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Effect of Consortium of Halophilic and Halotolerant Microorganisms on Reclamation of Saline Sodic Soil on Sugarcane Yield

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ABSTRACT

The aim of this field research trial was to evaluate the effect of consortium of halophilic and halo tolerant bacteria on reclamation of sodic soil and increasing yield of sugarcane. It was revealed that application GRDF with consortium of HP and HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up could reduce Exchangeable Sodium Percentage (ESP) by 10.92% and can increase Hydrolic Conductivity (HC) by 26.31% over 100% GRDF. Also cane yield were increased by 40.99 t and CCS yield by 10.68 t by application of consortium of halophilic and halo tolerant bacteria @ 12.5lit/ha at planting and 12.5 lit/ha at earthing up alongwith GRDF over 100% GRDF.

Keywords : Halophilic microorganism, halotolerant microorganisms, reclamation, saline soil, sugarcane yield.

INTRODUCTION

In India, an area of 6.73 million ha of soil is salt affected. This affected area is Gangetic plain of Uttar Pradesh, the arid and semiarid regions of Gujarat and the peninsular zone of Maharashtra state. Nearly 75% of salt-affected soils in the country exist in the states of Gujarat (2.23 million ha), Uttar Pradesh (1.37 million ha), Maharashtra (0.61 million ha), West Bengal (0.44 million ha), and Rajasthan (0.38 million ha) (Mandal et al. 2018). It was observed that in canal-irrigated sugar cane tracts, excessive use of water and chemical fertilizers has degraded the soil. 6,06,759 ha of land in Pune, Sangli, Ahmednagar, Solapur and Nashik is affected. (Pharande, 2015). Soil salinity and sodicity can affect plant growth both physically (osmotic effect) and chemically (nutrient and/or toxicity effect). It becomes more difficult for crops to uptake water when the salts of the soil increases.

The microbial biomass was lower in the untreated saline soil, the effect of adding gypsum in saline soil was insignificant. Arora et al. (2014) reported successful experiments in the recovery of saline-sodic soils when a mixture of different microorganisms was applied, without the prior application of gypsum. Beka et al. (2024) recorded that the saturated hydraulic conductivity of saline-sodic sols increased by application of the halophilic microorganisms.

The salt affected soils are dominated by different types of halophilic and halotolerant microorganism. Halophilic microorganisms are metabolically different and adapted to high salt concentration. These microorganisms are good candidates for bioremediation of saline sodic soil which also promote the plant growth that helps to increase the crop yield. Millions of hectares of land around the world are salt-affected and more are becoming prone to salinity due to the accumulation of salt, making them increasing unsuitable for agriculture, with an estimated 25% of all irrigated land currently begin covered by saline areas. Thus, there is an increasing need to understand saline environment and the microbial diversity found in these saline systems as a model system to understand the interaction of simple ecosystem where only few types of microorganisms are found. Extremophiles and particular halophiles are of interest especially when considering the future

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possibility of increasing food storage and food preservation problem (Perez et al. 2022).

Salt-affected soils, which are usually washed or amended with calcium salts, but bioreclamation by using microorganisms as an innovative and environment friendly option.

Biological reclamation of saline sodic soil can be possible using consortium of halophilic and halotolerant microorganisms. Consortia may reduce the salinity and sodicity of the soil and enhance the crop productivity. The attempt was to study saline sodic soil reclamation ability of consortium of halophilic microorganisms, evaluation of efficiency of consortium of halophilic microorganisms for increasing yield and quality of sugarcane in saline sodic soil and to study reclamation of salinity and sodicity of soil by consortium of halophilic microorganisms.

MATERIALS AND METHOD

The field research trial was conducted at R&D farm of VSI in Suru season. The variety used was CoM 0265. The gross plot size was 5 rows(1.37 m) x 9m and net size was 3 rows (1.37m) x 8m. The design for trial was randomized block design. Three replications were used. The soil type of trial was salt affected. The consortium of halophilic (HP) and halotolerant (HT) bacteria were procured from R&D lab of Agril Microbiology section, VSI, Pune.

The following treatments were used during trial with general recommended dose of fertilizers. All schedule of operations and applications were followed as per schedule.

T1 : Abs. Control

T2 : GRDF

T3 : GRDF + Consortium of HP & HT bacteria @15 lit/ha at planting

T4 : GRDF + Consortium of HP & HT bacteria @7.5 lit/ha at planting @7.5 lit/ha at earthing up

T5 : GRDF + Consortium of HP & HT bacteria @ 20 lit/ha at planting

T6 : GRDF + Consortium of HP & HT bacteria @10 lit/ha at planting @10 lit/ha at earthing up.

T7 : GRDF + Consortium of HP & HT bacteria @25 lit/ha at planting

T8 : GRDF + Consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up.

T9 : GRDF + Gypsum

All schedule of operations and applications were followed as per schedule.

RESULTS AND DISCUSSION

Yield attributing characters

Cane yield: The data presented in Table 4 and Figure 1 showed that higher cane yield (136.78t /ha) was achieved where application of consortium of HP and HT bacteria @12.5 lit/ha at planting @12.5lit/ ha at earthing up along with GRDF as compared to GRDF cane yield (95.79 t/ha) was applied.

Table 1 : Soil analysis at initial stage (before planting)

Stage	pH (1:2.5)	ECe dS m^{-1}	Available Nitrogen (kg/ha)	Available Phosphorous (kg/ha)	Available Potash (kg/ha)	Organic Carbon (%)
Initial stage	8.61	2.17	224.6	60.1	341.5	0.48

Table 2 : Analysis at initial (before planting) - saturation extraction method

Stage	Ca	Mg	Na	K	CEC	ESP (%)	HC cm h^{-1}
	meq/lit						
Initial stage	20.6	8.3	7.4	0.47	43.7	16.9	0.47

Table 3 : Microbial analysis at initial stage (before planting)

Media	Dilution		
	10^{-2}	10^{-4}	10^{-6}
Total bacteria	65	8	3
Total Fungi	6	2	-
Halophilic and Halotolerant bacteria	95	27	5

CCS yield: The CCS yield (27.02/ha) was recorded higher where application of GRDF+consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up as compared to GRDF CSS yield (16.34tha) was found.

Plant population: The higher millable canes per ha (63144.78/ha) was recorded in where application of GRDF+ consortium of HP and HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up as compared to GRDF CSS yield (57235.55/ha) was found.

Girth: The higher cane girth (11.80 cm) was recorded where application of GRDF + Consortium of HP & HT bacteria @ 20 lit/ha at planting as compared to GRDF girth was recorded(10.88cm).

Millable height: The higher millable height (232.41cm) was recorded where application of GRDF + consortium of HP & HT bacteria @ 20 lit/ha at planting as compared to GRDF millable height (219.42cm) was recorded.

Tillering ratio: The highest tillering ratio (4.82) was recorded where application of GRDF + Consortium of HP & HT bacteria @7.5 lit/ha at planting @7.5 lit/ha at earthing up was done as compared to GRDF tillering ratio (4.44) was recorded.

Cane juice quality: The higher sucrose content in juice (19.86%) was observed where application of GRDF + Consortium of HP & HT bacteria @25 lit/ha at planting as compared to GRDF sucrose % (18.85%) was found (Table 5).

B: C ratio

The higher Cost Benefit ratio (1 : 2.86) was observed where application of GRDF+ Consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up as compared to application of GRDF B:C ratio was found 1:1.34 (Table 6).

Soil properties after harvest of sugarcane.

Lowest pH8.50, ECdS m^{-1} 2.14, highest available nitrogen 270.03 kg ha^{-1}, available phosporous 82.47 kg ha^{-1}, available potash 427.23 kg ha^{-1} and 0.77% organic Carbon was recorded as compared to GRDF i.e. pH8.65, EC2.31dS m^{-1}, available Nitrogen 238.37 kg ha^{-1}, available Phophorus65.33 kg ha^{-1}, available potash 392.737.23 kg ha^{-1} and 0.50 % organic carbon was recorded (Table 7-9).

Exchangeable sodium percentage (ESP)15.90 % was recorded where GRDF with consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up was applied and in only GRDF it was 17.85 % 40.25 meq/lit cation exchange capacity (CEC)was found in treatment of consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up whereas in GRDF control 42.57 meq/lit was recorded (Table 9).

In 100% GRDF treatment, 1.83 g/cm^3 bulk density was recorded whereas 1.47 g/cm^3 was recorded where consortium of HP and& HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up was applied alongwith GRDF. 0.57cm h-1hydrolicconductivity(HC) was found where consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up was applied alongwith GRDF and in only GRDF 0.42h^{-1} (Table 10).

DISCUSSION

Arora and Vanza (2014) showed there was increase in plant growth parameters and yield of wheat when halophilic bacteria were inoculated with seeds, and saline water irrigation was applied. In our study we found same that, plants inoculated with a consortium of halophilic bacteria also showed growth at 10% NaCl, whereas inoculation with single isolates did not promote plant growth at this salt concentration.

Table 4 : Effect of halophilic and halotolerant bacteria on biometric & growth characters of sugarcane

Treatment	Cane Yield (t/ha)	CCS Yield (t/ha)	N.M.C. ('000/ha)	Millable Height (Cm)	Girth (Cm)	No. of internodes	Internodal Distance	Tillering ratio	Germination %	BC ratio
Abs. Control	87.79	14.76	47734.91	209.67	9.43	18.73	9.73	4.16	42.27	2.16
GRDF	95.79	16.34	57235.55	219.42	10.88	19.47	10.33	4.44	46.67	1.34
GRDF+ Consortium of HP & HT bacteria@15lit/haat planting	119.76	22.46	58394.16	224.57	11.42	23.81	10.55	4.72	49.20	2.58
GRDF+ Consortium of HP & HT bacteria @7.5 lit/ha at planting @7.5 lit/ha at earthing up	120.39	22.40	59089.33	226.32	11.39	23.99	10.81	**4.82**	**54.13**	2.56
GRDF + Consortium of HP & HT bacteria @ 20 lit/ha at planting	122.26	22.76	58625.88	227.23	11.51	24.20	10.91	4.76	47.33	2.59
GRDF + Consortium of HP & HT bacteria @10 lit/ha at planting @10 lit/ha at earthing up	124.84	23.55	60247.94	228.19	11.61	24.44	11.10	4.79	49.33	1.71
GRDF+ Consortium of HP & HT bacteria @25 lit/ha at planting	128.19	25.28	61436.79	230.89	11.61	25.02	11.34	4.72	46.40	1.75
GRDF+ Consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up	**136.78**	**27.02**	**63144.48**	**232.41**	**11.80**	**25.87**	**11.39**	4.77	50.67	**2.86**
T9: GRDF+ Gypsum	105.40	19.20	57814.85	220.77	10.92	22.98	10.73	4.68	49.87	2.27
SE	***6.31***	***1.44***	***2343.12***	***6.92***	***0.22***	***0.53***	***0.51***	***0.47***	***3.78***	**-**
CD @ 5%	***18.93***	***4.34***	***7024.69***	***20.75***	***0.68***	***1.61***	***1.55***	***1.42***	***11.34***	**-**
	S	***S***	***S***	***S***	***S***	***S***	***S***	***NS***	***NS***	**-**

Table 5 : Effect of halophilic and halotolerant bacteria on juice quality of sugarcane

Treatment	**Brix %**	**Sucrose%**	**CCS %**	**Purity%**
Abs. Control	20.29	17.81	16.83	92.05
GRDF	18.99	17.49	17.00	90.99
GRDF + Consortium of HP & HT bacteria @15 lit/ha at planting	20.81	18.85	18.59	94.60
GRDF+ Consortium of HP & HT bacteria @7.5 lit/ha at planting @7.5 lit/ha at earthing up	20.60	18.93	18.60	92.76
GRDF + Consortium of HP & HT bacteria @ 20 lit/ha at planting	20.19	12.64	18.63	95.15
GRDF + Consortium of HP & HT bacteria @10 lit/ha at planting @10 lit/ha at earthing up	20.08	18.66	18.86	93.21
GRDF+ Consortium of HP & HT bacteria @25 lit/ha at planting	20.15	**19.86**	19.72	97.29
GRDF+ Consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up	20.33	19.73	**19.80**	93.74
GRDF+ Gypsum	19.91	18.63	18.22	94.29
SE	***0.48***	***2.12***	***0.55***	***1.90***
CD @ 5%	***1.46***	***6.38***	***1.67***	***5.37***

Table 6 : Effect of halophilic and halotolerant bacteria on cost benefit ratio

Tr. No.	**Cane Yield (t/ha)**	**Monetory returns (Rs/ha)**	**Agronomic cultivation (Rs.)**	**Cost of Fertilizers**	**Cost of BR Consortium**	**Total cost of cultivation (Rs/ha)**	**Net Profit (Rs.)**	**Cost Benefit Ratio**
T1	87.79	245807.30	113660	0	0	113660	130570.33	2.16
T2	95.79	268215.73	113660	14091	0	199751	51041.11	1.34
T3	119.76	335319.07	113660	14091	3750.00	131501	180667.04	2.58
T4	120.39	337090.19	113660	14091	3750.00	131501	207306.19	2.56
T5	122.26	342327.10	113660	14091	5000.00	132751	197530.51	2.59
T6	124.84	349557.83	113660	14091	5000.00	204751	149095.77	1.71
T7	128.19	358945.92	113660	14091	6250.00	206001	154145.98	1.75
T8	136.78	382987.83	113660	14091	6250.00	134001	256916.27	2.86
T9	105.40	295114.97	113660	14091	112.51	127863.5	156406.08	2.27

Table 7 : Effect of halophilic and halotolerant bacteria on soil properties at harvest of sugarcane

Treatments	**pHs**	**ECe dS m^{-1}**	**Available Nitrogen (kg/ha)**	**Available Phosphorous (kg/ha)**	**Available Potash (kg/ha)**	**Organic carbon (%)**
Abs. Control	8.61	2.28	225.80	65.60	388.69	0.52
GRDF	8.65	2.31	238.37	65.33	392.73	0.50
GRDF + Consortium of HP & HT bacteria @15 lit/ha at planting	8.51	2.20	244.60	65.47	394.63	0.57
GRDF+ Consortium of HP & HT bacteria @7.5 lit/ha at planting @7.5 lit/ha at earthing up	8.56	2.23	246.67	66.53	407.53	0.61
GRDF + Consortium of HP & HT bacteria @ 20 lit/ha at planting	8.53	2.29	248.53	74.50	415.57	0.73
GRDF + Consortium of HP & HT bacteria @10 lit/ha at planting @10 lit/ha at earthing up	8.57	2.25	253.00	75.60	420.70	0.74
GRDF+ Consortium of HP & HT bacteria @25 lit/ha at planting	8.52	2.18	255.07	77.85	421.83	0.75
GRDF+ Consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up	**8.50**	**2.14**	**270.03**	**82.47**	**427.23**	**0.77**
GRDF+ Gypsum	8.53	2.12	225.80	63.27	393.13	0.63
SE	***0.09***	***0.04***	***8.77***	***0.94***	***0.10***	***0.049***
CD @ 5%	***0.27***	***0.13***	***NS***	***2.83***	***0.31***	***0.14***

Table 8 : Effect of halophilic and halotolerant bacteria on soil properties at harvest (saturation extraction method)

Treatments	**Ca**	**Mg**	**Ma**	**K**
	meq./lit			
Abs. Control	21.2	8.3	7.42	0.29
GRDF	21.0	7.9	7.6	0.24
GRDF + Consortium of HP & HT bacteria @15 lit/ha at planting	21.9	6.6	7.1	0.20
GRDF+ Consortium of HP & HT bacteria @7.5 lit/ha at planting @7.5 lit/ha at earthing up	22.4	7.4	7.8	0.24
GRDF + Consortium of HP & HT bacteria @ 20 lit/ha at planting	20.7	5.4	7.0	0.29
GRDF + Consortium of HP & HT bacteria @10 lit/ha at planting @10 lit/ha at earthing up	21.7	6.5	7.5	0.27
GRDF+ Consortium of HP & HT bacteria @25 lit/ha at planting	20.9	7.4	7.2	0.31
GRDF+ Consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up	19.2	6.2	6.4	0.20
GRDF+ Gypsum	20.6	7.2	6.0	0.22
SE	***0.27***	***0.28***	***0.27***	***0.03***
CD @ 5%	***0.81***	***0.85***	***0.82***	***0.09***

Table 9 : Effect of halophilic and halotolerant bacteria on soil properties at harvest

Treatments	**ESP (%)**	**CEC (meq/lit)**	**Bulk Density (g/ cm³)**	**HC cm h⁻¹**
Abs. Control	16.89	43.80	1.91	0.40
GRDF	17.85	42.57	1.83	0.42
GRDF + Consortium of HP & HT bacteria @15 lit/ha at planting	17.37	40.87	1.67	0.43
GRDF+ Consortium of HP & HT bacteria @7.5 lit/ha at planting @7.5 lit/ha at earthing up	17.77	43.90	1.57	0.47
GRDF + Consortium of HP & HT bacteria @ 20 lit/ha at planting	17.25	40.58	1.51	0.45
GRDF + Consortium of HP & HT bacteria @10 lit/ha at planting @10 lit/ha at earthing up	17.33	43.27	1.53	0.47
GRDF+ Consortium of HP & HT bacteria @25 lit/ha at planting	17.45	41.25	1.50	0.51
GRDF+ Consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up	**15.90**	**40.25**	**1.47**	**0.57**
GRDF+ Gypsum	14.55	41.23	1.51	0.61
SE	***0.54***	***0.83***	***0.06***	***0.02***
CD @ 5%	***1.62***	***2.50***	***0.18***	***0.07***

Table 10 : Effect of halophilic and halotolerant bacteria on microbial count at harvest

Treatments	**Total Bacteria**	**Total Fungi**	**Total Actinomycetes**	**HP & HT bacteria**
Abs. Control	4 x106	1 x106	5 x106	7 x106
GRDF	5 x106	2 x106	5 x106	7 x106
GRDF + Consortium of HP & HT bacteria @15 lit/ha at planting	1 x108	10x x106	11 x106	15x108
GRDF+ Consortium of HP & HT bacteria @7.5 lit/ha at planting @7.5 lit/ha at earthing up	5x108	13x106	18x106	22x1010
GRDF + Consortium of HP & HT bacteria @ 20 lit/ha at planting	16x108	24x106	25x106	28x1010
GRDF + Consortium of HP & HT bacteria @10 lit/ha at planting @10 lit/ha at earthing up	21x108	33x106	38x106	35x1010
GRDF+ Consortium of HP & HT bacteria @25 lit/ha at planting	4x1010	1x108	32x106	48x1010
GRDF+ Consortium of HP & HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up	6x1010	5x108	1x108	42x1010
GRDF+ Gypsum	7 x106	4 x106	6 x106	8 x106

HP- Halophilic HT- Halotolerant

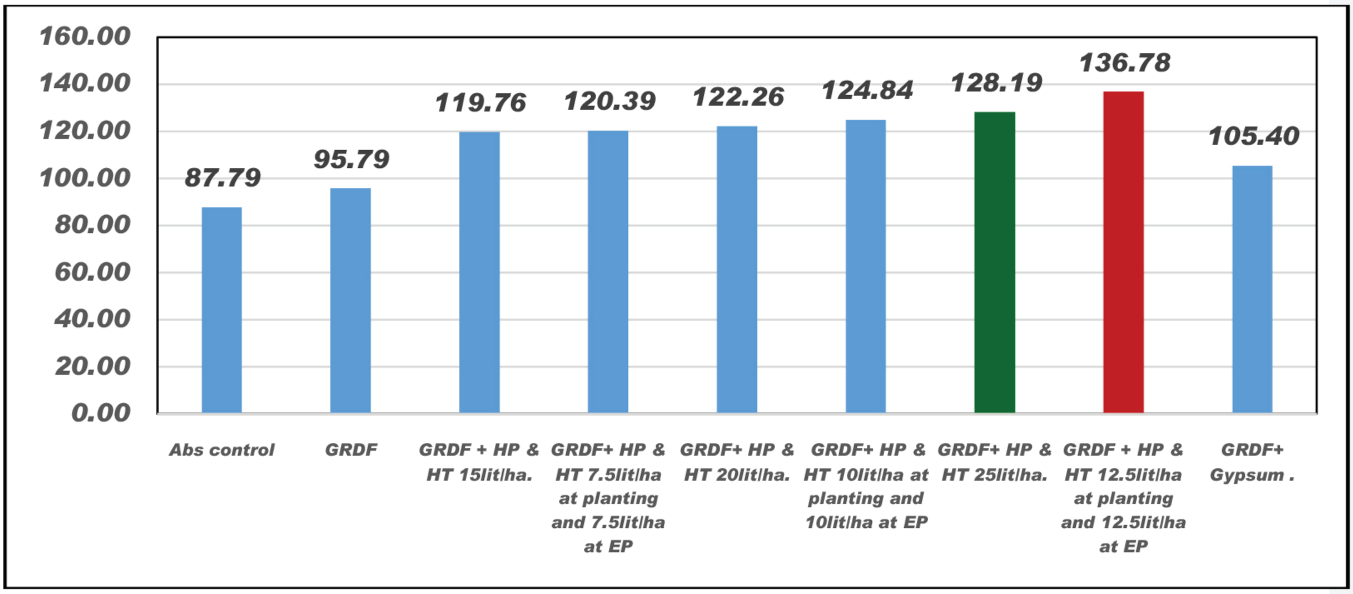

Figure 1 : Effect of consortium of halophilic and halotolerant bacteria on cane yield (t/ha)

The maximum 194.5% fresh weight, 98.97% dry weight, 15.37 cm shoot length and 7.4 cm root length of plant were found in consortium with 5% NaCl' treated pot as compared to the uninoculated control. Another very likely mechanism may be alleviation of salinity stress via plant growth-promoting rhizobacteria that express ACC deaminase activity. This enzyme removes stress ethylene from the rhizosphere. Also, the halophilic/halotolerant bacteria remove sodium from the surrounding soil and thus useful in plant growth promotion in salt-affected soils. Halophilic microbes were found to have the ability to remediate the saline soil and can be used by glycophytes/crop plants for optimum growth under saline condition.

A. chroococcum strains C5 and C9 protected plants against the inhibitory effects of NaCl argued on the basis of our findings that bacterial amelioration of saline stress could be the integration of several aspects including increasing plant antioxidative capacity, improving plant mineral nutrition, and promoting plant growth by bacterial synthesis of plant hormones or regulation of ions transporters that resulted in an improved K^+/Na^+ ratio in plants. However, extensive research is needed to elucidate how bacteria mediate this effect on maize growth. In summary, results indicated that bacteria could ameliorate saline stress of maize plants caused by high levels of NaCl in soil. Hence, use of selected PGPB may be important inputs to decrease the deleterious effects of saline soils.

Nisha et al. (2017) reported consortia of two indigenous heterocystous cyanobacteria, *Nostocellipsosporum* HH-205 and *Nostocpunctiforme* HH-206 isolated from a salt affected area of Hisar, Haryana (India) used as biofertilizer in bioremediation of salt affected soils. The experiments were conducted in a pot house for the period of 240 days. There was a significant (P/0.05) increase in carbon, phosphate, nitrogen, potassium, magnesium, cation exchange capacity, mean weight diameter and hydraulic conductivity of soil with biofertilizers treatment whereas sodium ion and electrical conductivity were found to be decreased. Improvement in soil aggregation and stability due to increased soil microbial activities (dehydrogenase, invertase and phosphomonoesterase) were also observed. Significant increase in growth and yield of pearl millet–wheat crop was observed in amended pots even under low water regime. Thus, the indigenous cyanobacterial species show effective exploitation for phytoremediation and improved productivity of saline soils under semi-arid condition.

CONCLUSION

A field research trial was carried out for the first year, for evaluation of effect of application of consortium of halophilic (HP) and halo tolerant (HT) bacteria. It was revealed that GRDF with consortium of HP and HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing up can reduce Exchangeable Sodium Percentage (ESP)and can increase Hydraulic Conductivity (HC) as compared to GRDF only. Highest cane yield (136.78 t/ha)and CCS yield (27.02 t/ha) was also found where application of consortium of halophilic and halo tolerant bacteria@ 12.5lit/ha at planting and 12.5 lit/ha at earthing up with 100 % GRDF was done followed by cane yield (128.19t/ha) and CCS yield (25.28t/ha) by application of consortium of halophilic and halo tolerant bacteria@ 25lit/ha at planting with 100% GRDF over control (100% GRDF) where cane yield (95.79t/ha) and CCS yield (16.34 t/ha) was found.

Therefore, it can be concluded that, consortium of HP and HT bacteria @12.5 lit/ha at planting @12.5 lit/ha at earthing upalong with GRDF can be applied for biological reclamation of sodic soil. Further trials for another plant cane and ratoon are in progress.

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