Research Article

Impact of Different Strains of Cyanobacteria on Rice Crop Growth and Nutrients Uptake under Saline Soil Condition

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Abstract | Saline soils have complex agro-ecosystems, difficult to manage. In early stages, the salinity affects the germination and emergence of the young seedlings and then the growth and yield of various crops and ultimately disturbing the socioeconomics of the farming community. Among the microbes, cyanobacteria are known as photoautotrophic, blue green algae which is not a truly eukaryotic algae and grown in different and such complex habitats freely and symbiotic association with large numbers of plants and microbial mats. In this regard, a pot experiment was carried out with the aim to assess the impact of different strains of cyanobacteria on rice crop growth and nutrients uptake under saline soil condition at National Agricultural Research Center (NARC), Islamabad Pakistan during summer 2016. A total of 18 experimental pots were induced with salinity of 7.0 dS m^{-1} and arranged in Completely Randomized Design (CRD) with three replications. Six treatments consisted of a control (no strains) and 5 different strains of cyanobacteria i.e Oscillatory-MMF-1 (*Oscillatoria princeps*), Leptolyngbaya-MMF-2 (*Lyngbya mucicola*), Leptolyngbaya-MMF-3 (*Lyngbya Phormidium*), Gloeobacter-MMF-4 (*Gloeocapsa*) and Microcoleus-MMF-5 (*Cryophilus) were applied randomly to flooded rice in pots. Five* seedlings of rice (Kianat cv.) were transplanted to each pot on 18th of July 2016. The growth of rice crop was maintained for about 3 months and 12 days and shoots harvested on October 30, 2016. The data were recorded on agronomic parameters and rice shoots and roots tissue analysis for various nutrients uptake/concentration. The data revealed that all strains of cyanobacteria had significantly ($p \leq 0.05$) improved the nutrients up-take/concentration and agronomic traits of rice crop as compared to control. Among the strains, the Gloeobacter strain (MMF-4) surpassed by augmenting all agronomic parameters of rice crop like plant height (85 cm), plant fresh weight (45 g), dry weight (24.5 g) and root dry weight (2.80 g) followed by MMF-5 treatment. As regard shoot tissue analysis, the nutrients concentration was significantly changed in plant. The highest concentration of N (3.62 %), P (0.77 %), K^+ (2.68 %), Ca^{++} (0.60 %), Mg (0.44 %) and Na^+ (2.49 %) was found in the shoot of rice crop grown in saline condition of 7.0 dS m^{-1} treated with Gloeobacter strain as compared to other strains. As per roots tissue analysis, all the strains significantly ($p \leq 0.05$) increased the mean of nutrient concentration in root. The highest amount of N (3.37 %), P (0.86 %), K^+ (2.89 %), Ca^{++} (0.47 %) and Mg^{++} (0.35 %) was recorded in saline soil treated with MMF-4 strain as compared to control. It was concluded that all the strains of cyanobacteria improved the saline soil and agronomic parameters of rice crop but MMF-4 (Gloeobacter) and MMF-5 (Microcoleus) surpassed the aforementioned and recommended for rice crop in the ecosystems of saline soils.

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Introduction

Soil salinity is one of the major constrains to rice production in developing countries like Pakistan. Its early effect is on germination and then on growth and production of various crops at severe ratio. The increase of soluble salts and exchangeable sodium in the soils usually causes both salinity and sodicity and pose a main threat to various crops cultivation (Ashraf and Khan, 1994). These salts are greatly responsible for declining the cultivated land worldwide. I is estimated that about 310 million hectares (m ha) land of the world is irrigated, out of which 20 % (62 m ha) is affected by various salts (Qadir et al., 2014). Pakistan has about 6.30 m ha salt affected land (Alam et al., 2000) which is irrigated and un-irrigated. In other prime agriculture land, the practices like pesticides and fertilizers application, hard pan creation due to the use of heavy machinery and reuse of brackish water for irrigation purposes have built up root zone salinity. In salt affected soils, osmotic stress, specific ion toxicity and disturbance of nutrients are the dangerous effects of salinity on plants at various growth stages (Qayyum at al., 2007). The cultivation of such salt affected lands through various management strategies for getting economic and sustainable yield is of great importance for increased population.

In the past, even nowadays, the soil microbiologists and microbial ecologist are using the microorganisms for the reclamation of salt affected soils to increase the crop growth, production and improve soil fertility status for sustainable agriculture (Jha et al., 1987; Jan et al., 2017). Among these, the cyanobacteria (blue green algae) are photosynthetic, prokaryotic blue green algae and grown in a variety of habitat freely and symbiotic association with large numbers of plants and microbial mats. These are very beneficial microbes and can grow and tolerate in the soils of saline agriculture ecosystems especially the rice growth in saline conditions. Cyanobacteria strains are used for treatment of salt affected soils because they are more tolerant and grow well in saline soil and tolerate up to 8 dS m^{-1} and can be easily mass cultured in the presence of light because of its higher efficiency for photosynthesis (Singh, 1950). Some of the studies showed that cyanobacteria can convert sodium clay into calcium clay (Singh, 1961). In the saline-waterlogged condition, it provides the oxygen to the roots of the rice crops. For the first time, it is reported that cyanobacteria could be an effective tool for the reclamation of salt affected soils by producing a thick stratum on the surface of saline soil as well as conserve and improve the soil organic matter, N, P and K (Singh, 1950; Singh, 1961; Jan et al., 2017). Tonina et al. (1993) and Jan et al. (2017) reported that Cyanobacteria (blue green algae) improved the yield of rice crop in saline and high alkaline condition.

In Pakistan, the rice is the second important cereal crop. During 2016-2017, rice crop have sown on area of 2724 thousands hectares, production of 6849 thousand metric tons with average yield of 2514 kg per hectare (Pakistan Economic Survey, 2016-17) and exported to other countries like Iran, UAE, Saudi Arabia, Afghanistan and Kenya (World Rice Production USDA, 2016). The rice crop production can be enhanced in salt affected soils by both genetic and management processes/methods and as estimated that about one third area of globally irrigated land is salt affected. The rice production is too much sensitive to salts as a slight increase in salinity leads to a material decline of 20 % in the production (Shannon, 1998).

Keeping in view the importance of microbes like cyanobacteria and the afore mentioned problem of lands i.e salt affected soils, the present experiment was conducted to study the impact of different strains of cyanobacteria on rice crop growth and development, ions/nutrients uptake/concentration under saline soil conditions and improvement of saline soils.

Materials and Methods

A pot experiment was carried out to study the impact of different strains of cyanobacteria on rice crop growth and nutrient uptake under saline soil conditions at the Green house of the National Agricultural Research Center (NARC) Islamabad during summer 2016. Experimental pots were arranged in completely randomized design (CRD) with three replications. Each pot was induced with salinity of 7.0 dS m^{-1}. Five different identified strains of cyanobacteria i.e Oscillatory-MMF-1 (*Oscillatoria princeps*), Leptolyngbaya-MMF-2 (*Lyngbya mucicola*), Leptolyngbaya- MMF-3 (*Lyngbya Phormidium*), Gloeobacter-MMF-4 (*Gloeocapsa*) and Microcoleus-MMF-5 (*Cryophilus*) were obtained from the laboratory of Microbiology and Genetics, University of Punjab, Lahore and further multiplied for mass multiplication in the laboratory of Soil Biology and Biochemistry, National Agricultural Research Center, Islamabad. These five strains of cyanobacteria and a control (no strains) (a total of six treatments) were used to treat the pots of induced salinity of 7.0 dS m^{-1} soil.

The detail of the treatmnets are as under

T_1 = Control (No strains);T_2 = MMF-1 Oscillatoria (*Oscillatoria princeps)*; T_3 = MMF-2 Leptolyngbaya (*Lyngbya mucicola)*; T_4 = MMF-3 Leptolyngbaya *(Lyngbya Phormidium)*; T_5 = MMF-4 Gloeobacter (*Gloeocapsa)*; T_6 = MMF- 5 Microcoleus (*cryophilus)*.

Collection, analysis of soil and plant samples and agronomic data

The soil was collected for pot experiment from the field of Research Farm of National Agricultural Research Center, Islamabad. The soil sample was taken and processed from collected soil for various physic-chemical properties. A total number of 18 pots made of plastic (diameter, 25cm and height, 50 cm) were taken and filled each with 5 kg soil by developing the required/induced salinity of EC= 7 dS m^{-1}.

Solution method was used for the application of cyanobacteria. In this method, the required amount of cyanobacteria was dissolved in one-liter water and recommended rate (20 kg ha^{-1}) of cyanobacteria of each strain was applied to the respective pots. No application of organic and chemical fertilizer was done. Five seedlings of rice (Kainat smooth cv.) crop from the nursery were transplanted to each flooded pot on 18th July 2016 for their growth and development. The rice in all pots was flooded from transplanting till harvesting. All the cultural practices were applied during the growth period in green house and temperature ranged from 30-38 C^0. Rice crop growth was maintained for about 3 months, 12 days and shoots of rice crop harvested on October 30, 2016.

Agronomic data on rice crop i.e plant height (cm), plant fresh weight (g pot^{-1}), plant dry weight (g pot^{-1}) and root dry weight (g pot^{-1}) were collected. The pre-sowing composite soil and the post-harvest soil samples, rice shoots and roots samples from each pot were obtained and analyzed in the laboratory of Soil Biology and Biochemistry of NARC, Islamabad, according to the standard methods/procedures for determining soil physiochemical properties, tissue and root concentration, respectively. The plant nitrogen was determined by Kjeldahl nitrogen apparatus (Bremner and Mulavaney, 1982). The phosphorus was determined by spectrophotometer. Sodium and Potassium were determined by flam photometer. Calcium and magnesium were measured by atomic absorption spectrophotometer.

Characterization of the pre-sowing soil

The analysis of pre-sowing soil sample was done before starting of the experiment, to determine the physiochemical properties of soil i.e. electrical conductivity, pH, organic matter, calcium, magnesium, texture, nitrogen, phosphorus and potassium. The soil texture of the experimental soil was silt loam in nature, alkaline in reaction and having less organic matter content (Table 1).

Table 1: *Physio-chemical Properties of Soil before starting of the experiment***.**

Soil property	Value	Soil property	Value
Particle size distribution %		***AB-DTPA Ext. cations (mg kg^{-1})**	
Clay	7.00	Na^+	2552
Silt	68.40	Ca^{++}	870
Sand	24.60	Mg^{++}	285
Textural class	Silt loam	AB-DTPA Ext. nutrients (mg kg^{-1})	
Chemical properties			
pH	8.3	NO_3-N	1.96
EC (dS m^{-1})	7.0	P	1.87
		K	273

**Ammonium Bicarbonate-Diethylene Triamine Pentaacetic Acid Extractable (AB-DTPA Ext.).*

Procedure for mass culture

Before starting the experiment, the obtained strains of cyanobacteria were mass cultured in BGA-11 media in the laboratory of NARC, Islamabad and the specific environment, optimum temperature 29°C and conditional fluorescent light 40 Watt (Sixteen hours' light and 8 hours' dark interval) were provided for the photosynthesis. They were cultured in bottle or flask through maintaining all the environmental condition with 1 % more CO_2 than normal air.

Blue Green Algae (BGA-11) media preparation for mass culture of cyanobacteria

Different chemicals were used in BGA-11 media preparation for the multiplication of cyanobacteria which are as under.

- **Stock solution**: (1): Na_2MG EDTA = 0.1 g L^{-1}; (2): Ferric Ammonium citrate = 0.6 g L^{-1}; (3):

Citric Acid H_2O = 0.6 g L^{-1}; (4): $CaCl_2$.$3H_2O$ = 3.6 g L^{-1}
- **Stock solution:** $MgSO_4$.$7H_2O$ = 7.5 g L^{-1}
- **Stock solution**: K_2HPO_4 .$3H_2O$ = 4.0 g L^{-1} Or K_2HPO_4 = 3.0 g L^{-1}
- **Stock solution (Micronutrients):** H_3BO_3 = 2.86 g L^{-1}; $MnCl_2$. $4H_2O$ = 1.81 g L^{-1}; $ZnSO_4$. $7H_2O$ = 0.222 g L^{-1}; $CuSO_4$. $5H_2O$ = 0.079 g L^{-1}; $CoCl_2$. $6H_2O$ = 0.050 g L^{-1}; $NaMoO_4$. $2H_2O$ = 0.391 g L^{-1}

Combined the stock solution and adjusted pH to 7.5 (used 1 N HCl).

Stock Solution	Per liter of medium
Stock a	10 ml
Stock b	10 ml
Stock c	10 ml
Stock d	1.0 ml
Na_2CO_3	0.02 g

Procedure and calculation for developing induced salinity

Procedure and Calculation for developing induced salinity is as under. First found out the electrical conductivity (EC) and saturation percentage (SP).

Soil original EC = 1.35 dS m^{-1}
EC to develop = 7 dS m^{-1}
EC different = 7 -1.35 = 5.65 dS m^{-1}

A 5.65 dS m^{-1} was required for development of 7 dS m^{-1} salinity in soil. According to handbook 60 (Richards, 1954), solution (1 dS m^{-1} EC of soil contain 10 meq salts).

Soil original EC = 1.35 = 13.5 meq kg^{-1}
EC to develop = 7 = 70 meq kg^{-1}
EC different = 70 -13.5 = 56.5 meq kg^{-1}
Required meq = 56.5 meq kg^{-1}

The eq. wt. of NaCl = 58.5 meq
The saturation percentage = 32 %
Amount of NaCl, to develop the 7 dS m^{-1}
= Required meq kg^{-1} x Eq.wt of NaCl
= 56.6 x 58.5
= 3305.25 meq/1000
= 3.30 g kg^{-1}

$$Saturation\ Percentage = \frac{3.30g\ kg^{-1}}{32\%} \times 100\% = 10.31\ g\ kg^{-1}$$

So, 10 g sodium chloride was taken for one kg soil and developed 7 dS m^{-1} EC (required EC).

Statistical analysis

The collected data were statistically analyzed by analysis of variance (ANOVA) method of complete randomized design procedure using Statistix 8.1 Package. The probability level for LSD test i.e 5 % level of significance was used to distinguish between the means (Steel and Torrie, 1980).

Results and Discussion

Plant height (cm)

The data on plant height revealed that the treatments means were significantly ($p \leq 0.05$) different from one another (Table 2). The maximum growth of rice in term of plant height (85 cm) was measured in saline soil condition treated with MMF-4 followed by MMF-3 and MMF-2, both having 70 cm plant height. The significantly minimum plant growth of rice crop in term of height (54 cm) was noted in control (saline with no strain). These results are supported with the work of Aziz and Hashem (2004) and Rodríguez et al. (2006). The secretion of cyanobacteria responded sodium-induced reserve on shoot extension and enlarged root dry weight, the salt effect on shoot dry weight.

Shoots fresh weight (g pot^{-1})

Statistical analysis of data on shoots fresh weight showed that the treatments means were significantly ($p < 0.05$) different from one another (Table 2). The significantly maximum fresh weight (45 g pot^{-1}) of rice shoots was recorded in induced soil salinity of pots treated with MMF-4 (Gloeobacter) strain of cyanobacteria followed by MMF-3 (42 g pot^{-1}) and MMF-2 treatment (41 g pot^{-1}). The minimum fresh weight (30 g pot^{-1}) of rice shoots was found in control. These results are supported by the findings of Subhashini and Kaushik (1984) and Kaushik (1994). They reported that rice straw yield increased with combine application of gypsum and cyanobacteria and also reduced the soil pH and electrical conductivity.

Shoots dry weight (g pot^{-1})

Data on the plant dry weight of rice crop revealed that treatments means were significantly ($p < 0.05$) different from one another (Table 2). The maximum shoots dry weight (24.4 g pot^{-1}) of rice crop was measured in induced soil salinity of pots treated with MMF-4 (Gloeobacter) followed by MMF-3 treatment (23.5 g pot^{-1}) which were statistically at par with each other.

The minimum dry weight (17.7 g pot^{-1}) of rice shoots was recorded in control pots. These results are accordance with the finding of Brotherson and Rushforth (1983), Harper and Pendleton (1993), Pendleton and Warren (1995) and Aziz and Hashem (2003), (2004). They stated that the secretion of cyanobacteria responded sodium-induced reserve on shoot extension and enlarged root dry weight, the salt effect on shoot dry weight the dry mass of rice in pot.

Table 2: *Plant height (cm), shoot fresh weight, shoot and root dry weight (g pot^{-1}) of rice crop grown in saline soil as influenced by different strains of cyanobacteria.*

Treatment	Plant height (cm)	Shoots fresh Weight (g)	Shoots dry Weight (g)	Root dry Weight (g)
Control (no-strain)	54 c	30 c	17.7 b	1.20 c
MMF-1 Oscillatoria	62 bc	38 abc	20.7 ab	2.06 b
MMF-2 Leptolyngbaya	70 b	41 ab	21.0 ab	2.43 ab
MMF-3 Leptolyngbaya	70 b	42 ab	23.5 a	2.12 b
MMF-4 Gloeobacter	85 a	45 a	24.4 a	2.80 a
MMF-5 Microcoleus	64 bc	35 bc	21.0 ab	2.20 b
LSD (5 %)	9.37	8.32	4.62	0.5

In each column means followed by different letter (s) are significantly different from one another.

Root dry weight (g pot^{-1})

The statistical analysis of the data on root dry weight of rice crop showed that treatment mean values were significantly ($p < 0.05$) changed with one another (Table 2). The maximum dry weight (2.80 g pot^{-1}) of rice roots was noted in induced soil salinity of 7.0 dS m^{-1} in pots treated with MMF-4 (Gloeobacter) strain of cyanobacteria followed by MMF-2 treatment (2.43 g pot^{-1}) while the data obtained from MMF-1, MMF-3 and MMF-5 treatments were statistically at par with each other (Table 2). The lowest root dry weight (1.20 g pot^{-1}) was noted in control. Similar results are also reported by Shields and Durrell (1964), Harper and Pendleton (1993) and Pendleton and Warren (1995). They studied that the dry mass of rice in pots with cyanobacteria was up to 2-4 time greater than without pots of cyanobacteria.

Rice shoots analysis

Shoots sodium and potassium: The statistical analysis of the data on rice shoot Na as well as K revealed that the treatments means were significant ($p \leq 0.05$) (Table 3). The maximum concentration of Na (2.49 %) was measured in MMF-4 followed by MMF-1 and MMF-5 treatment (2.11%). As regards the K uptake, the maximum uptake of K (2.68%) was noted in rice shoots grown on induced salinity treated with MMF-4 strain of cyanobacteria followed by MMF-5 strain (2.52%) (Table 3). In saline condition, the uptake of K by rice crop treated with MMF-2 (2.32 %) and MMF-1 (2.29%) were statistically at par with each other. The minimum amount of K uptake (1.93%) was recoded in saline soil with no strain application (control). These results are supported by the finding of Brotherson and Rushforth (1983), Harper, Pendleton (1993), Pendleton, Warren (1995), Shields and Durrell (1964). The secretion of cyanobacteria responded to sodium reserve on shoot extension and enlarged root dry weight, the salt effect on shoot dry weight.

Table 3: *The concentration of sodium, potassium, calcium, magnesium, nitrogen and phosphorus (all are in %) of rice shoots grown in saline soil as influenced by different strains of cyanobacteria.*

Treatments	Na	K	Ca	Mg	N	P
Control- (no-strain)	1.83 c	1.93 d	0.35 e	0.25 c	0.34 d	0.20 d
MMF-1 Oscillatoria	2.21 b	2.29 bc	0.41 d	0.37 b	3.22 b	0.63 b
MMF-2 Leptolyngbaya	1.62 cd	2.32 bc	0.54 b	0.41 a	2.85 c	0.51 bc
MMF-3 Leptolyngbaya	1.52 d	2.23 c	0.54 b	0.43 a	3.11 b	0.60 bc
MMF-4 Gloeobacter	2.49 a	2.68 a	0.61 a	0.44 a	3.62 a	0.77 a
MMF-5 Microcoleus	2.21 b	2.53 ab	0.45 c	0.36 b	2.83 c	0.49 c
LSD (5 %)	0.254	0.241	0.02	0.03	0.218	0.121

In each column means followed by different letter (s) are significantly different from one another.

Shoots calcium and magnesium: Statistical analysis of the data on concentration of Ca and Mg of rice crop shoot showed that treatment means values of Ca and Mg were significantly ($p \leq 0.05$) different from one another (Table 3). The maximum absorption of Ca (0.60 %) by rice shoots was measured in induced saline soil treated with MMF-4 (Gloeobacter) followed by MMF-3 treatment (0.54%) and MMF-2 treatment (0.54%) which are statistically at par with each other. The minimum uptake of Ca

(0.35%) was recoded in control (saline but no strain). As in case of the uptake of Mg, the maximum value of Mg (0.44%) of rice shoots was recorded in saline pots treated with MMF-4 (Gloeobacter) followed by MMF-3 and MMF-2, which were statistically at par. Also the uptake of Mg value in MMF-5 treatment and MMF-1 treatment were statistically at par with each other. The lowest uptake of Mg (0.25 %) by rice crop was measured in control (saline). These results are in accordance with the results of Kaushik (1994) and Rodríguez et al. (2006) and reported that the combine application of both cyanobacteria and gypsum increased the yields as compare to others.

Shoots nitrogen (N): The data on shoots N of rice crop revealed that results were significantly ($p \leq 0.05$) different from one another (Table 3). The maximum uptake of N (3.62 %) by rice crop was noted in soil of pots induced with salinity of 7.0 dS m^{-1} treated with MMF-4 (*Gloeobacter*) strain of cyanobacteria followed by MMF-3 (*Leptolyngbaya*) and MMF-1(*Oscillatoria*) treatment. The lowest uptake of N (0.35 %) was measured in control (salinity with no strain). These results are supportive with the findings of Mitra (1951), Venkataraman (1975), (1979), (1981), Kannaiyan (1990), El-Shahaby (1992), Mandal et al. (1998), Whitton (2000), Vaishampayan et al. (2001), Haroun and Hussein (2003) and Jan et al. (2017) . They reported that the cyanobacteria bio-fertilizer or indigenous cyanobacteria applications can fulfill the NPK requirements for rice growth and yield. The greater concentration of N was found in rice crop treated with cyanobacteria because at first attempt it has greater possibility for N fixation in the water-logged culture as well as availability of soil N also and secondly, it can favor/improve the physiological condition of saline soil.

Shoots phosphorus (P): The statistical analysis of the data on phosphorus concentration of rice shoots showed that maximum uptake of P (0.77 %) by rice crop under saline condition of pots was found treated with MMF-4 strain followed by MMF-2 and MMF-3 treatment. The results of MMf-4 and MMF-2 and MMF-3 are overlapping with each other while values of MMF-2 and MMF-3 are statistically at par. The minimum uptake P (0.20 %) was recorded in control (saline but no strain). These results are supported by Mitra (1951), Venkataraman (1975), (1979), (1981), Kannaiyan (1990), El-Shahaby (1992), Mandal et al. (1998), Whitton (2000), Vaishampayan et al. (2001), Haroun and Hussein (2003) and Jan et al. (2017). They described that the cyanobacteria bio-fertilizer or indigenous cyanobacteria application can satisfy the P requirement for rice growth and development in saline ecosystem.

Rice roots analysis

Concentration of sodium and potassium: The statistical analysis of the data on rice root Na and K showed that there was significant ($p \leq 0.05$) difference among the treatment means (Table 4). The maximum amount of Na (2.50 %) was recorded in MMF-3 treatment and MMF-2 treatment (2.50 %). Control (2.36 %) and MMF-5 treatment (2.18 %) were statistically similar. The lowest amount of sodium was founded in MMF-1 treatment (1.87%) followed by MMF-4 treatment (2.08%). As in case of K uptake by rice shoots showed that the highest value of K (2.89 %) was noted in saline condition treated with MMF-4 (Gloeobacter) followed by MMF-2 (2.64%), MMF-3 treatment (2.63 %) and MMF-5 treatment (2.56 %). The lowest uptake of K (2.39 %) was recoded in control. These results are supported by the finding of Shields and Durrel (1964), Brotherson and Rushforth (1983), Harper and Pendleton (1993), Pendleton and Warren (1995). They said that cyanobacteria replied sodium reserve on shoot extension and enlarged root and shoot dry weight.

Table 4: *The concentration of sodium, potassium, calcium, magnesium, nitrogen and phosphorus (%) in rice root grown in saline soil condition as influenced by different strains of cyanobacteria.*

Treatments	Na	K	Ca	Mg	N	P
Control (no-strain)	2.36 ab	2.39 b	0.27 e	0.23 c	0.46 d	0.30 d
MMF-1 Oscillatoria	1.87 d	2.48 b	0.33 c	0.24 c	2.17 b	0.74 b
MMF-2 Leptolyngbaya	2.50 a	2.64 ab	0.42 b	0.32 b	1.80 c	0.61 bc
MMF-3 Leptolyngbaya	2.50 a	2.63 ab	0.46 a	0.35 a	2.07 b	0.70 bc
MMF-4 Gloeobacter	2.08 cd	2.89 a	0.47 a	0.36 a	3.37 a	0.86 a
MMF-5 Microcoleus	2.19 bc	2.56 b	0.27 d	0.22 c	1.78 c	0.59 c
LSD (5 %)	0.263	0.290	0.01	0.01	0.46	0.30

In each column means followed by different letter (s) are significantly different from one another.

Roots calcium and magnesium: Results on rice roots' calcium (Ca) and magnesium (Mg) showed that the treatments means were significantly ($p \leq 0.05$) altered from one another (Table 4). The maximum concentration of calcium (0.47 %) in roots of rice crop was measured in saline soil treated with MMF-4 (Gloeobacter) strain of cyanobacteria followed by MMF-3 (0.45%). Also the results of cyanobacteria strain named MMF-5 treatment and MMF-1 treatment were statistically different from one another. The minimum concentration of Ca (0.27 %) in rice roots was recoded in control. Data regarding of Mg uptake by rice roots revealed that maximum value of Mg^{+2} (0.36 %) was put on record in saline condition treated with MMF-4 (Gloeobacter strain) followed by MMF-3 (0.35 %), MMF-2 treatment (0.32 %) and MMF-1 (0.24 %) (Table 4). The lowest amount of magnesium uptake (0.22 %) was measured in MMF-5 treatment. These results are in accordance with Kaushik (1994) and Rodríguez et al. (2006) and said that the combine application of both cyanobacteria and gypsum increased the yields as compared to other chemicals.

Roots nitrogen and phosphorus: Data on roots N and P revealed that the treatments mean values were significantly ($p \leq 0.05$) with one another (Table 4). The maximum concentration of N (3.37 %) of roots was recorded in saline culture of pots treated with MMF-4 strain of cyanobacteria followed by MMF-1 strain (2.17 %) and MMF-3 treatment (2.07 %). While the results of MMF-2 and MMF-5 treatments were statistically at par with each other. The lowest uptake value of nitrogen (0.46%) was measured in control. As in case of P concentration in root of rice crop indicated that maximum concentration (0.86 %) of P was measured in pots treated with MMF-4 strain (Table 4). Statistically the results of MMF-3 and MMF-2 treatments were similar. The lowest concentration of P (0.30 %) in roots was recorded in control. These results are in pipeline with the findings of Kannaiyan (1990), Whitton (2000) and Jan et al. (2017) stated that the cyanobacteria bio-fertilizer or indigenous cyanobacteria applications cover the N and P requirements for rice growth.

Conclusions

Based on the results of the experiment, all cyanobacteria strains significantly affected all growth parameters of rice crop as compared to control. Further, among all the strains, the Gloeobacter-MMF-4 (*Gloeocapsa*) surpassed by augmenting all agronomical parameters of rice like plant height, plant fresh and dry weight and improved the nutrients uptake of shoots and roots very well as reflected in the form of increase of the agronomic data.

All these strains of cyanobacteria studied, can be applied to the rice crop in saline condition but Gloeobacter-MMF-4 (*Gloeocapsa*) and Microcoleus-MMF-5 (*Cryophilus)* surpassed the aforementioned parameters and recommended for rice crop in the ecosystems of saline soils.

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Author's Contribution

Shamsher Ali conceived the idea, designed the experiment, write up and overall management of research and article. Zakirullah Jan conducted this piece of research and collected the data. Tariq Sultan helped in spot experimentation and provided facilities. Muhammad Jamal Khan helped in writing of the section under materials and methods. Zahir Shah helped in data analysis and Farmanullah Khan did proof reading of the manuscript.

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