Annals of Plant and Soil Research 24(1): 45-52 (2022)
https://doi.org/10.47815/apsr.2022.10122

Effect of microbial growth and development on chemical properties of saline water

RAJAGOPAL V*, P SANTHY®, K NAGARAJAN#, T KALAISELVI@ AND N. CHANDRA SEKARAN®

Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore -641003

Received: August, 2021; Revised accepted: September, 2021

ABSTRACT

Secondary soil salinization is a major issue for sustaining food grain production in arid and semi-arid region due to the use of poor quality saline water, whichneeds amelioration before to be used for crop irrigation.In this regard, totally 12 saline bacterial isolates from saline water ecosystem, of which three best isolates, namely C_8, C_{10} and $C_{12,}$ identified and used for amelioration of saline water whose electrical conductivity value (EC) ranged between 0.5 and 8.0 dS m^{-1} over the incubation period of two, five and seven days under laboratory conditions during 2017-20. The C_{10} and C_{12} bacterial isolates were highly efficient recording more than 30 % EC value decline but microbial efficiency decreased with increased salt concentration. The five days incubation optimized with 20 % reduction of EC value. However, the biological amelioration of water salinity was highly specific that five days incubation with C_{12} culture recording amelioration nearly 64 % decline of EC value only in low saline water. In contrast, all the cultures were equally effective on every saline water studied lowering more than 38% in 2.0 dS m^{-1} saline water, more than 22 % in 4.0 dS m^{-1} saline water, more than 16 % in 6.0 dS m^{-1} saline water, and more than 12 % in 8.0 dS m^{-1}saline water for two days incubation period. On the whole, the microbial techniques based saline water amelioration abated 30% reduction of EC value associated with declining of ionic concentrations, such as Ca^{2+} by 40 %, Mg^{2+} by 31 %, Na^{+} by 24 %, SO_4^{2-} by 18.4 % and Cl^{-} by 10.5 %. The reduced salt build-up and increased crop performance would be the implication and characterization of the isolates is suggested further studies.

Keywords: Saline bacteria, microbial techniques, saline water, ionic concentration, saline water amelioration

INTRODUCTION

Increasing world populations, declining natural resources and plateaued crop productivity over the periods are threatening force for world food security. To feed ever-growing population in India, annual food production should be increased to330 Mt in 2050 from 297 MT in 2020 (ICAR 2015), which could be difficult without addressing abiotic stress as the numbers and level of them increases with time. Among the abiotic stress, soil salinity is a drastically very severe one accounts the yield loses between 20 and 50 % and it covers total area 6.5 mha accounting nearly 5 % total cultivated area in India (Kumar *et al.* 2020). Secondary soil salinization due to use of poor quality saline water is the major cause for development of salt affected soils. Water salinity is mainly for presence of excessive concentrations of soluble salts such as calcium, magnesium, sodium, potassium, chloride, sulphate and carbonate ions. When salt concentration exceeds more than 3 dS m^{-1}, it affects growth and development of most of the annual crops considered generally unfit for agriculture. In contrast to that, following guidelines developed for appropriate short-term saline water management and crop selection a satisfactory yield can be obtained for many crops with use of saline water up to 6 dS m^{-1} (Wang *et al.* 2011). Since moisture deficit is already prevailing in many parts of country as well as different seasons. Annually huge amount of waste water produced from industries can be used as water as well as nutrients source for agriculture provided the high salts and organic matters is reduced to below the crop threshold level. Moreover, salt removal operations by physico-chemical processes such as reverse osmosis, ion exchange or electro dialysis before biological treatment are rather expensive that it is necessary to have new and chapter techniques for saline water treatment.

Microbes play many soil functions even in the chemically degraded soil for maintenance of agro ecosystem. Salt accumulation (potassium chloride) and organic solutesproduction at cellular level are the internal adaptive response of microbes under saline ecosystem (Gunde *et*

*Scientist, ICAR-National Institute of Abiotic Stress Management, Baramati, Pune-413115 Maharashtra, #Professor (SWCE), Water Technology Centre, @Professor, Department of Agricultural Microbiology, ®Professor (Soil Science), Dept. of SS & AC), Tamil Nadu Agricultural University, Coimbatore -641003, Corresponding author mail id: v.rajagopal@icar.gov.in

al. 2018). Studies have reported that saline bacteria producing exopolysaccharides, characterized with high surface area and high porosity, which are capable to adsorb excessive ionic concentrations present in water (El-Ghany *et al.* 2020). Industrial waste water and mine water has been ameliorated about 88% of sulphate content through biological reduction in two step process in which the sulphate is converted to sulphide using *Desulfovib riodesulfuricans* and then to elemental sulphur using *Chlorobiumthiosulfatophilum* (Maree and Hill 2013). Similarly, 40-65 % of sodium removed through accumulation from seawater containing 3 % sodium chloride solution over the period of two days with growing photosynthetic bacteria (Sasaki *et al.* 2017). Urease enzyme producing bacteria through biomineralization process induces calcium precipitation and thereby excessive calcium gets removed from waste water (Anbu *et al.* 2016). Mouhamad *et al.* (2017) observed change of chemical properties of saline water (EC value between 4 and 12) when they incubated with effective microorganism containing Lactic acid bacteria, Photosynthetic bacteria, Yeasts, Actinomycetes and Fermenting fungi over 40 days which converts ions into deionised and chelated form. Similarly, shift in microbial species and level of population is being recorded with change in soil salt content indicates its role in amelioration soil salinity and increase of food grain production (Yan *et al.* 2015). All these research work suggest implicitly that microbes can play critical role in salt dynamics and their amelioration in water and eventually growth and development of crop. With this background information, the research work aimed to investigate the saline bacteria growth and development effect on chemical characteristics of saline water.

MATERIALS AND METHODS

This research work was conducted during the period of 2017-20 at Tamil Nadu Agricultural University, Coimbatore. Soil and water samples collected from the saline water ecosystem of the Picharvaram forest, Tamil Nadu were characterized for pH, EC, organic carbon, N, P and K content, calcium, magnesium, and sodium ions concentration and chloride and sulphate concentrations (Table1 A & B).

Table 1: Chemical characterization of water and soil samples collected from Marshy land ecosystem, Pichavarm forest Tamil Nadu

A. water

S. No	pH	EC ($dS\ m^{-1}$)	($mg\ L^{-1}$)							
			N	P	K	Ca^{2+}	Mg^{2+}	Na^{+}	Cl^{-}	SO_4^{2-}
			$X10^3$	$X10^3$	$X10^3$	($X10^2$)	($X10^2$)	($X10^2$)	($X10^3$)	($X10^3$)
W1	8.21	52	3.5	0.5	650	9.4	36.0	279.1	28.2	4.9
W2	7.92	50.5	3.1	0.7	565	10.0	39.4	271	27.4	4.9
W3	8	49.1	3.3	0.6	680	8.9	40.8	257.2	26.26	5.0
W4	8.13	47.6	3.5	0.7	595	9.2	39.3	255.1	25.73	5.1
W5	8.32	55.5	2.9	0.9	610	9.5	39.7	297.2	29.91	5.2

B. Soil

S. No	pH	EC	OC	TN	TP	TK
		($dS\ m^{-1}$)	($g\ kg^{-1}$)	(%)	(%)	(%)
Soil-1	8.81	36.5	18.2	0.193	0.09	2.12
Soil-2	8.23	38.3	22.0	0.191	0.08	2.76
Soil-3	8.45	39.6	21.2	0.187	0.08	2.54
Soil-4	8.78	41.2	19.0	0.176	0.1	3.12
Soil-5	8.65	38.7	18.0	0.165	0.09	2.87
Soil-6	8.86	39.3	17.8	0.19	0.07	1.98
Soil-7	9.12	43.2	18.7	0.156	0.08	2.54
Soil-8	8.8	41.2	19.3	0.126	0.08	1.43
Soil-9	9.03	37.9	23.1	0.16	0.08	2.21
Soil-10	8.92	41.2	18.44	0.145	0.08	2.13
Soil-11	9.12	40.7	19.11	0.176	0.08	2.09
Soil-12	8.4	43.2	17.3	0.16	0.08	2.32
Soil-13	8.8	39.8	16.2	0.157	0.08	2.03
Soil-14	8.54	43.3	17.8	0.17	0.07	2.21
Soil-15	8.32	42.1	21.0	0.187	0.08	2.43

One-gram soil was added to 9 ml of distilled water in the 25 ml test tube to prepare 10-1soil solution concentrations. The 10^{-6}, $10^{-7}$and 10^{-8}soil solution concentration and directly the seawater samples were used for isolation of salt tolerant microorganism. There were two growth medium such as Luria Bertani (LB) and Nutrient agar (NA) medium used for isolation and the NA medium for purification purpose. The solutions and sea water samples spread to cover the whole area of plate following pour plate techniques. After plating, they were incubated for two days and observed for growth of different colonies. From well-established colonies without any contamination they were purified and mass multiplied.

With the totally 12 cultures were isolated and purified. The identified salt tolerant bacterial cultures were grown in LB broth prepared with seawater over two, five and seven days' incubations durations. The culture one which brought down a larger EC value screened, such as C_8, C_{10} and C_{12} cultures were studied with synthesized salinewater. The saline water representing different EC value was prepared following the procedure given by Hussain (1989). Accordingly, 2.009 g of sodium chloride, 2.996 g of sodium sulphate, 1.15 g of calcium chloride dehydrate and 0.961 g magnesium sulphate hepta hydrate were dissolved in 5000 ml of distilled water in order to have the solution conductivity value 2.0 dS m^{-1}. Similarly, different kinds of saline water EC 4.0, 6.0 and 8.0 dS m^{-1} prepared using distilled water in the laboratory. The saline water characteristics such as electrical conductivity, calcium, magnesium, sodium, chloride and sulphate concentrations (Table 2) were determined following standard methods (Tandon, 2005). The treatment effect were converted from original units to per cent for all characteristics saline water data since the experimental unit as well as observation unit are one and same and also the variability is so high.The percentage data subjected to appropriate transformation upon failure toconfirm the normal deviations before analysis of variance. The SPSS.16 version softwarepackage wasused for data analysis.

Table 2: Basic chemical characteristics of saline waters

Kinds of saline water	pH	EC (dS m^{-1})	Ca^{2+}	Mg^{2+}	Na^{+}	Cl^{-}	SO_4^{2-}
			(meq L^{-1})				
S1 (0.5 dS m^{-1})	7.6	0.6	0.45	0.34	3.8	2.43	1.28
S2 (2.0 dS m^{-1})	7.7	1.82	1.85	1.35	13.6	9.7	5.2
S3 (4.0 dS m^{-1})	7.7	4.1	3.71	2.71	27.18	19.4	10.4
S4 (6.0 dS m^{-1})	7.7	5.9	5.55	4.05	40.8	29.1	15.6
S5 (8.0 dS m^{-1})	7.8	8.21	8.4	6.61	56.2	38.8	20.8

RESULTS AND DISCUSSION

Growth pattern of saline tolerant bacterial cultures in different salinity levels

In this assay, the efficient bacterial isolates were grown on synthetic saline water such as 0.5, 2.0, 4.0, 6.0 and 8.0 dS m^{-1}over the period of two, five and seven days durations (Fig 1). The initial inoculums used were $1X10^7$cfu's ml^{-1}, 1.3 $x10^7$cfu's ml^{-1} and 1.7 X 10^7cfu's ml^{-1} for C_8, C_{10} and C_{12} cultures, respectively. The growth of saline bacterial cultures measured in terms of colony forming units (cfu's) per ml. The population differed significantly due to various levels of salinity. Among the three bacterial isolates, significantly higher population was observed in the C_{12} culture grown in salt (3.1 $x10^7$ cfu's ml^{-1}) and the lowest population of 1.3 $x10^7$cfu's ml^{-1} in the 0.5 dS m^{-1} saline water that was on par with 2 dS m^{-1} saline water. The finding suggests that bacterial isolates differ in adaptive response to same salt concentration and eventually growth and development of microbes (Yan *et al.* 2015).

Effect of salt tolerant bacterial cultures on chemical characteristics of saline waters

Electrical conductivity: Among the studied isolates, the C_{12} was highly efficient over others recording 34.2 % low EC value which was on par with C_{12} culture.However, the efficiency of isolates decreased with increased salt content. The C_{10} culture recorded higher decline of 68 % at low saline water ensuring microbial population 1.7x107 colony forming units (cfu's) per ml. Nevertheless, all the cultures were almost had the same effect on each of saline water, 2.0, 4.0, 6.0 and 8.0 dS m^{-1} saline water.

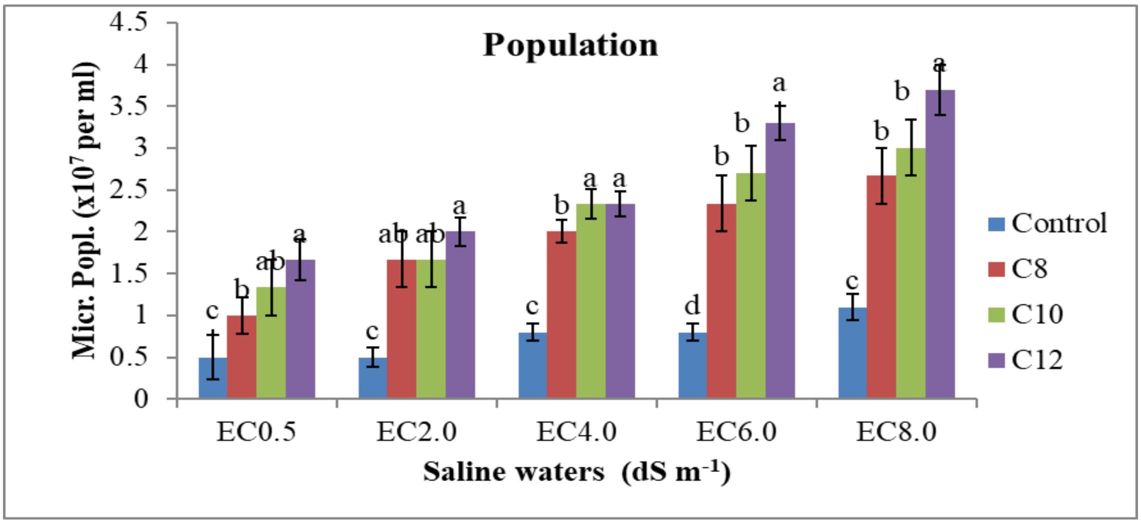

Fig1. Saline bacteria population for saline waters and sea water being treated with different bacterial cultures

Even though the five days incubation was optimized with significantly higher decline of EC value at 32.5 % for microbiological amelioration, it varied with salt content that the five days for low saline water at 64 % decline and two days for remaining saline water at 39 % for 2.0 dS m^{-1} saline water, 23 % for 4.0 dS m^{-1} saline water, 16.5 % for 6.0 dS m^{-1} saline water and 13 % for 8.0 dS m^{-1} saline water (Table 3). This is suggest that the incubation duration is high under low saline water due to low ionic concentration which subjected to adsorption on the surface of polysaccharides produced by microbes as acclimation responses besides growth and development(Dayma *et al.*2015). The decreasing incubation duration with increase of salt concentration implies the quick process of ion adsorption (Chikkanna *et al.* 2018).

The interactive effect of saline water, incubation duration and bacterial isolateswas significant. The C_{10} isolates growth in low saline water brought a significant effect in all the incubation duration while others were at par. In contrast to this, all the isolates were equally effective at each duration forremaining saline water. This regard significant difference in polysaccharide production, growth and development of microbes controlling the salt content of saline water can be inferred from difference in activity among microbes in saline soil (Cavallero *et al.* 2020). The EC value of saline water was highly and positively correlated with anions concentration and cations concentration (Table 3).

Cationic characteristics of saline water: The calcium concentration decline of saline water due to growth and development of microbes was highly differed for bacterial cultures, incubation durations and saline water. The significantly higher calcium decline was observed from the C10 culture at 44.6 %, which was on par with C12 culture. The performance of microbial cultures varied with salt content of saline water as the C10 culture had the best effect at 85 % decline of ion concentration. Whereas, all the cultures were equally effective for reaming all saline water. For incubation duration effect, the decrease of 43 % ion concentration recorded at five days' incubation duration was the highest observed on par with seven days' duration. However, the incubation duration significantly varied with salt content that the low saline water had the higher decline at five days' incubation duration (79 %) while the remaining all saline water had two days as the optimized duration declining 51%, 30%, 23 % and 17 % calcium content in 2.0, 4.0, 6.0 and 8.0 dS m^{-1} kinds of saline water, respectively (Table 3).

Similar to calcium, the magnesium concentration of saline water differed highly for bacterial cultures, incubation durations and saline waters. The significantly higher magnesium decline was observed in the C_{10} culture (nearly 39 %).Among different concentration of saline water, the higher per cent reduction was observed in the 0.5 dS m^{-1}, which was nearly 58.5 % and the effect decreased with increased salt content. Further, the optimum incubation for higher removal of ions varied with salt. The low saline water had 63 % of the ion decline at five days' duration while all remaining water had two days' duration for effective decline, which was 42 % for 2.0 dS m^{-1} saline water, 26 % for 4.0 dS m^{-1}saline water, 20 % for 6.0 dS m^{-1}saline water and 14 % for 8.0 dS m^{-1} saline water. The main effect of incubation period, the ion adsorption and their removal increased with incubation duration and five days' incubation duration was highly effective with 35 % reduction. The interactive effect of saline water and bacterial isolates was highly significant as all cultures are highly significant under low saline water and the C_{10} culture recorded the effect of 69 % magnesium content decline, but all cultures were equally effective in remaining saline water kinds. The microbial effects varied significantly with salt content and incubation duration that the cultures were equally effective in ion removal for two days' incubation period, whereas C_{10}culture were highly effective in both in five days (75 % reduction) as well as seven days' incubation duration (80% reduction). In contrast to this, all cultures observed with almost same effect in all incubation duration studies in each saline water (Table 3).

Table 3: Effect of saline bacterial growth and development on per cent decline of electrical conductivity water salinity, and calcium and magnesium ion concentration of saline water

Saline water types (S)	Incubation period (days)	EC (dS m^{-1})				Ca^{2+} conc. (Meq L^{-1})				Mg^{2+} conc. (Meq L^{-1})			
		C_8	C_{12}	C_{10}	Mean	C_8	C_{12}	C_{10}	Mean	C_8	C_{12}	C_{10}	Mean
S1 0.5 dSm^{-1}	Two	42.0	45.0	56.0	47.7	42.0	45.0	56.0	47.7	37.9	44.1	52.9	47.7
	Five	56.0	61.0	74.0	63.7	56.0	61.0	74.0	63.7	52.9	61.8	75.0	63.7
	Seven	60.0	62.0	75.2	65.7	60.0	62.0	75.2	65.7	55.9	66.2	79.4	65.7
S2 2.0 dS m^{-1}	Two	35.5	38.0	41.0	38.2	35.5	38.0	41.0	38.2	37.6	41.5	46.7	38.2
	Five	40.5	43.0	47.0	43.5	40.5	43.0	47.0	43.5	41.1	45.2	51.8	43.5
	Seven	41.3	43.9	48.2	44.4	41.3	43.9	48.2	44.4	41.8	46.3	52.9	44.4
S3 4.0 dSm^{-1}	Two	20.8	22.0	23.3	22.0	20.8	22.0	23.3	22.0	22.6	25.3	29.0	22.0
	Five	23.3	24.3	26.0	24.5	23.3	24.3	26.0	24.5	24.7	27.9	32.3	24.5
	Seven	24.3	25.0	27.0	25.4	24.3	25.0	27.0	25.4	25.3	28.6	33.2	25.4
S4 6.0 dS m^{-1}	Two	15.3	15.8	16.3	15.8	15.3	15.8	16.3	15.8	17.8	20.1	23.5	15.8
	Five	16.8	17.3	18.2	17.4	16.8	17.3	18.2	17.4	19.3	21.8	25.6	17.4
	Seven	17.3	18.2	18.7	18.1	17.3	18.2	18.7	18.1	19.7	22.5	26.3	18.1
S5 8.0 dSm^{-1}	Two	12.3	11.5	12.9	12.2	12.3	11.5	12.9	12.2	12.2	14.0	16.2	12.2
	Five	13.4	12.6	14.3	13.4	13.4	12.6	14.3	13.4	13.2	15.0	17.8	13.4
	Seven	13.9	12.9	14.5	13.8	13.9	12.9	14.5	13.8	13.5	15.5	18.2	13.8
	Mean	28.8	30.2	34.2	30.1	28.8	30.2	34.2	30.1	29.0	33.1	38.7	31.1
	Culture (C)	Dura-tion (D)	Salinity (S)	SXD		Culture (C)	Duration (D)	Salinity (S)	SXD	Culture (C)	Duration (D)	Salinity (S)	SXD
Sed	2.7	2.5	3.4	3.1		2.7	2.5	3.4	3.1	2.7	2.5	4.1	2.3
CD(0.05)	5.3	5.1	7.1	6.0		5.3	5.1	7.1	6.0	5.3	5.1	8.0	4.5
	CXD	SXC	CXSXD			CXD	SXC	CXSXD		CXD	SXC	CXSXD	
Sed	3.3	4.1	4.6			3.3	4.1	4.5		2.8	4.0	4.6	
CD(0.05)	NS	8.2	NS			NS	8.2	NS		NS	8.0	9.1	

NS-Non-significant, Sed- Standard error mean, CD-Critical difference value

Among the cultures, the C_{12} culture had higher effect with the decline of 29 % sodium concentration. For the main effect of incubation duration, the five days incubation duration had significantly higher decline of sodium concentration at 25 %. Among various salt concentrations, the 0.5 dS m^{-1} saline water had significantly higher decline of sodium concentration at 43.0 % and the effect decreased with increased salt concentration.However, the sufficient duration required for sodium removal varied with salt content confirmed five days duration for low saline and two days for remaining saline water for higher removal of sodium. Further, the microbial effect was also varied with salt content that the C_{10} isolate had significantly higher effect under low saline water while the C_{10} and C_{12} isolates were equally effective in bringing down of sodium content from 2.0 dS m^{-1} saline water. For reaming all saline water kinds, all the three cultures had the same effect. The interactive effect between saline water, incubation duration and bacterial isolates was highly significant. Under low saline water, the C_{10} culture had high sodium removal in all incubation period, whereas both C_{10} and C_{12} cultures were equally efficient isolates under 2.0 dS $m^{-1}$and 4.0 dS m^{-1}saline water. Further, all the bacterial isolates were at par for remaining saline water(Table 4).

Table 4: Effect of saline bacterial growth and development on per cent decline of sodium, chloride and sulphate concentration of saline water

Saline water types (S)	Incubation period (days)	Na^+ conc. (Meq L^{-1})				Cl^- conc. (Meq L^{-1})				SO_4^{2-} conc. (Meq L^{-1})			
		C_8	C_{12}	C_{10}	Mean	C_8	C_{12}	C_{10}	Mean	C_8	C_{12}	C_{10}	Mean
S1 (0.5 dS m^{-1})	Two	27.8	38.4	46.5	38.9	16.5	19.3	23.5	19.7	34.1	41.9	52.0	42.7
	Five	33.3	44.9	54.3	45.5	24.7	29.6	35.4	30.0	41.9	51.3	63.4	52.2
	Seven	35.2	47.0	57.2	47.8	30.4	36.6	43.2	36.8	44.2	54.0	66.9	55.0
S2 (2.0 dS m^{-1})	Two	21.5	30.7	37.1	31.1	6.4	7.7	9.4	7.9	9.7	12.7	16.4	12.9
	Five	23.2	32.9	39.6	33.2	8.2	9.9	11.9	10.1	11.3	14.9	18.8	15.0
	Seven	23.9	33.7	40.6	34.1	9.7	11.6	13.9	11.8	12.1	15.8	19.9	15.9
S3 (4.0 dS m^{-1})	Two	11.7	19.0	22.9	19.2	3.9	4.6	5.6	4.8	8.8	10.7	12.8	10.8
	Five	12.6	20.0	24.1	20.2	4.9	5.8	7.1	6.0	9.8	11.8	14.2	11.9
	Seven	12.9	20.4	24.6	20.6	5.6	6.7	8.0	6.8	10.0	12.1	14.6	12.2
S4 (6.0 dS m^{-1})	Two	7.5	13.8	16.7	14.0	3.1	3.7	4.5	3.8	6.6	7.9	9.5	8.0
	Five	8.1	14.5	17.5	14.7	3.6	4.3	5.2	4.4	7.2	8.7	10.4	8.8
	Seven	8.3	14.9	17.9	15.0	4.0	4.9	5.8	4.9	7.4	9.0	10.8	9.1
S5 (8.0 dS m^{-1})	Two	4.9	10.7	12.9	10.9	2.6	3.0	3.7	3.1	5.3	6.4	7.7	6.5
	Five	5.3	11.2	13.5	11.3	2.9	3.0	4.2	3.6	5.8	7.0	8.4	7.1
	Seven	5.5	11.5	13.8	11.6	3.3	3.9	4.8	4.0	6.0	7.3	8.5	7.3
	Mean	16.1	24.2	29.3		8.7	10.3		10.5	14.7	18.1	22.3	
	Culture (C)	Durat-ion (D)	Salinity (S)	SXD		Culture (C)	Duration (D)	Salinity (S)	SXD	Culture (C)	Duration (D)	Salinity (S)	SXD
Sed	2.1	1.8	3.0	3.9		1.2	1.3	2.1	2.5	1.3	1.5	2.4	4.2
CD(0.05)	4.0	3.8	5.8	8.0		2.4	2.5	4.0	5.2	2.5	3.0	5.1	8.5
	CXD	SXC	CXSXD			CXD	SXC	CXSXD		CXD	SXC	CXSXD	
Sed	3.2	4.0	3.6			3.2	2.4	3.2		3.4	4.1	3.3	
CD(0.05)	NS	8	7.3			NS	5.0	6.4		NS	8.4	6.5	

NS-Non-significant

The microbial techniques on efficiency saline water cationic concentration suggested the higher effect for calcium and magnesium compared to sodium might be associated with its preferential adsorption of divalent cations over monovalent ions to polysaccharides as that of soil clay minerals(Sancey *et al.* 2011). In parallel to saline water EC, the efficiency in adsorptive removal of cations decreased with increased salt concentration. Further, change of duration required for higher removal of ions and the effect due to microbial growth and development also is changed (Ahechti *et al.* 2020).

Anionic characteristics of saline water: The chloride concentration of saline water differed greatly for bacterial cultures, incubation duration and saline water (Table 4). The significantly higher chloride decline was observed in the C_{10} culture at 12.4 % decline which was on par with C_{12} culture. The concentration decline for saline water, the higher magnitude reduction was observed in the 0.5 dS m^{-1}, which was nearly 29.0 % and the microbial effect was same for 4.0, 6.0 and 8.0 dS m^{-1} saline water recording lower decline of chloride concentration. Similarly, as the incubation duration increased the per cent decline of chloride concentration also increased and 11.0%decline was the highest noticedatfive days incubation duration, which almost equal to seven days incubation durations. The interactive effect of salinity and incubation duration was also significant that the low saline water (0.5 dS m^{-1}) had seven days incubation duration recording higher decline of concentration (37%) while the two days appeared to optimum incubation duration for all remaining saline water.The chloride concentration varied significantly for the interactive effect of water salinity, incubation duration and bacterial isolates. Seven days duration was an optimum for C_{10} (43 %) and C_{12} cultures (37 %) had significantly higher decline while the five days incubation duration for C_8 culture under low saline water while the remaining all saline water had higher decline at two days incubation duration. The microbial treatments in over all can remove around 10.5 % chloride concentration from the saline water between 0.5 and 8.0 dS m^{-1} EC value (Table 4).

Similar to chloride, the sulphate concentration of saline water differed widely for bacterial culturesand the significantly higher decline were observed in the C10 culture (22.3 %) which was on par with C_{12} cultures. The microbial effect of ion concentration for incubation period, the two days duration optimized with decline of 16 % the sulphate concentration. Whereas, the effect for 2.0 and 4.0 dS m^{-1} saline water are almost the same and the saline water 6.0 and 8.0 dS m^{-1} was almost on par. For interactive effect of saline water, incubation duration and bacterial cultures, the sulphate decline varied significantly among treatments. The five days incubation duration was the standardized duration for all culture under low saline water of 0.5 dS m^{-1}, whereas the remaining medium and high saline water showed no significant change with duration that the two days incubation duration optimized for microbial treatments irrespective of isolates used for treatment. Thus, the C_{10} isolated grown in low saline water showed the highest decline of sulphate content at 63.4 % at five days incubation duration over other treatments. As a whole, the saline bacterial treatment can remediate around 18.4 % sulphate content from the saline water ranged between 0.5 and 8.0 dS m^{-1}(Table 4).

As that of cations, the anions were also subjected to similar fashion of adsorption at relatively low-level recording more for divalent anions removal for microbial amelioration of saline water. An electrostatic force from the positively charged ion usuallypresent in the different functional groups on the surface of polymers are involved for anionic adsorption, which has already been reported for anionic removal with crop residues (Charles *et al.* 2016).

In conclusion, the C_{10} and C_{12} isolates with seeding rate of 1.3 $x10^7$cfu's ml^{-1} and 1.7 X 10^7cfu's ml^{-1}recommended for amelioration of saline water whose EC value ranged between 0.5 and 8.0 dS m^{-1} for the effect of more than 30% decline of EC value.This could improve growth development and yield of crop and reduce salt build up in soilwhen the treated saline water used for irrigation. The characterization and identification of both bacterial isolates and field confirmation studies to assess the treated saline water effect on salt dynamics in soil and crop yield improvement are the suggested future research under the area of saline water improvement and their management for getting sustainably high yield.

ACKNOWLEDGEMENT

Help and support from Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University Tamil Nadu, Coimbatore and ICAR-National Institute of Abiotic Stress Management, Pune, Maharashtra and are acknowledged. First author acknowledges the guidance and financial support received for his PhD programme.

REFERENCES

Ahechti, M.,M. Benomar, M. El Alami, and C. Mendiguchía. (2020) Metal adsorption by microplastics in aquatic environments under controlled conditions: exposure time, pH and salinity. *International Journal of Environmental Analytical Chemistry* 1(8):1-7

Anbu, P., Kang, C.H., Shin, Y.J., and J.S. So (2016) Formations of calcium carbonate minerals by bacteria and its multiple applications. *Springerplus* 5(1): 1-26.

Cavallero, G.J., Ferreira, M.L., Casabuono, A. C., Ramírez, S.A., Vullo, D.L., and A.S. Couto, (2020) Structural characterization and metal biosorptive activity of the major polysaccharide produced by Pseudomonas veronii 2E. *Carbohydrate Polymers* 245(116458):1-11

Charles, J. C. Bradu, N. Morin-Crini, B. Sancey, P. Winterton, G. Torri, P.-M. Badot, and G. Crini (2016) Pollutant removal from industrial discharge water usingi ndividual and combined effects of adsorption and ion-exchange processes: Chemical abatement. *Journal of Saudi Chemical Society* 20 (2):185-194.

Chikkanna, A., Ghosh, D., and Kishore, A. (2018)Expression and characterization of a potential exopolysaccharide from a newly isolated halophilic thermotolerant bacteria Halomonasnitroreducens strain WB1. *Peer Journal* 6:1-8

Chowdhury, N., Marschner, P., and Burns, R. G. (2011) Soil microbial activity and community composition: impact of changes in matric and osmotic potential. *Soil Biology and Biochemistry* 43(6): 1229-1236.

Dattatreya, P. S., Madhavi, K., Satyanarayana, B., Amin, A., and Harini, C. (2018) Assessment of physico-chemical characteristics of mangrove region in the Krishnapatnam Coast, India. International *Journal of Current Microbiology and Applied Sciences* 7(5): 2326-2342.

Dayma, P., Raval, I. H., Joshi, N., Patel, N. P., Haldar, S., and Mody, K. H. (2015) Influence of low salinity stress on virulence and biofilm formation potential in Vibrio alginolyticus, isolated from the Gulf of Khambhat, Gujarat India. *Aquatic Living Resources* 28(2-4): 99-109.

El-Ghany, A., Mona, F., and Attia, M. (2020) Effect of exopolysaccharide-producing bacteria and melatonin on faba bean production in saline and non-saline soil. *Agronomy* 10(3): 316- page number

G. Crini (2011) Effect of additional sorption treatment by cross-linked starch ofwastewater from a surface finishing plant. *Industrial and Engineering Chemistry Research* 50 (3):1749-1756.

Gunde-Cimerman, N., Plemenitaš, A., and Oren, A. (2018) Strategies of adaptation of microorganisms of the three domains of life to high salt concentrations. *FEMS microbiology reviews* 42(3): 353-375.

Hussain, G., Qayyum, M. A., &Alajaji, A. N. (1989) Calculation for the preparation of salt mixtures to develop artificial salinity for use in soils and waters.*Arid Soil Research and Rehabilitation* 3(1):85-89

ICAR (2015)*ICAR-Vision 2050*. Indian Council of Agricultural Research DrRajendra Prasad Road, KrishiBhavan New Delhi 110 001, India. http://www.icar.org.in/

Kumar, A., Singh, S., Gaurav, A. K., Srivastava, S., andVerma, J. P. (2020) Plant growth-promoting bacteria: biological tools for the mitigation of salinity stress in plants. *Frontiers in Microbiology*11: 1216.

Maree, J. P., Gerber, A., and Hill, E. (2013) An integrated process for biological treatment of sulfate-containing industrial effluents. *Journal of Water Pollution Control Federation*, 59 (12): 1069-1074.

Mouhamad, R. S., Mutlag, L. A., Al-Khateeb, M. T., Iqbal, M., Nazir, A., Ibrahim, K. M., and Jassam, O. H. (2017) Reducing water salinity using effective microorganisms. *Net Journal of Agricultural Science* 5(3): 114-120.

Qurashi, A. W., andSabri, A. N. (2012) Biofilm formation in moderately halophilic bacteria is influenced by varying salinity levels. *Journal of basic microbiology* 52(5): 566-572.

Ramanathan, A. L., Ranjan, R. K., Prasad, M. B. K., Chauhan, R., and Singh, G. (2010) Sediment-nutrient dynamics in selected Indian mangrove ecosystems-land use and climate change implications. *IAHS-AISH publication* 337: 84-92.

Sancey, B., J. Charles, G. Trunfio, P.-M. Badot, M. Jacquot, X. Hutinet, S. Gavoille, and

Sasaki, K., Hosokawa, Y., Takeno, K., & Sasaki, K. (2017) Removal of sodium from seawater medium using photosynthetic bacteria. *Journal of Agricultural Chemistry and Environment* 6(03):1-8

Tandon, H. L. S. (2005). *Methods of Analysis of Soils, Plants, Waters, Fertilisers& Organic manures*. Fertilizer Development and Consultation Organization.

Wang, R., Kang, Y., Wan, S., Hu, W., Liu, S., and Liu, S. (2011) Salt distribution and the growth of cotton under different drip irrigation regimes in a saline area. *Agricultural Water Management* 100(1): 58-69.

Yan, N., Marschner, P., Cao, W., Zuo, C., and Qin, W. (2015) Influence of salinity and water content on soil microorganisms. *International Soil and Water Conservation Research* 3(4): 316-323.