosynthetic and lactic acid bacteria, actinomycetes and yeast. The main objective of the current work was to examine the reclamation and amelioration of saline water, 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. The results show that the characteristics of EMI and EMA is the presence of significant numbers of bacteria, actinomycetes, and fungi, respectively. Physical, chemical, and biological characteristic of 40-day fermentation of saline water showed significant differences among treatments. By heaping up, EMA-treated well water and saline water gave the effects on the EC of saline water. These data suggest that EM treated water can be recommended as an efficient saline adjustment to alleviate a slightly saline soil.

Keywords: Well water, electrical conductivity, incubation.

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INTRODUCTION

Soil salinity is one of the most urgent problems facing agriculture in Iraq. Previous studies stated that more than 70% of the lower Mesopotamian plain soils are salt-affected (Al Mahawili, 1983). Such wide area has been abundant by farmers and is considered as a wasteland. Numerous practices are suggested for reclamation and rehabilitation of such soils (Hussain et al., 1991; Mouhamad et al., 2014). The scarcity of treated water made rather impossible to apply common restoration practices by percolating excess salts from the soil profile to the drainage system (Gharaibeh et al., 2009). Other approaches using *in vitro* studies for increasing salt tolerance were also applied (Ibrahim, 1990; Omran, 2013; Mahmood and Ibrahin, 2017). A mixture of effective microorganisms (EM) was proved lately as a potential soil amelioration agent (Oad et al., 2002). The different species of the effective microorganisms are photosynthetic, lactic acid bacteria and yeasts have also their respective function in this respect. The technology of EM was developed during 1970's at the University of Ryukyus, Okinawa, Japan (Sangakkara, 2002). Studies have suggested that EM may have a number of applications, including agriculture, livestock, gardening and landscaping, composting, bioremediation, cleaning septic tanks, algae control and household use (EM Technology, 1998). The main species involved in EM include:

- Lactic acid bacteria – *Lactobacillus plantarum*, *L. casei*, *Streptoccus lactis*
- Photosynthetic bacteria – *Rhodopseudomonas palustrus*, *Rhodobacter spaeroides*
- Yeasts – *Saccharomyces cerevisiae*, *Candida utilis*
- Actinomycetes – *Streptomyces albus*, *S. griseus*
- Fermenting fungi – *Aspergillus oryzae*, *Mucor hiemalis* (Higa, 1991).

The successful work focused mainly on the use of effective microorganisms (EM) in the field of agriculture in many countries over the world. This kind of research work was undertaken to explore how EM Technology with all its components (manures treated with EM, and EM irrigations water and EM water spray) compared to conventional method of restoration helps to recover saline-sodic lands by dismissing soluble salts and swap adsorbed sodium present in the upper part of soil profile and simultaneously by augmenting the biological activity of the soil to maintain sustained production of crops, and to understand the EM mechanism .of ameliorating salt-affected soils (Nishio and Kusan, 1980; Sunathapongsuk et al.,1987; Higa, 2005). EM technology involves growing, applying, administration and resuming high populations of the beneficial microorganisms in an environment or system. It is a natural and organic technology useful in abundant ways to benefit mankind. It was discovered that EM display very thorough effects, and its use now is spreading into various applications, solving many of the world's problems. Demand for EM applications include sustainable agricultural, industrial, health (livestock, pets, and human), odor control, waste management and recycling, environmental remediation and eco-friendly cleaning (EM Technology, 1998; Higa et al., 1984; Higa, 2005). EM is easy and convenient for use, safe, harmless, low cost and economically effective and this has increased the effectiveness of the application of this technology. Moreover, the regular monitoring of the water pollution level of the river basin, appropriate refining therapy and community participation in water resources management will certainly help managers in taking informed decisions for water resources tenable and management. Accordingly, this study was conducted to esteem the role of EM in desalinization of water.

MATERIALS AND METHODS

Preparation of EM

EM1 was kindly obtained from Okinawa-Japan through AL-Anam Company for natural planting stock. A volume of 10 L EM secondary was prepared by mixing 0.5 L of molasses with water to obtain 9 L, then the mixture was supplemented with 0.5 L of effective microorganisms; EMA is already produced by Iraqi Ministry of Science and Technology, Soil and water resource center, Iraq. The mixture was kept in dark tanks till aerobically fermented for one week at a pH 3.5. The composition of the stock was then subjected to analysis (Table 1).

Laboratory Experiment 1 was conducted (Table 2), the different mixtures (50 ml) were put into 50 ml Erlenmeyer flasks covered with parafilm and incubated stationery at a temperature of about 37°C in the dark. Treatments of each series were duplicated. Conductivity measurements were taken regularly at 6, 12, 14, 19 and 40 day intervals. Samples were homogenized using an Ultra Turrex prior analysis (Page, 1982). In the laboratory Experiment 2 (Table 3), the different mixtures (100 ml of well water, Table 4) were put into 100 ml Erlenmeyer flasks covered with parafilm and incubated stationery at a temperature of about 37°C in the dark. Treatments of each series were duplicated. Conductivity measurements were taken regularly at 0, 1, 2, 3 and 4 month intervals. Samples were homogenized using an Ultra Turrex prior analysis (Page, 1982). Statistical analysis was performed to compare the means of the two different groups by using ANOVA test. Statistical significance was determined at $P < 0.05$.

Table 1. EM stock composition.

Content	Concentration
H_2O	96.50%
NO_3-N	23 ppm
NH_4-N	489 ppm
PO_4-P	8.06 ppm
Na	268.7 ppm
K	2034 ppm
Fe	9.14 ppm
Zn	1.33 ppm
Mn	2.43 ppm
Cu	0.81 ppm
Organic compound	
Ethanol	+
Propanol	+
Acetic acid	+
Propionic acid	+
Butyric acid	+
Alginate	+
Rhadopseudomonas plustris	+
Photosynthetic bacteria	+
Lactic acid bacteria	+
Lactobacillus plantar	+
Lactobacillus easei	+
Streptococcus laetis	+
Saccharomyces cerevisiae	+
O.D	6.2×10^6/ml

RESULTS AND DISCUSSION

Effective microorganisms (EM1)

Table 5 shows the influence of five periods (6, 12, 14, 19 and 40 days) at two doses of NaCl (25% NaCl, 50% NaCl) on EM1. EC decreased significantly compared with the control (EM1) accept the treatment for the period 40 days with no significant effect of the two doses of NaCl. These results agree with Syed et al. (2002; 2003), who stated that soil treated with EM contains beneficial bacterial types such as *Rhodobacter, Pseudomonas, Lactobacillus, Furababacterum,* and *Gluconobacter*, which have the ability to convert NaCl to protein and chalets by de-ionizing the salts. Table 5 also shows a good correlation between periods of incubation.

The effect of EM1combined with two doses of NaCl

Table 2. Substrate amounts used in the EM extension in experiment 1.

Series and treatments code	EM-1 (%)	Molasses (%)	Water (%)
1. EM1	100	0	0
2. EM1 + 25% NaCl	100	0	0
3. EM1 + 50% NaCl	100	0	0
4. EMA	5	5	90
5. EMA + 25% NaCl	5	5	90
6. EMA + 50% NaCl	5	5	90

Table 3. Substrate amounts used in the EM extension in experiment 2.

Series and treatment code
S1: Effective microorganism (15 ml EM+ 85 ml water)
S2: Effective microorganism (50 ml EM+ 50 ml water)
S3: Effective microorganism (75 ml EM+ 25 ml water)
EA: (5% Effective microorganism + 5% Molasses + 90% water)
EA1: Effective microorganism (15 ml EMA+ 85 ml water)
EA2: Effective microorganism (50 ml EMA+ 50 ml water)
EA3: Effective microorganism (75 ml EMA+ 25 ml water)

Table 4. Well water properties.

Well water	EC (dS. m^{-1})	pH	Na^{+1} (Mmol/L)	Mg^{+2} (Mmol/L)	Ca^{+2} (Mmol/L)	$SO4^{-2}$ (Mmol/L)	Cl^{-1} (Mmol/L)	SAR
W1	3.67	7.56	30.57	4.9	0.989	2.776	32.68	12.6
W2	9.26	7.17	74	14.03	13.51	7.57	62.98	14.1
W3	12.6	7.03	85.74	21.79	20.46	4.12	112.7	13.19

Table 5. Effect of EM levels as stock solutions added to saline water (%) on EC ($dSm^{-1)}$ after 0, 6, 12, 14, 19 and 40 days of incubation period at 37°C.

Time day	Control (EM1) (mean ± SD)	EM1 + 25% NaCl (mean ± SD)	EM1 + 50% NaCl (mean ± SD)
0	A,a 8.567 ± 0.902	A,b 27.333 ± 6.028	A,c 47.333 ± 6.429
6	AB,a 6.547 ± 1.069	AB,b 22.360 ± 6.400	AB,c 36.100 ± 5.507
12	B,a 5.907 ± 1.089	AB,b 21.610 ± 6.407	BC,c 30.667 ± 5.412
14	B,a 5.217 ± 2.009	B,b 17.710 ± 2.485	AB,c 35.300 ± 8.287
19	C,a 3.047 ± 1.601	B,b 18.233 ± 5.877	C,c 26.267 ± 8.664
40	BC,a 4.500 ± 1.803	C,b 10.833 ± 1.528	D,b 12.333 ± 6.526

Capital letters represent significant differences (P ≤ 0.05) between mean values in rows.
Small letters represent significant differences (P ≤ 0.05) between mean values in columns.
SD = Standard deviation between means.

was highly significant over time. The decline in electrical conductivity from 47.3 to12.3 dS/m^{-1} was clear after 40 days of incubation. The slow decrease in EC was clear at the first period of incubation. The third and fourth periods were similar in their effects on decreasing EC.

The relationship between the period of incubation and EM using well water is manifested in Table 6. The incubation period may be correlated with the number of microorganisms encouraging farmers to increase the incubation period of fermentation by providing EM. (Hussain et al., 1991; Oad et al., 2002).

In terms of salt-affected areas, reclamation, the reduction in water, electrical conductivity from 47 to 12 dSm^{-1} is considered promising to farmers. These results agree with Sunathapongsnk et al. (1987). Who pointed out that the variability in EC and pH of the amended soils indicates the activities of microorganisms in the soil? Higa (1991) found that when EC exceeds 0.4 dsm^{-1}, the microflora in the rhizosphere begin to change; in particular, the mycorrhizal fungi which disappear and thus the activities of microorganisms decline. When EC reaches <10 dSm^{-1}, harmful anaerobic microorganisms become dominant, and various disorders such as discoloration of plant leaves begins to appear.

The results displayed in Table 7 show a significant reduction in each at different exposure periods except the first period (6 days) in the presence of NaCl. Minimum reduction values in Ec were recorded after 40 days reached 14.8 dSm^{-1} which occurred in 50% NaCl.

Treatment of well water with EM after 4 months significantly reduced the salinity (Table 8). The highest decrease occurred in EA3W1. The disparity in results between EM1 and EMA treatments may be due to the large inoculum and the homogenous distribution of bacteria, actinobacteria and fungi within treatments. This agrees with Arunin (1988) and Lin et al. (2006) who observed that the bacteria, actinobacteria and fungi increased 2.3, 4.3 and 71 folds, respectively, after growing *Suaeda salsa* L. irrigated by dripping in coastal saline soil. However, Syed et al. (2003) reported successful experiments in the recovery of saline-sodic soils when a mixture of different microorganisms was applied, without prior application of plaster. Also, Gharaibeh et al. (2009) and Sahina et al. (2011) studied the effect of microbial application in four different saline-sodic soils with saturated hydraulic conductivity, and treated with plaster. Suspensions of three fungal isolate (*Aspergillus* spp. FS 9, 11 and *Alternaria* spp. FS 8) and two bacterial strains (*Bacillus subtilis* OSU 142 and M3 *Bacillus megaterium*) were mixed with the leaching water from the soil treated with plaster, and subsequently applied to the soil columns.

Table 6. Effect of EM levels as stock solutions are added to saline well water on EC (dSm^{-1}) after 0, 1, 2, 3 and 4 months of incubation period at 37°C.

Parameter	Well water	Zero day	1 month	2 month	3 month	4 month	Mean ± SD
S1W1	3.67	3.695	3.8	4.02	4.02	3.935	3.93 ± 0.143^{A}
S2W1	3.67	4.28	4.8	4.72	4.715	4.75	4.65 ± 0.211^{B}
S3W1	3.67	5.1	5.5	5.375	5.48	5.32	5.35 ± 0.160^{C}
S1W2	9.26	7.81	7.91	8.65	8.42	8.25	8.20 ± 0.349^{C}
S2W2	9.26	8.04	8.22	8.59	8.66	8.5	8.40 ± 0.262^{B}
S3W2	9.26	8.25	8.7	8.82	8.79	8.65	8.64 ± 0.229^{A}
S1W3	12.6	8.85	9.25	9.59	9.46	9.45	9.32 ± 0.289^{C}
S2W3	12.6	9.53	9.45	9.72	9.56	9.55	9.56 ± 0.098^{A}
S3W3	12.6	9.14	9.5	9.86	9.76	9.7	9.59 ± 0.284^{B}

Capital letters represent significant differences (P ≤ 0.05) between mean values in rows.
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SD= Standard deviation between means.

Figure 1 shows that the Effective Microorganism (stock solution) reduces harmful salts in saline water even at high concentrations (25% NaCl) from 30 to 12.8 dsm^{-1} while when NaCl concentration was 50% the decrease was from 40 to14.8 dsm^{-1} after 40 days of incubation. The decrease in value was 0.369 and 0.607 for 25 and 50% NaCl respectively, compared with control for the same incubation period.

Figure 2 shows that EM activity to reduce salinity in water (ECe) which decreased at 50% NaCl from 47.3 to 12.3 dsm^{-1}, while when the concentration of NaCl was 25%, the decrease in ECe value was from 8.6 to 4.5 dsm^{-1}. The decrease ECe in *a* value after 40 days of incubation period for concentration 25% NaCl and 50% NaCl were 0.380 to 0.784 respectively, compared with EM-A Control.

Table 7. Effect of EM as an active solution added to saline water (%) on ECe ($dSm^{-1)}$ after 0, 6, 12, 14, 19 and 40 days of incubation period at 37°C.

Time day	Control (EMA) (mean ± SD)	EMA + 25% NaCl (mean ± SD)	EMA + 50% NaCl (mean ± SD)
0	A,a 6.6067 ± 0.9717	A,b 30.177 ± 0.204	A,c 43.467 ± 6.004
6	AB,a 5.2500 ± 0.5726	B,b 22.200 ± 0.794	AB,c 33.000 ± 4.093
12	B,a 4.6667 ± 0.8505	B,b 21.933 ± 1.617	B,b 29.633 ± 4.506
14	B,a 4.5100 ± 0.8047	BC,b 20.400 ± 3.200	B,b 28.500 ± 4.979
19	BC,a 4.1667 ± 0.3786	C,b 18.500 ± 1.803	C,b 20.167 ± 8.461
40	C,a 3.1333 ± 1.0066	D,b 12.833 ± 3.014	D,b 14.833 ± 6.788

Capital letters represent significant differences (P ≤ 0.05) between mean values in rows.
Small letters represent significant differences (P ≤ 0.05) between mean values in columns.
SD= Standard deviation between means.

Table 8. Effect of EA (active solution) level added to saline well water on EC after 0,1, 2,3 and 4 months of incubation period at 37°C.

Parameter	Well water	0 month	1 month	2 months	3 months	4 months	Mean ± SD
EA1W1	3.67	2.76	2.8	2.95	2.94	2.89	2.86 ± 0.084^{C}
EA2W1	3.67	2.61	2.66	2.76	2.765	2.71	2.70 ± 0.066^{B}
EA3W1	3.67	2.47	2.55	2.65	2.62	2.61	2.58 ± 0.071^{A}
EA1W2	9.26	6.95	7.05	7.54	7.43	7.3	7.25 ± 0.249^{C}
EA2W2	9.26	6.45	6.45	6.85	6.86	6.7	6.66 ± 0.203^{B}
EA3W2	9.26	5.98	6.05	6.41	6.42	6.3	6.23 ± 0.203^{A}
EA1W3	12.6	8.03	8.35	8.69	8.45	8.5	8.4 ± 0.242^{C}
EA2W3	12.6	7.41	7.65	8.04	7.59	7.78	7.6 ± 0.234^{B}
EA3W3	12.6	6.86	7.15	7.42	7.38	7.2	7.2 ± 0.222^{A}

Accordingly, water salinity decreased with increasing the incubation period and the magnitude of decrease is found to increase with the increase of initial water salinity. These findings may suggest full utilization of such microbial mixture (EM) as amelioration agent for saline water used for irrigation purposes. This is in agreement with the finding of Sunathapongsnk et al. (1987) who has suggested a huge reduction in the water electrical conductivity from 40 to 12 dsm^{-1} which has a considerable importance to the farmers. Higa (1991) found that when EC exceeds 0.4 dsm^{-1} the microflora in the rhizosphere begin to change, especially mycorrhizal fungi which disappear and activity of other microorganism decline.

Conclusion

In summary, the EMA adopted locally are emerging as one of the environmental solutions towards reducing

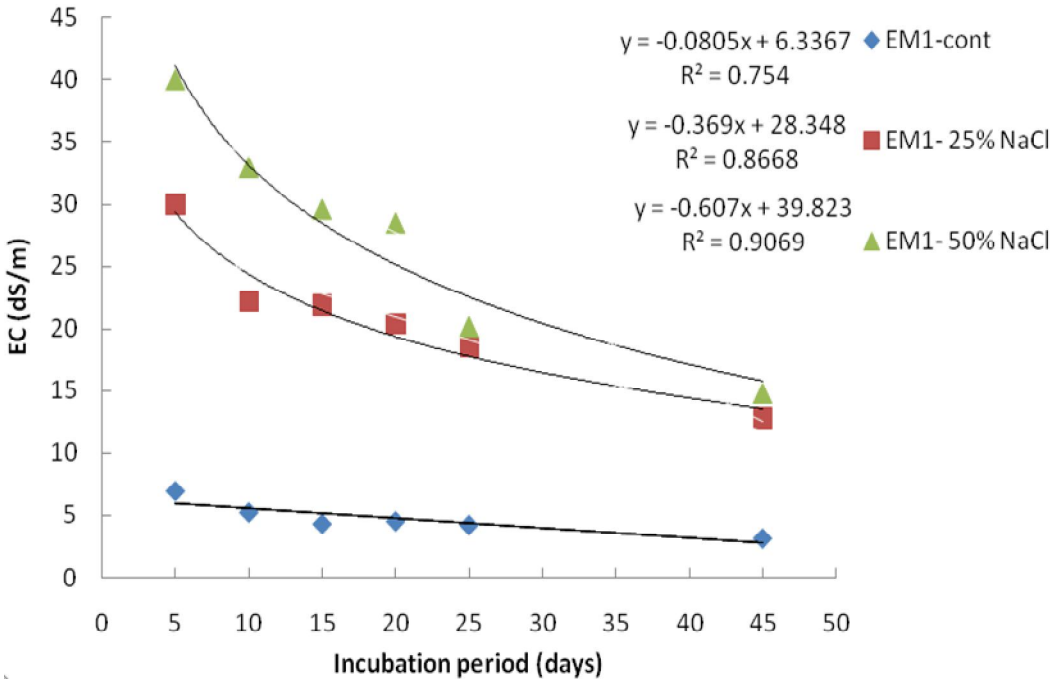

Figure 1. Effect EM (stock solution) added to saline water (%) on ECe after 5, 10, 15, 20, 25 and 45 days of incubation period at 37°C.

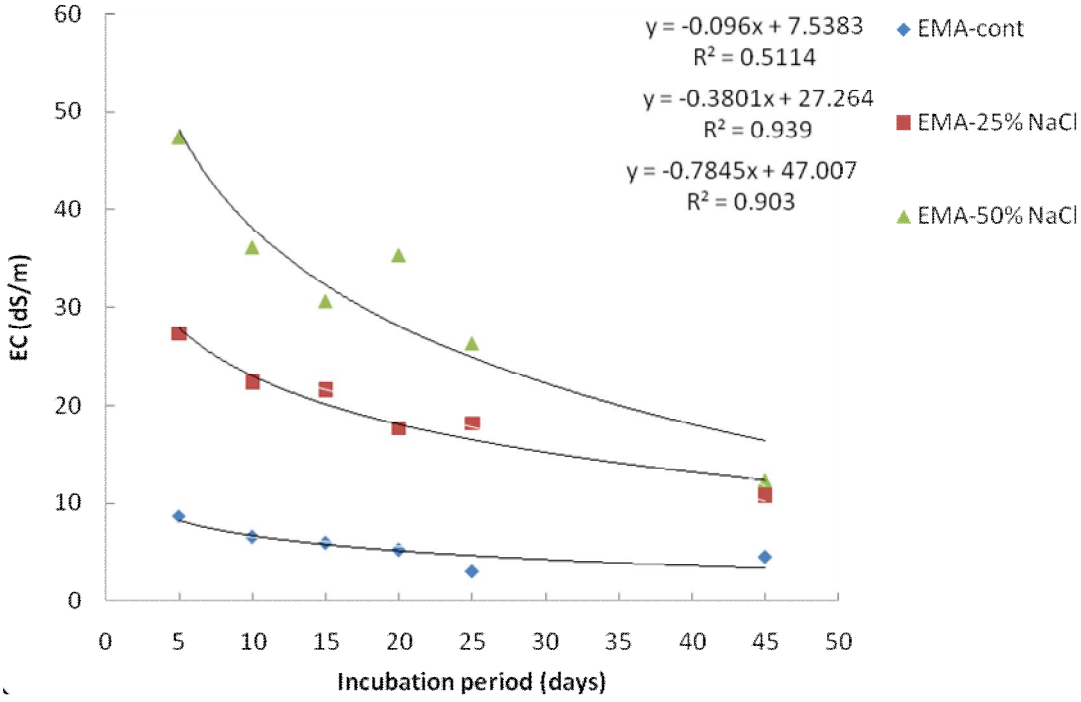

Figure 2. Effect EM (active solution) added to saline water (%) on ECe after 5, 10, 15, 20, 25 and 45 days of incubation period at 37°C.

water salinity and thus improving water quality in ground water and drains. The results of the work globally have demonstrated that the effectiveness of EM technology will assist Iraqi farmers in utilizing drainage and ground water for irrigation and better exploitation of water resources (Fadhell et al., 2016; Mouhamad et al., 2017). EM is easy

to produce, ease of use, safe, low cost and economically effective and finally, it may contribute in a sustainable agriculture and environment.

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Citation: Mouhamad RS, Mutlag LA, Al-Khateeb MT, Iqbal M, Nazir A, Ibrahim KM, Mussa RA, Jassam OH, 2017. Reducing water salinity using effective microorganisms. Net J Agric Sci, 5(3): 114-120.