Isolation and characterization of endophytic plant growth-promoting bacteria (PGPB) associated to the sodicity tolerant polyembryonic mango (*Mangifera indica* L.) root stock and growth vigour in rice under saline sodic environment

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Accepted 24 January, 2014

In the recent times, there has been a reversed interest in the search of plant growth promoting endophytes (PGPE) for sustainable crop production. Mango is an economically important fruit crop, which is highly sensitive to saline environment. In the present study the importance of PGPR in growth promotion and their ability to elicit ‘induced systemic tolerance’ against abiotic (sodicity) stresses has been documented. Sixteen (16) putative of endophytic bacteria were isolated from sodicity tolerant polyembryonic mango root stock of GPL-3 and ML-4 from Shivari experimental farm, Central Soil Salinity Research Institute, Regional Research station, Lucknow, Uttar Pradesh, India. These endophytic bacteria were characterized using morphological and biochemical parameters and assessed for their plant growth promoting rhizobacteria (PGPR) traits like indole acetic acid (IAA) production, hydrogen cyanide (HCN) production, phosphate solubilization and siderophore production with 2.5 M NaCl concentration. The results based on specific biochemical characters revealed that the endophytic bacteria belonged to 14 different species and two uncultured organisms comprising five genera. Based on multifunctional properties under saline environment, four isolates were further selected to determine the PGP as vigor index of rice seedlings in pot culture experiments under saline sodic soils of pH 9.35 and EC 4.2. Of the bacteria tested, the isolate CSR-M-16 showed increased root and shoot length of rice followed by CSR-M-8, CSR-M-9 and CSR-M-6. The outcome of this research proves plausible practical applicability of these PGPB for crop production in saline sodic environment.

**Key words:** Endophytes, salt tolerant, PGP bacteria, mango root stock, polyembryony.

**INTRODUCTION**

Plant tissues are not sterile-spaces; within them there are different species of bacteria known as endophytes. Most of these microorganisms are not pathogenic to the host plant. Moreover, the association between the plant and
endophytic bacteria is very often mutualistic. Endophytes enter plant tissue primarily through the root zone; however, aerial portions of the plants such as flowers, stems and cotyledons may also be used for entry (Kobayashi and Palumbo, 2000). Once they get inside the plant tissue, endophytic bacteria may either remain localised at the point of entry or spread throughout the plant (Hallmann et al., 1997). Selections of microbial isolates from naturally stressed environment or rhizosphere are considered as possible measures for improving crop health which can control diseases and also promote plant growth (Lugtenberg and Kamilova, 2004; Mayak et al., 2004).

Worldwide, salinity is one of the most severe abiotic stresses that limit crop growth and productivity; about 20% of world’s irrigated land is salt affected, with 2,500-5,000 km² of production lost every year as a result of salinity (Nellemann, 2009). As reported, (Gupta and Abrol, 2000) 60% of salt affected soils are of sodic and saline sodic in nature which has increased steadily over decades in the northwest plains of the Indus-Gangetic basin and in China’s Yellow River basin. High alkalinity (pH > 8.5) and high exchangeable sodium percentage (ESP) of the soil render it inhospitable for normal crop production and there is minimal bioproductivity in such soil (Chhabra, 1995). The utilization of salt-affected soil for agriculture has become necessary to meet the rise in food demand and one possible strategy to counteract the adverse effect of salinity is to exploit the avenues of bioagents or bio-inoculants (Egamberdieva, 2012). Under salt stress, PGPR have shown positive effects in plants on parameters such as germination rate, tolerance to drought, weight of shoots and roots, yield and plant growth (Raju et al., 1999). The combination of IAA production ability (Goldstein et al., 1999), phosphorous solubilisation (Gyaneshwar et al., 1998) and siderophore production (Duffy and Défago, 1999) of bacteria aid the plant rhizosphere in enhancing the nutrient absorption potential even under sodic environment for enabling economic production of commercial horticultural crops (Damodaran et al., 2011). This has been extensively attracting attention due to their efficacy as biological control and growth promoting ability in many crops. Though the researchers earlier have worked on isolation of salt (NaCl) tolerant rhizobacteria from halophilic environment where the conductivity (EC) of the soils is > 4 dS m⁻¹. Little is known about their tolerance to saline sodic environment where the soils are severely affected by high pH characterized by high Na⁺ in the soil solution phase as well as on cation exchange complex (Qadir and Schubert, 2002), exhibiting unique structural problems.

Mango is more sensitive to salinity and sodicity particularly at early growth stage which necessitates the requirement of salt tolerant true to type polyembryony rootstocks. According to Kadman et al. (1976) and Gazit and Kadman (1980, 1983), mango rootstock 13-1 very popular in Israel, is tolerant to low quality waters.

However, in the Southeast of the Spanish peninsula and in the Canary Islands this is not popular and the most commonly used rootstocks are Gomera-1 and Gomera-3 (Galan and Garcia, 1979; Galan and Fernandez, 1988). Mango is considered sensitive to saline conditions (Maas, 1986), leading to scorched leaf tips and margins, leaf curling, and in severe cases reduced growth, abscission of leaves, and death of trees (Jindal et al., 1976). The information concerning the salt tolerance of mango rootstocks is lacking, particularly on the impact of salinity on fruit yield (Ayers and Westcot, 1989; Maas and Grattan, 1999). Further, it was suggested that polyembryony rootstocks are more preferred for mango breeding studies for abiotic stress (Mohammad et al., 2001; Varu and Barad, 2010). The nucellar seedlings of the polyembryony varieties produce true to type parent character and is also known for their performance under stress environment (Damodaran et al., 2011). Consequently, sustaining and enhancing the growth under salt affected field of polyembryonic mango plants have become a major focus of research. The growth and performance of ployembryonic mango plants in the field are adversely affected by sodium toxicity. Therefore the present study is focused to survey plants habitat of the sodic lands, isolate the endophytic bacteria from growing polyembryonic mango root stock under saline sodic environment, characterize them by morphological and biochemical means and screen them for their PGP under salinity and sodicity environment.

MATERIALS AND METHODS

Plant material

For the isolation of endophytes, salt tolerant root stock of polyembryonic mango (Mangifera indica) accessions ML-2 and GPL-3 grown in sodic soil were collected from Shivari experimental farm (22°41S 47°33W) of Central Soil Salinity Research Institute (ICAR), Regional Research Station, located in Lucknow, Uttar Pradesh, India.

Physico-chemical analysis of soil

The collected sodic soil sample (pot culture experiment) was analyzed for physiochemical parameters like pH and conductivity. The pH and EC of the soil extract was determined potentiometrically by an ORION ion analyzer (5 star series) using a pH electrode and conductivity electrode.

Isolation of endophytic bacteria

The uprooted healthy sodicity tolerant mango plants were briefly washed with sterile water and the root, stem and leaves were cut into 2-3 cm long pieces. These pieces were rinsed in sterile water and then surface disinfected by soaking in 70% ethanol for 30 s and then treated with sodium hypochlorite (3-5% available chlorine) for 3 min. Samples were exhaustively rinsed with sterile water so that all the epiphytic microorganisms could be removed. Next, they were cut longitudinally with a sterile scalpel and laid, with the exposed
inner surface facing downwards, on plates of sterile nutrient agar (NA) as adapted by Hung and Annapurna (2004). As a control, uncut, surface-disinfected stem pieces and non-disinfected pieces were also placed on the same agar. All plates were incubated for 48 h at 27°C.

Bacterial identification

The isolates were initially categorized into two broad groups based on Gram staining by Hucker’s modified method (Rangaswami and Bagyaraj, 1993). Morphological and cultural characters of the isolates were used for further grouping. Based on the results of various biochemical tests such as indole production, nitrate reduction, citrate-utilization, hydrolysis of lactose, cellulose and sucrose, the catalase activity of the organisms were performed to identify on generic level by using specific biochemical tests (Cappuncincco and Sherman, 1992).

In vitro analysis for the identification of PGP activity bacteria

Screening of NaCl tolerance

Nutrient broth (10 mL) was supplemented with NaCl so as to give 0.1-3.5 M NaCl. All the isolates were grown in tubes and incubated on rotary shaker (150 rpm) at 37°C. Bacterial growth was determined as OD_{600} to find out NaCl tolerance. Actively growing bacteria were then serially adapted to 2.0 M NaCl concentration.

Phosphate solubilization by the selected salt tolerant isolates

NaCl tolerant isolates were checked for phosphate solubilization by the ability to solubilize inorganic phosphate. For this, Pikovskaya’s agar amended with 2.0 M NaCl and calcium phosphate was used. Spot inoculation of the tolerant isolates was done in the center of the medium and kept for incubation at 28°C for 48-72 h. The appearance of transparent halo zone around the bacterial colony indicated the phosphate solubilizing activity of the bacteria.

IAA production by the selected tolerant isolates

Indole acetic acid (IAA) production was detected as described by Brick et al. (1991). Bacterial cultures were grown for 72 h in nutrient broth medium containing supplement of 2.0 M NaCl at 36–38°C. Fully grown cultures were centrifuged at 3,000 rpm for 30 min. The supernatant (2 mL) was mixed with 2 drops of orthophosphoric acid and 4 mL of Salkowski reagent (50 mL, 35% of perchloric acid and 1 mL 0.5 M FeCl₃ solution). Development of pink colour indicated IAA production. The amount of IAA produced by rhizobacteria was estimated quantitatively by Salkowski method (Dubey and Maheshwari, 2012). The cultures were incubated in peptone broth together with tryptophan for 24 and 48 h, and IAA production was estimated.

HCN production by the selected tolerant isolates

Production of HCN was detected according to the method of Lorck (1948). Briefly, nutrient broth was amended with 4.4 g glycine L⁻¹ and 2.0 M NaCl. Bacteria were streaked on modified agar plate. A Whatman filter paper no. 1 soaked in 2% sodium carbonate in 0.5% picric acid solution was placed at the top of the plate. Plates were sealed with parafilm and incubated at 36±2°C for four days. Development of orange to red colour indicated HCN production.

Siderophore production by the selected tolerant isolates

Bacterial culture (48 h) was streaked on nutrient agar amended with an indicator dye and 2.0 M NaCl. The tertiary complex chrome-azurol-S (CAS)/Fe³⁺ / hexadecyl trimethyl ammonium bromide served as an indicator. Change of blue color of the medium surrounding the bacterial growth to fluorescent yellow indicated production of siderophore. The reaction of each bacterial strain was scored either positive or negative to the assay (Schwyn and Neilands, 1987).

Sodium uptake by the tolerant isolates

The screened isolates for salt tolerance were further studied for sodium uptake pattern. To determine the sodium uptake pattern, the isolates were grown overnight at 37°C in Nutrient broth containing different NaCl concentration (0.1, 0.5, 1.0, 1.5, 2.0 and 2.5 M). After 24 h of incubation the bacterial cells were harvested by centrifugation and bacterial pellet obtained was washed with sterile distilled water to remove the traces of medium. Washed pellet was digested overnight with 0.1N HCl at room temperature. Samples were centrifuged and supernatant was taken for the estimation of sodium uptake by bacterial cells using flame photometer.

In vivo plant growth promotion under saline sodic soil conditions

The endophytic bacteria were grown on nutrient broth with constant shaking on rotary shaker at 150 rpm for 48 h at room temperature (28±2°C) and were harvested by centrifugation at 6,000 rpm for 15 min. The bacterial cells were resuspended in PB (0.01M, pH 7.0). The concentration was adjusted to approximately 10⁸ CFU (OD₅₉₅=0.3) and used as inoculums for treating rice seeds (Thompson, 1996). Plant growth promoting activities of bacterial strains were assessed based on the seedling vigor index of rice seed under pot culture studies in soil of pH 9.35 ECe (4.2), Na⁺ (23.50 meq L⁻¹) and sodium adsorption ratio (SAR) 19.36. Sodium (Na⁺) was determined by flame photometer (Richards, 1954) while SAR was determined by following the generic equation:

\[ \text{SAR} = \frac{Na}{\sqrt{(Ca + Mg)/2}} \]

The vigor index was calculated by using the formula as described by Abdul Baki and Anderson (1973).

Statistical analysis

The pot culture experiment on assessing vigor index in rice seeds treated with bacterial isolates was conducted in completely randomized design (CRD) with three replications and the data was analyzed using SAS 9.2 version. Prior to analysis of variance the percentage values of germination were arcsine transformed.

RESULTS

Endophytic bacteria were isolated from the root, stem and leaves of the sodicity tolerant polyembryonic mango accessions (GPL-3 and ML-4) grown in sodic soils of pH 9.51. The population of the endophytic bacteria in the
Table 1. Endophytic bacterial population isolated from sodicity tolerant polyembryonic mango accessions GPL-3 and ML-4 (CFU g⁻¹ FW).

| Place of collection | Accession | GPS data     | Plant Part | Bacterial population (CFU g⁻¹ FW) | Number of phenotypes selected |
|---------------------|-----------|--------------|------------|-----------------------------------|------------------------------|
| Guptapara           | GPL-3     | N 11°, 32', 15.6 | Stem       | 4.4 × 10⁴                            | 2               |
|                     |           | E 92°, 39', 0.7  | Leaves     | 4.8 × 10⁴                            | 1               |
|                     |           |               | Root       | 9.0 × 10³                            | 4               |
|                     |           | N 11°, 32', 32', 7.6  | Stem       | 5.8 × 10³                            | 2               |
| Manjeri             | ML-4      | E 92°, 39', 5.6  | Leaves     | 5.5 × 10⁴                            | 1               |
|                     |           |               | Root       | 10.5 × 10⁴                           | 6               |
| Total no isolates   |           |               |            |                                    | 16              |

Table 2. Phenotypic characteristic as determined by Gram staining of selected bacterial isolates obtained from both salt tolerant (sodicity) tolerant polyembryonic mango accessions GPL3 and ML-4.

| Salt tolerant polyembryonic mango accessions | Plant parts | No of Gram-positive isolates | No of Gram-negative isolates | Group of isolates | Total gram-positive and gram-negative isolates | Lowest denomination ratio of Gram-positive and Gram-negative | Rod:cocci:spirillum:Oval |
|----------------------------------------------|-------------|------------------------------|-------------------------------|-------------------|-----------------------------------------------|-------------------------------------------------------------|-------------------------|
| GPL-3                                        | Stem        | 2                            | 0                             | CSR-M-05, CSR-M-12 | 7                                            | 2.2:1                                                          | 10:1:2:3                |
|                                               | Leaves      | 0                            | 1                             | CSR-M-05, CSR-M-12 |                                               |                                                               |                         |
|                                               | Root        | 4                            | 0                             | CSR-M-01, CSR-M-02, CSR-M-08, CSR-M-09 |                                                               |                                                               |                         |
|                                               | Stem        | 1                            | 1                             | CSR-M-03, CSR-M-11 |                                               |                                                               |                         |
|                                               | Leaves      | 1                            | 0                             | CSR-M-13          |                                               |                                                               |                         |
|                                               | Root        | 3                            | 3                             | CSR-M-04, CSR-M-06, CSR-M-07, CSR-M-14, CSR-M-15, CSR-M-16 |                                               |                                                               |                         |
| Total Isolates                                |             | 11                           | 5                             |                   |                                               |                                                               |                         |

Various plant tissues of the sodicity tolerant polyembryonic mango root stock is shown in Table 1. In both accessions, bacterial growth was observed. The population of bacteria in root ranged from 9.0 to 10.5 × 10⁴ cfu followed by stem which was 4.4 to 5.8 × 10⁴ cfu and 4.8 to 5.5 × 10⁴ cfu in leaves (Table 1). About 40 bacterial isolates were collected, among them 16 were selected based on their ability to survive at 2.5 M NaCl concentration for further experiment. Further they were screened for Gram nature, pigmentation, colony colour and morphological characteristic (Tables 2 and 3). Among 16 isolates, CSR-M-03, CSR-M-05, CSR-M-06, CSR-M-08, CSR-M-14 and CSR-M-15 were yellowish to creamy yellow colour while the others were white to creamy white. Pigmentation was absent in most of the isolates except CSR-M-03, CSR-M-04, CSR-M-14 and CSR-M-15 which displayed yellow to greenish yellow pigments production. The isolates were of lowest denomination ratio of Gram-positive (88.75 %) and Gram negative (31.25 %) with a range of 2.2:1 ratio under microscope observation. The shapes ranged with a ratio of 10:1:2:3 for rod: cocci:spirillum:oval where rods were found to be the major phenotypes (Table 2). Carbohydrate utilization indicated that 2 out of 16 isolates were
able to produce acid and hydrolyses glucose, lactose, sucrose and fructose while 12 isolates were able to assimilate nitrate and citrate utilization and produced catalase enzyme and 7 were positive for indole production (Table 4).

Salt tolerance traits

On screening the 16 bacterial isolates for growth in different NaCl concentrations; four isolates growing luxuriantly in 2.5 M NaCl concentration were selected for further evaluations. These four isolates were further analysed for their sodium uptake pattern (Figure 1) at different molar (M) concentration of NaCl. The four isolates had an increasing sodium (Na⁺) uptake up to 2.5 M NaCl compared to other isolates. However, four isolates CSR-M-06, CSR-M-08, CSR-M-09 and CSR-M-16 identified as *Bacillus pumilus* and *Bacillus subtilis* showed higher uptake of Na⁺ (23,400 ppm g⁻¹, 19,240 ppm g⁻¹, 19,440 ppm g⁻¹ and 19,540 ppm g⁻¹ of fresh weight respectively) at 2.0 M NaCl concentration.

PGP traits with supplement of NaCl

In PGP traits (Table 5) with supplement of 2.0 M sodium chloride concentration, four isolates showed IAA, siderophore production and phosphate solubilization and none of the isolate showed HCN production. The isolates CSR-M-06 (49.5 µg mL⁻¹), CSR-M-09 (25.2 µg mL⁻¹) and CSR-M-16 (74.0 µg mL⁻¹) had extensive formation for IAA production. Further, this four isolates CSR-M-06, CSR-M-08, CSR-M-09 and CSR-M-16 showed higher phosphate solubilisation. The results are reported as ranking in Table 5.

Plant growth promotion potential of salt tolerant bacteria under in vivo condition

The four isolates were furthermore screened for plant growth potential (PGP) in saline-sodic soils of pH 9.35 and EC 4.2 dS m⁻¹ under pot culture experiment with rice seed. All four isolates (CSR-M-06, CSR-M-08, CSR-M-09 and CSR-M-16) showed plant growth enhancing activities with the germination percentage of 88.33, 91.66, 86.66 and 93.33 %. Significantly higher shoot and root growth was observed in CSR-M-16 followed by CSR-M-8, CSR-M-6 and CSR-M-9 with higher vigour index (4,675.8, 4,393.5, 4,260.4 and 3,992.1, respectively). The efficiency of isolates is shown as ranking in Table 6.

DISCUSSION

A detailed screening of polyembryonic mango accessions screened in sodic soils, the sodicity tolerant polyembryonic mango root stock of ML-4 and GPL-3 isolate and identification of the endophytic bacteria that could express plant growth promotion (PGP) traits at high salt concentrations were done. The study indicates that there was reduction in bacterial diversity with increase in soil pH. This agrees with the finding of earlier researcher (Borneman et al., 1996) which also stated the reduction of bacterial diversity under environmental stress such as salinity. In our study, we isolated 16 isolates from sodicity tolerant polyembryonic mango root stock. Majority of the bacterial isolates were identified as *Bacillus* spp. based on morphological and biochemical observations. Earlier studies (Tank and Saraf, 2010) also indicated the dominant of genera such as *Bacillus* sp and *Pseudomonas* sp in saline soils PGP activity of the bacteria present in the rhizosphere is found to exert beneficial effects on plant growth mechanism. Several mechanisms such as production of phytohormones, suppression of deleterious organisms, production of IAA, activation of phosphate solubilization and promotion of the mineral nutrient uptake are believed to be involved in plant growth promotion by PGPR (Glick et al., 1995). Auxin is the most effective plant growth hormone and among them IAA is a common one. IAA may function as important signal molecule in the regulation of plant development (Usha Rani et al., 2012).

**Table 3. Morphological characteristics of bacterial endophytes.**

| Experiment Procedure | M-1 | M-2 | M-3 | M-4 | M-5 | M-6 | M-7 | M-8 | M-9 | M-10 | M-11 | M-12 | M-13 | M-14 | M-15 | M-16 |
|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Colour               | W   | W   | Y   | CW  | Y   | Y   | W   | Y   | PW  | W   | W   | W   | W   | CY  | Y   | W   |
| Shape                | R   | R   | R   | R   | R   | O   | R   | C   | S   | S   | O   | R   | R   | O   | R   | R   |
| Elevation            | Cv  | Ra  | Cv  | Ra  | Ra  | Ra  | Ra  | F   | Ra  | Ra  | Ra  | Ra  | Ra  | Ra  | Ra  | Ra  |
| Pigmentation         | NP  | NP  | Y   | G   | N   | N   | N   | N   | N   | N   | N   | N   | Y   | Y   | N   |

W=White; Y= yellow; CW= creamy white; PW= Powdery white; CY= Creamy yellow; S= spherical; C= cocci; R= rod; Cv= convex; Ra= raised; F= flat; Y= yellow; NP= no pigmentation.
Among the isolates under study, only four isolates (CSR-M-6, CSR-M-8, CSR-M-9 and CSR-M-16) exhibited IAA production. Phosphorous (P) is an essential nutrient for plant growth, development and is typically insoluble or poorly soluble in soils under salt stressed conditions (Harrison et al., 2002). Some of the bacteria are known to
improve the solubilization of the fixed soil phosphorous and applied phosphates, resulting in higher yields even under stress conditions (Banerjee et al., 2010). The four endophytic bacterial isolates showed in-vitro phosphate solubilization activity. Ability to solubilize various insoluble phosphates is always desirable attribute for a competent PGPR. Phosphate solubilization by *Bacillus* sp. isolated from salt stressed environment had been observed by earlier researchers (Son et al., 2006). Siderophore chelates iron and other metals thereby contributes in disease suppression and acquisition of Fe to plants for increasing the crop growth under stressed conditions (Hofte et al., 1992; Duffy and Défago, 1999). The siderophore production ability was found to be a productive PGPR trait for selection. Hydrogen cyanide (HCN) is an important attribute of PGPR which influences plant growth indirectly and strengthen the host disease resistance mechanism (Schippers et al., 1990). In the present study, four isolates were found to produce HCN. Majority of the PGPR properties producing bacteria were identified to be of genus *Bacillus* sp.

These four isolates were found to be tolerant to high salt concentration (2.5 M NaCl) and also showed higher uptake of sodium when cultured under in-vitro conditions at this concentration. It has also been reported previously that bacteria isolated from saline soil are more likely to withstand salinity conditions (Upadhyay et al., 2009). On the other hand, if such bacteria also possess plant growth promoting traits they would be ideal for use in sustainable agriculture (Egamberdiyeva and Islam, 2008). Based on biochemical parameters, the four bacterial isolates CSR-M-6, CSR-M-8, CSR-M-9 and CSR-M-16 identified as *Bacillus coagulans, Bacillus megatarium, Bacillus pumilus* and *Bacillus subtilis* respectively exhibited all the in-vitro PGPR characteristics like IAA, HCN, siderophore and phosphate solubilization production. Production of IAA, siderophore, phosphate solubilization had been observed in *Bacillus* sp. in earlier studies (Xie et al., 1996; Loper and Henkels, 1997). Furthermore, in the current experiment, the vigor index studies in rice seeds treated with salt tolerant isolates showed that the isolates CSR-M-6, CSR-M-8, CSR-M-9 and CSR-M-16 are potential growth promoter even under saline-sodic conditions apart from salinity. Though PGPR are more commonly known to induce resistance against pathogen infection, reports are now available on their ability to elicit ‘induced systemic tolerance’ against abiotic stresses (Usha et al., 2011).

Results of our study suggest that sodicity tolerant polyembryonic mango root stock is naturally associated with a variety of endophytic bacteria, which have NaCl tolerance capacity and exhibited PGPR traits like IAA production, phosphate solubilization. The earlier finding (Cohen et al., 2008; Glick et al., 1998) suggested a strong relationship between rhizobacterial capabilities and colonized plant tolerance to salt stress. Therefore, we could speculate about an “endophytic consensus” generated between four strains that colonize the plant in which everyone expresses one or more mechanisms to jointly determine a global response to promote plant...

### Table 5. Assessment of plant growth promoting properties of endophytic bacteria from salt tolerant polyembryonic mango accessions (GPL-3 and ML-4).

| Bacterial Isolate | IAA production (µg mL⁻¹) | Siderophore production | HCN production | PO₄ Solubilisation |
|-------------------|--------------------------|------------------------|----------------|------------------|
| CSR-M-6           | 49.5                     | ++                     | +              | +++              |
| CSR-M-8           | 65.7                     | ++                     | +              | +++              |
| CSR-M-9           | 25.2                     | +                      | +              | -                |
| CSR-M-16          | 74.0                     | +++                    | +              | +++              |

IAA, Indole-3-acetic acid; HCN, hydrogen cyanide; PO₄, phosphate; - No production; +, 0.3-0.5 cm; ++, 0.6-0.9 cm; ++++, >1 cm

### Table 6. Plant promotion activity of rice seedling vigour and inoculation endophytic bacteria treated rice seed under sodic soil.

| Bacterial isolate | Root length (cm) | Shoot length (cm) | Root dry weight (g) | Shoot dry weight (g) | % Germination | Vigour index |
|-------------------|------------------|------------------|---------------------|----------------------|---------------|--------------|
| CSR-M-6           | 12.8b            | 35.5d            | 0.44a               | 1.68b                | 88.33b        | 4260.45b     |
| CSR-M-8           | 12.3b            | 35.6b            | 0.34c               | 1.67b                | 91.66a        | 4393.57b     |
| CSR-M-9           | 12.1b            | 34.0c            | 0.38b               | 1.86a                | 86.66b        | 3992.14c     |
| CSR-M-16          | 13.6a            | 36.5a            | 0.38b               | 1.75b                | 93.33a        | 4675.83a     |
| Control           | 3.7f             | 8.31d            | 0.14d               | 0.12c                | 6.67b         | 80.22d       |

Notes: Values are the means of three replicates. Means in the column followed by the same superscript letter are not significantly different according to Duncan’s multiple range test at P = 0.05.
growth or regulate under extreme saline conditions.

ACKNOWLEDGMENT

The authors are thankful to the, Central Soil Salinity Research Institute, RRS, Lucknow and NAIP, ICAR for his encouragement and help in carrying out this work.

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