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RESEARCH ARTICLE

Salt Tolerant Bacterial Inoculants as Promoters of Rice Growth and Microbial Activity in Coastal Saline Soil

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Abstract Salinity stress is one of the major abiotic stresses to rice crop production in coastal saline soils. The aim of the present investigation was to study effect of salt tolerant microbes and organic matter supplementation on rice plant growth and soil chemical and biological properties in coastal saline soils under pot condition. Three microbial inoculants—*Pseudomonas multiresinivorans*, *Microbacterium esteraromaticum*, and *Bacillus subtilis* individually and their consortium with amended farmyard manure (FYM) were compared against untreated control and FYM without the microbial inoculant. The treatments with combined application of *B. subtilis* with FYM and consortium with FYM were the best performers. Highest root fresh (67.8 g) and dry (13.9 g) weight and root volume (113 ml) were recorded in treatment with *Bacillus* and FYM. FYM caused 37.6, 63 and 83.4% increase in root volume, root fresh weight and dry weight respectively over treatment with *Bacillus* only. A similar trend was observed for consortium and consortium with FYM. Consortium with FYM caused significantly ($p < 0.01$) highest shoot fresh (21.5 g) and dry (8.11 g) weight. This treatment also showed highest phosphatase (105 µg PNP g^{-1} soil day^{-1}) activity, soil microbial biomass carbon (2985 µg C g^{-1} soil) and soil microbial biomass carbon as a fraction of soil organic carbon (0.3%). Thus, combined application of salt tolerant microorganisms and organic amendment helps rice plants alleviate salt stress and improves plant growth. Furthermore, evaluation of these microorganisms under field conditions needs to be undertaken through systematic experimentation.

Keywords Coastal saline soils · Rice · Salt tolerant bacteria · Soil enzyme activity · Soil microbial activity

Significance Statement The present study reveals that applying salt tolerant microorganisms individually and in combination with FYM can significantly improve rice plant growth parameters, soil chemical properties and biological activity in coastal saline soil. Thus, microorganisms along with organic manure could be used for amelioration of saline soils.

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Introduction

Rice (*Oryza sativa* L.), belonging to the family Gramineae, is a primary source of food for more than half of the world population [1]. Rice is a choice crop of millions of poor, small and marginal farmers, not only for gaining income but also as a household food security.

In India, an area as large as 8 Mha is reported to be under salinity effect, of which 3.1 Mha is in coastal regions [2]. The coastal saline soils in Goa, India are locally known as *Khazan* lands. These lands are protected from saline water intrusion by the construction of an intricate system of dykes, sluice gates and canals [3]. Rice is the most prevalent crop in coastal saline soils. However, excess rainfall during monsoon causes flooding and deep water submergence. The problem is further complicated by inundation through backwash from sea, tidal waters, wind borne salts and underground intrusion of sea water in sub soils

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[4]. The coastal saline soils have an acidic soil reaction and high level of soluble salts. Salinity under acidic condition results in decrease in soil enzyme and microbial activities. These soils are low with respect to soil available nitrogen (N) and phosphorus (P) [5]. High salinity affects plant growth through osmotic effects, suppresses the phosphorus uptake by plant roots and inhibits nitrification [6]. All these factors result in low yields of the traditionally cultivated varieties of rice, even though they are tolerant to salinity and submergence. Sustainable agricultural production in these soils can be achieved by chemical, organic or microbial interventions along with the use of salt tolerant high yielding varieties. Plant growth promoting microorganisms (PGPM) survive in and around the root rhizhosphere and enhance the plant growth and yield by symbiotic and asymbiotic nitrogen fixation, solubilization of mineral phosphates, production of plant growth regulators, extracellular hydrolytic enzymes, antibiotics, siderophores, hydrogen cyanide (HCN) and substrate competition [7]. Alleviation of salt stress by PGPM inoculants has been shown in rice, wheat, maize, cotton, lettuce, tomato, and pepper [8]. However, little information is available with respect to use of halotolerant plant growth promoting bacterial inoculant for rice cultivation in coastal saline soils.

The aim of the present study was to investigate the diminution of salt stress in coastal saline soils of Goa, India with halotolerant saltpan bacteria, farmyard manure as an organic amendment and CSR 27, a high yielding salt tolerant variety developed by ICAR—Central Soil Salinity Research Institute, Karnal, India.

Material and Methods

Collection and Preparation Of Soil

Experimental saline soil (0–0.15 m in depth) was collected from an identified rice field with 7.87 dS m^{-1} salinity during the pre-monsoon season (May 2014). The field was located in the coastal region of Tiswadi taluka, Goa, India (73°53′46.1″E and 15°32′20.3″N as longitude and latitude respectively). A bulk soil collected for the experiment was air-dried in shade and grounded enough to make it homogenous and 3.5 kg of the soil was put in each of the pot. As plant nutrients 158.5 mg N, 79.1 mg P_2O_5 and 79.1 mg K_2O was added to each of the pot in a liquid form and mixed uniformly. For the treatments with farmyard manure (FYM) as organic amendment, 46.7 g of FYM was added per pot.

Microbial Cultures

Halotolerant salt pan bacteria (isolate ABSK9, ABSK29, ABSK186) identified as *Pseudomonas multiresinivorans*, *Microbacterium esteraromaticum*, and *Bacillus subtilis* were used in the present study. These cultures were isolated from salt pans of Ribandar, Goa, India which are a part of the khazan ecosystem. Each of these isolates were selected for a distinct plant growth promoting activity viz. *P. multiresinivorans*, a phosphate solubilizer, also produced Indole acetic acid (IAA) and extracellular pectinase; *M. esteraromaticum*, an IAA producer, also secreted extracellular amylase and *B. subtilis* produced extracellular amylase, protease, cellulase, lipase and solubilized phosphate. In addition, all the isolates produced ammonia, were able to grow on nitrogen free medium and tolerated salinity up to 1.7 M NaCl. These bacterial isolates were individually grown in quarter strength Zobell marine agar (ZMA) for 2 days at room temperature (28 ± 2 °C). The bacterial mat was scrapped and harvested in 0.85% saline to give a uniform suspension. The viable count was determined by serial dilutions. The final count was adjusted to 10^8 - cfu ml^{-1}. For preparation of consortium, the three isolates were mixed in a ratio of 1:1:1.

Pot Experiment

The pot experiment was carried out with a high yielding salt tolerant variety of rice, CSR 27. The details of the treatments are given in Table 1. Roots of the rice seedlings (21 days) were dipped in the respective culture suspension containing 0.06% gum acacia solution for 1 h and 3 seedlings were transplanted per pot. Three replications were maintained for each of the treatments. The pots were arranged in completely randomized design under natural conditions of light and rainfall till the flowering stage from June to September 2014.

Meteorological Conditions

The average yearly rainfall during the year 2014 was 3285.6 mm, of which 2835.4 mm was received during June to September. The monthly rainfall, minimum and maximum temperature from June to October (rice growing season) is recorded in Fig. 1.

Physical and Electrochemical Properties of Soil

Soil samples from each pot were collected after harvesting of the plant at the flowering stage. The soil samples were air dried, grounded and passed through a 2 mm sieve and analyzed for electrochemical properties. The soil pH and electrical conductivity (EC) was measured in 1:2.5 soil to water suspension using pH and EC meter [9]. The soil organic carbon (SOC) was determined by chromic acid wet oxidation method [10]. Soil available N was estimated by alkaline potassium permanganate method [11]. Soil available P was estimated spectrophotometrically [12]. Soil available K was determined by 1 N ammonium acetate

Table 1 Details of the treatments of the experiment

No.	Treatment designation	Microbial inoculant applied	Organic ammendment applied
1	Control	–	–
2	*Pseudomonas*	*Pseudomonas multiresinivorans*	–
3	*Microbacterium*	*Microbacterium esteraromaticum*	–
4	*Bacillus*	*Bacillus subtilis*	–
5	PMB	*Pseudomonas multiresinivorans* + *Microbacterium esteraromaticum* + *Bacillus subtilis*	–
6	FYM	–	Farmyard manure
7	*Pseudomonas* +FYM	*Pseudomonas multiresinivorans*	Farmyard manure
8	*Microbacterium* + FYM	*Microbacterium esteraromaticum*	Farmyard manure
9	*Bacillus* + FYM	*Bacillus subtilis*	Farmyard manure
10	PMB + FYM	*Pseudomonas multiresinivorans* + *Microbacterium esteraromaticum* + *Bacillus subtilis*	Farmyard manure

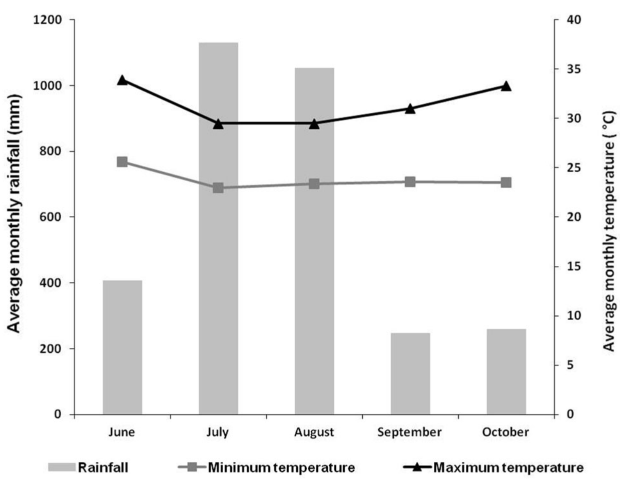

Fig. 1 Average monthly rainfall and temperature variation from June to October 2014 (rice growing season)

extraction method with flame photometry [13]. Micronutrients, Fe, Cu, Mn and Zn were estimated by DTPA extraction method with atomic absorption spectrometry [14]. The soil available B was analyzed spectrophotometrically using the hot water soluble method [15].

Microbial Properties

Field moist soil samples were gently sieved through a 2 mm sieve and used for determining soil biological parameters. Basal soil respiration (BSR) was determined using incubation and titration method [16]. Soil microbial biomass carbon (C_{mb}) in moist soil was determined immediately after sampling by fumigation extraction method [17]. The qCO_2 was calculated as a ratio of BSR to C_{mb} and expressed as μg CO_2–C mg^{-1} h^{-1}. The C_{mb}SOC was expressed as a percentage of total SOC.

Enzyme Activities

Dehydrogenase activity of the soil was determined spectrophotometrically and expressed as μg Triphenylformazan (TPF) formed g^{-1} soil h^{-1} [18]. Acid phosphatase activity of the soil was estimated spectrophotometrically and expressed as μg paranitrophenol (PNP) released g^{-1} soil h^{-1} [19]. Urease activity in soils was estimated as amount of urea hydrolyzed after incubation and expressed as μg urea hydrolyzed g^{-1} soil h^{-1} [20].

Plant Parameters

Plant height was measured at the panicle initiation stage and expressed in centimeters. At harvest, the plants were uprooted and washed carefully in running tap water, then with distilled water and the surface moisture was blotted in a cushion of absorbent paper sheets. Shoot and root were separated. Primary root length was measured with the help of measuring scale and expressed in centimeters. Root volume was measured by water displacement method. Fresh weight of root and shoot of each plant was recorded on an electronic balance and expressed in grams. Plant parts (shoot and root) were dried in a hot air oven at 60 ± 2 °C till constant weight was achieved. Shoot and root dry weights were recorded on an electronic balance and expressed in grams.

Statistical Analysis

The statistical analysis was carried out using SAS software version 9.3 (SAS, 2012). The difference between chemical and biological properties of soil and plant growth parameters influenced by application of microbial inoculant in combination with organic amendments was evaluated by one-way analysis of variance. The experimental means were compared at 0.05 and 0.01 levels of significance.

Results and Discussion

Soil Chemical Properties

The effect of microbial inoculants and organic manure application on soil electrochemical properties and soil available nutrients is presented in Table 2. The difference in soil pH and electrical conductivity between treatments was found to be insignificant ($p > 0.05$). The soil EC at the harvesting time for all the treatments ranged from 0.25 to 0.7 dS m^{-1} respectively. This radical reduction in salinity (initial EC = 7.87 dS m^{-1}) is attributed to leaching of the salts due to heavy rainfall (Fig. 1). The soil available macronutrients—N, P, K and micronutrients—Cu, Fe, Mn were significantly ($p < 0.05$) affected by the application of microbial inoculants. All the treatments except *Pseudomonas*, caused significant ($p < 0.05$) improvement in soil available N as compared to the control. The highest soil available N of 212 ppm was observed in PMB + FYM and it was 63% higher than the control. This result was on par with *Bacillus* + FYM and *Microbacterium* + FYM. There was significant ($p < 0.01$) improvement of phosphorous availability in all the treatments except *Pseudomonas* and *Microbacterium* as compared to control. The phosphorus availability was highest (53.3 ppm) in PMB and *Pseudomonas* + FYM and this increase was 152% higher than the control. All the treatments except PMB + FYM showed significant ($p < 0.01$) improvement with respect to soil available K. The highest soil available K was observed in *Microbacterium* + FYM (1414 ppm). All the soil available micronutrients were sufficient which was in accordance with this soil reaction i.e. acidic (pH 6.63–6.86).

Plant Growth Parameters

Data pertaining to the effect of application of microbial inoculants and organic carbon on rice plant growth parameters is presented in Table 3. Application of microbial inoculants and organic amendment, improved rice plant growth parameters significantly ($p < 0.05$). Lowest root length of 22.2 cm was recorded in control whereas longest root length of 30.3 cm was recorded in *Pseudomonas* treatment. Improvement of root length by microbial inoculants was comparable to each other. Surprisingly, application of microbial inoculants in combination with FYM was recorded insignificant ($p > 0.05$) for root length variations as compared to the control. Amongst the different treatments, control and FYM had the lowest root volume of 48 and 49.3 ml respectively. *Bacillus* + FYM, showed a highest root volume of 113 ml which was comparable to *Pseudomonas* + FYM, *Microbacterium* + FYM, PMB + FYM and PMB. The lowest root dry and fresh weight was observed in control treatment which was 6.70 and 35.5 g respectively. The treatments PMB, *Pseudomonas* + FYM, *Microbacterium* + FYM, *Bacillus* + FYM and PMB + FYM had significantly ($p < 0.01$) higher dry and fresh root weight as compared to the control. Highest root dry weight (13.9 g) and fresh weight (67.8 g) was recorded in

Table 2 Effect of application of microbial inoculants and organic amendment on soil chemical properties

Treatment	Soil $pH_{1:2.5}$	EC (dS m^{-1})	Soil available N (ppm)	Soil available P (ppm)	Soil available K (ppm)	Soil available B (ppm)	Soil available Cu (ppm)	Soil available Fe (ppm)	Soil available Mn (ppm)	Soil available Zn (ppm)
Control	6.63	0.40	130	21.1	1067	2.20	6.55	16.5	29.3	1.00
Pseudomonas	6.86	0.34	154	28.0	1288	3.76	5.29	25.5	24.1	1.18
Microbacterium	6.76	0.63	164	28.9	1381	3.30	5.44	25.9	24.5	1.04
Bacillus	6.80	0.35	162	39.0	1332	4.66	5.88	29.8	30.5	1.18
PMB	6.66	0.32	173	53.3	1239	2.90	6.42	30.9	32.9	1.34
FYM	6.76	0.25	173	34.9	1332	4.46	5.36	31.8	32.7	1.24
Pseudomonas + FYM	6.60	0.70	177	53.3	1385	2.86	4.94	30.5	32.8	1.20
Microbacterium + FYM	6.66	0.60	188	32.4	1414	3.76	5.30	31.2	33.2	1.20
Bacillus + FYM	6.73	0.38	209	36.5	1187	3.56	5.92	31.2	33.0	1.59
PMB + FYM	6.70	0.42	212	43.3	1120	4.23	6.07	31.5	33.2	1.41
LSD	ns	ns	27.6**	9.10**	117**	ns	1.020*	2.63**	2.94**	ns

ns, non- significant; LSD, least significant difference

* Significance at 0.05 level; ** significance at 0.01 level

Table 3 Effect of application of microbial inoculants and organic amendment on rice plant growth parameters (the values of all the root and shoot parameters presented in the table below are given as per plant)

Treatments	Root length (cm)	Root volume (ml)	Root fresh weight (g)	Root dry weight (g)	Shoot fresh weight (g)	Shoot dry weight (g)
Control	22.2	48.0	35.5	6.70	13.8	5.38
Pseudomonas	30.3	87.3	45.6	7.36	15.8	5.78
Microbacterium	27.0	72.0	42.8	8.59	17.1	6.57
Bacillus	26.2	82.3	41.6	7.62	15.9	6.10
PMB	27.1	102	63.8	13.4	16.6	6.37
FYM	24.2	49.3	37.3	7.57	15.4	5.77
Pseudomonas + FYM	23.7	97.0	52.2	8.26	18.5	6.70
Microbacterium + FYM	22.2	100	54.1	10.6	18.7	6.99
Bacillus + FYM	25.0	113	67.8	13.9	18.8	6.31
PMB + FYM	24.8	97.3	59.3	12.3	21.5	8.11
LSD	4.05*	17.3**	11.7**	2.68 **	1.53**	0.77**

ns, non- significant; LSD, least significant difference

* Significance at 0.05 level; ** significance at 0.01 level

Bacillus + FYM. With respect to improving root parameters, application of *Bacillus* + FYM was the most effective. It is intriguing that, the improvement in these parameters increased by the application of FYM in combination with *Bacillus*. FYM caused 37.6, 83.4 and 63% increase in root volume, root dry weight and fresh weight respectively as compared to *Bacillus* treatment. A similar trend was also observed for PMB and PMB + FYM. The lowest shoot dry and fresh weight was observed in the control treatment which was 5.38 and 13.8 g respectively. PMB + FYM caused significantly ($p < 0.01$) highest improvement of 50.6 and 55% in shoot dry and fresh weight respectively over the control. Interestingly, all the treatments were equally effective in improving shoot fresh weight. It is evident from the Fig. 2 that microbial and organic amendment application increases the plant height at panicle initiation. All the treatments except FYM caused significant ($p < 0.05$) variations in plant height. Highest plant height was observed in PMB (70.2 cm) followed by *Bacillus* + FYM (69.4 cm). Lowest plant height of 61.7 cm was observed in the control.

Inoculation of all strains of PGP bacteria, individually and in combination with FYM, resulted in an increase in root length, root volume, root dry weight, root fresh weight and shoot fresh weight. Our results are concordant with Abbas et al. [21], who have recorded significant increase in rice straw and grain yield through cyanobacterial inoculation. Application of *Bacillus* inoculum to rice under saline environment increased rice growth and rice yield significantly [22, 23]. Improvement in root parameters can be explained by significantly higher soil available phosphorous. Prior preliminary studies have shown phosphate

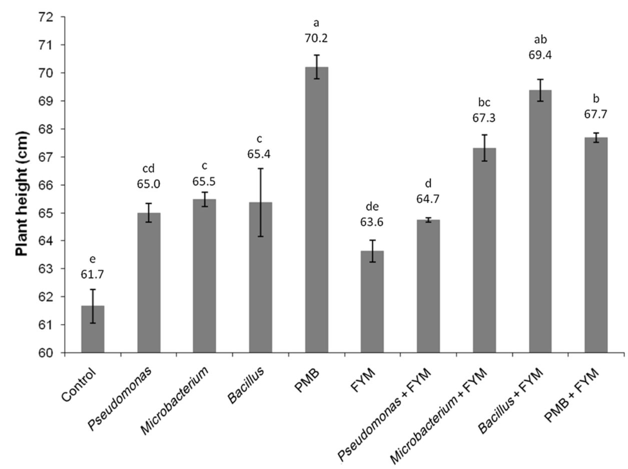

Fig. 2 Rice plant height (panicle initiation) with different treatments. Values in one *bar* followed by *similar letters* are non-significantly different at 1% level of significance

solubilization activity by *B. subtilis* and *P. multiresinivorans* (data unpublished). This result is also supported by the significant ($p < 0.01$) improvement in soil phosphatase (Table 4). Production of phosphatase enzyme and organic acids by *B. subtilis* and organic amendment might have led to more phosphorus solubilization and availability. Interesting, the results of *Bacillus* + FYM with respect to root parameters were on par with PMB + FYM. PMB + FYM also revealed highest shoot dry and fresh weight (Table 3). These results corroborate with results reported in rice by Barua et al. [23] and Chakraborty et al. [24] and maize by Iqbal et al. [25]. The improvement in shoot dry and fresh weight by could be due to indirect mechanisms such as improved availability nutrients of soil available N

Table 4 Effect of application of microbial inoculants and organic amendment on soil biological activity

Treatments	Dehydrogenase (μg TPF g^{-1} soil h^{-1})	Urease (μg urea g^{-1} soil h^{-1})	Phosphatase (μg PNP g^{-1} soil h^{-1})	Soil organic carbon (%)	Basal soil respiration (mg CO_2 g^{-1} day^{-1})	Soil microbial biomass carbon (μg C g^{-1} soil)	Metabolic quotient (μg CO_2–C mg^{-1} h^{-1})	Soil microbial biomass carbon as a fraction of soil organic carbon (%)
Control	107	1982	87.6	0.88	0.07	1556	0.04	0.17
Pseudomonas	20.8	1978	116	0.89	0.11	2191	0.05	0.24
Microbacterium	88.8	1981	87.5	0.84	0.10	2338	0.04	0.27
Bacillus	132	1981	75.0	0.89	0.08	2358	0.03	0.26
PMB	68.9	1981	106	0.82	0.08	2483	0.03	0.31
FYM	85.6	1980	99.1	0.94	0.07	1950	0.03	0.20
Pseudomonas + FYM	141	1979	99.8	0.95	0.12	2256	0.05	0.23
Microbacterium + FYM	54.6	1982	98.5	0.97	0.11	2856	0.04	0.29
Bacillus + FYM	175	1978	99.4	0.93	0.11	2402	0.04	0.26
PMB + FYM	65.9	1980	105	0.98	0.12	2985	0.04	0.30
LSD	61.6**	ns	12.6**	ns	ns	448**	ns	0.05**

ns, non- significant; LSD, least significant difference

* Significance at 0.05 level; ** significance at 0.01 level

(Table 2) and better root growth (Table 3). It was found during primary investigation, that the microorganisms grow on N free media and thus might possess N fixing ability.

Soil Microbial Activities

Data on soil biological activity influenced by microbial inoculants and organic amendment is presented in Table 4. Dehydrogenase and phosphatase enzyme activity, C_{mb} and C_{mb}SOC responded significantly ($p < 0.01$). The soil dehydrogenase activity was significantly ($p < 0.01$) lower in *Pseudomonas* (20.806 μg TPF g^{-1} soil h^{-1}) and significantly ($p < 0.01$) higher in Bacillus + FYM (175.064 μg TPF g^{-1} soil h^{-1}) with respect to control. Application of *Bacillus* + FYM improved soil dehydrogenase activity by 63%. The phosphatase enzyme activity was significantly ($p < 0.01$) higher in *Pseudomonas*, PMB and PMB + FYM. It was highest in PMB + FYM (105 μg PNP g^{-1} soil h^{-1}). The C_{mb} and C_{mb}SOC responded significantly ($p < 0.01$) to microbial inoculants and organic amendment over control (1556 μg C g^{-1} -soil). PMB + FYM had significantly ($p < 0.01$) highest C_{mb} (2985 μg C g^{-1} soil). It was on par with *Microbacterium* + FYM (2856 μg C g^{-1} soil). Lowest C_{mb}SOC was observed in control (0.17%) whereas it was highest in PMB (0.31%). *Microbacterium*, *Microbacterium* + FYM, *Bacillus* + FYM and PMB + FYM were found on par with PMB with respect to C_{mb}SOC. The soil biological activity—urease enzyme, BSR and qCO_2 responded insignificantly ($p > 0.05$).

Depressive effect of soil salinity on soil microbial activity has been documented widely. Mahajan et al. [11] recorded significant negative correlation between the level of salinity and dehydrogenase activity, urease activity, phosphatase activity, C_{mb}, BSR and qCO_2. The use of organic materials significantly improved C_{mb} and dehydrogenase activity in coastal Sunderbans of India [26]. In the present study, conspicuous improvement was observed in C_{mb} and C_{mb}SOC. The C_{mb} is responsible for decomposition of plant and animal residues and soil organic matter to release plant available nutrients and carbon dioxide [27]. Higher C_{mb} helps in mineralization of key nutrients and this is evident from significant correlation between C_{mb} and soil available N (r = 0.71, $p < 0.01$), soil available P (r = 0.43, $p < 0.05$) and phosphatase activity (r = 0.337, $p < 0.05$) (Table 5). In the present investigation, C_{mb}SOC is significantly ($p < 0.01$) improved by the application of microbial inoculants and organic matter. Under strong salinity situations, C_{mb}SOC could be very low (0.5%) [28]. The observed C_{mb}SOC in the present experiments was less than 0.3%. Though the C_{mb}SOC, is low, the increase cannot be neglected as it has

Table 5 Correlation matrix of soil chemical and biological properties (n = 30)

	Soil $pH_{1:2.5}$	EC	Soil available N	Soil available P	Soil available K	Dehydrogenase	Phosphatase	SOC	BSR	C_{mb}	qCO_2	$C_{mb}SOC$
Soil $pH_{1:2.5}$	1.00											
EC	0.38*	1.00										
Soil available N	0.13	0.17	1.00									
Soil available P	−0.03	0.25	0.50**	1.00								
Soil available K	0.29	0.38*	0.12	0.21	1.00							
Dehydrogenase	0.10	0.26	0.26	0.30	−0.01	1.00						
phosphatase	0.27	0.08	0.37*	0.25	0.05	−0.32	1.00					
SOC	0.48**	0.53**	0.50**	0.29	0.24	0.33	0.33	1.00				
BSR	0.36*	0.51**	0.58**	0.38*	0.38*	0.14	0.47**	0.65**	1.00			
C_{mb}	0.30	0.33	0.71**	0.43*	0.32	−0.04	0.37*	0.43*	0.60**	1.00		
qCO_2	−0.30	−0.08	−0.30	−0.28	−0.08	−0.08	0.05	−0.35	−0.07	−0.29	1.00	
$C_{mb}SOC$	−0.04	−0.03	0.39*	0.27	0.18	−0.28	0.17	−0.29	0.15	0.73**	−0.08	1.00

SOC, soil organic carbon; BSR, basal soil respiration; C_{mb}, soil microbial biomass carbon; qCO_2, metabolic quotient; $C_{mb}SOC$, soil microbial biomass carbon as a fraction of soil organic carbon

* Significance at 0.05 level; ** significance at 0.01 level

importance in several key nutrient mineralization processes. $C_{mb}SOC$ was correlated with soil available N ($r = 0.39$, $p < 0.05$), the lower $C_{mb}SOC$ is attributed to the microbial stress due to higher organic consumption per unit C_{mb} to maintain cell integrity and release sodium (Table 5). Chakraborty et al. [24] also recorded an improvement in enzyme activities in soil under rice cultivation, by inoculation of salt tolerant bacteria. Thus, the present investigation revealed that crop salinity stress could be alleviated by application of salt tolerant microbes and organic amendment through several direct and indirect associated mechanisms.

Conclusion

Results of the pot experiments revealed that applying salt tolerant microorganisms individually and in combination with farmyard manure can significantly improve rice plant growth parameters, soil chemical properties and biological activity. The best results were obtained in treatments comprising of *B. subtilis* with farmyard manure and consortium with farmyard manure. Though results under pot condition give a sound proposal on beneficial use of salt tolerant microorganisms to improve rice plant growth under coastal saline soils, their evaluation in real field conditions needs to be ascertained.

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Compliance with Ethical Standard

Conflict of interest The authors declare that they have no conflict of interest.

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