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Effect of plant growth promoting rhizobacteria on the crop growth and yield of foxtail millet (*Setaria italica* L. Beauv)

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Abstract
The most productive use of land resources has emerged as a significant challenge for India's food production security in recent years. Soil micro-organisms have been generally assumed to have a beneficial impact on soil fertility and productivity. A sustainable approach to boost crop production and growth is the use of plant growth promoting rhizobacteria (PGPR), This work primarily aimed to study the influence of some PGPR on promoting crop growth under greenhouse condition and the effects of PGPR on crop yield of foxtail millet under field condition. Initially, the PGPR were isolated from the sorghum rhizosphere using the serial dilution method. The molecular identity of the isolated bacteria was identified by 16S rDNA sequencing. The strains were identified as *Pseudomonas putida*, *Bacillus subtilis*, *Bacillus cereus*, and *Pantoea Stewart*. Foxtail millet seeds were inoculated with bacterial strains and evaluated for shoot and root growth under greenhouse condition, whereas ear-head weight, grain weight, fodder weight, and ear-head length under field condition. According to our findings, foxtail millet produced the highest root and shoot lengths when seeds were inoculated with *Bacillus cereus* (19.33cm) and *Pseudomonas putida* (28.66cm), respectively, under greenhouse conditions. On the other hand, among the four bacterial cultures, *Bacillus subtilis* exhibited the best performance in terms of grain weight (40.42%), ear-head weight (30.19%), fodder weight (49.72%) and ear-head length (42.56%) compared to the control group under field conditions. When considered collectively, the empirical evidences suggests that plant growth promoting rhizobacteria can improve crop growth and production under green house and field conditions, respectively.

Keywords: PGPR, foxtail millet, biofertilizers, plant growth, crop yield

Introduction
Foxtail millet (*Setaria italica* L. Beauv), also known as Italian millet, is one of the oldest cultivated crops, originated in China and is now cultivated worldwide (Yang *et al*., 2012) [31]. Foxtail millet is often cultivated in drought-prone areas and impoverished soils of semi-arid regions, where other crops fail to thrive (Lata *et al*., 2012) [12]. In India, it is primarily grown by the small and marginal farmers in the drought-prone arid and semi-arid zones (Sharma *et al*., 2014) [26]. The main components of foxtail millet include starch, crude protein (12.3%), lipid, vitamins and minerals (3.3%) (Rai, 2002) [22]. It is rich in fibre and magnesium and possesses several nutritional and therapeutic benefits (Choi *et al*., 2005) [6]. The high magnesium levels regulate the glucose metabolism in the body and helps in insulin secretion.

The use of agrochemicals is vital for increasing crop productivity. However, its indiscreet usage deteriorates soil fertility through nitrogen leaching, soil compaction, reduction in soil organic matter and loss of soil carbon. Also, agro-chemicals often increase the cost of production. The use of plant growth promoting bacteria is considered as an environment friendly, cost-effective and long-term substitute to dangerous chemical fertilizers (Egamberdieva *et al*., 2016) [9].

The PGPR's are exogenous bacteria found in the rhizosphere in association with plant root systems, both at the root surface and in endophytic associations. When they are introduced into the agriculture ecosystem, the beneficial effects of PGPR include direct plant growth promotion, biological control and inducing systemic resistance in host plants, nitrogen fixation for plant use, phytohormone production (including auxins, cytokinins and gibberellins), solubilisation of mineral phosphates, and iron sequestration by bacterial siderophores (Glick *et al*., 1999) [12].

Fortuitously, plant growth promoting rhizobacteria (PGPR) enhances plant nutrient absorption and efficient utilisation, thus reducing fertiliser application (Adesemoye *et al*. 2009) [1].

The well-known PGPR includes organisms belonging to *Pseudomonas, Bacillus, Azotobacter, Azospirillum, Azoarcus, Klebsiella, Arthrobacter, Enterobacter, Burkholderia, Serratia,* and *Rhizobium*. These micro-organisms influence plant growth and development directly by producing indole acetic acid (IAA), siderophore and 1-aminocyclopropane1-carboxylate (ACC) deaminase enzyme, as well as by mobilising nutrients like phosphorus (P) to the plants by solubilising insoluble soil phosphates (Glick *et al*., 1995; Glick *et al*., 1999) [10, 12] and indirectly by exhibiting antagonistic effects towards many plant pathogenic fungi. In recent years, the concept of PGPR-mediated plant growth promotion and disease management has been gaining importance and acceptance on a global scale. The rhizobacteria assemblages of many crops have been studied and the use of PGPR holds promise for plant growth promotion and alleviation of plant drought stress (Mayak *et al*., 2004) [19].

However, adapting PGPR's to drought-stressed soils is a serious issue, particularly for the microbes that had previously acclimatized to high water tension (Van Meeteren *et al*., 2008) [28]. Conversely, foxtail is a hardy crop, that thrives well in low moisture soils. Hence, it is necessary to test the efficiency of PGPR's for inclusion in the foxtail millet cultivation practices under the low moisture ecosystem. Hence, the current study was framed to determine the effect of PGPR's on the growth and yield of foxtail millet.

Material and Methods

Isolation and purification of bacteria

The sorghum rhizospheric soil samples were collected from the University of Horticultural Sciences, Bagalkot, Karnataka. A total of 10g of soil was suspended in 90 ml sterile water blanks and vortexed three times for five seconds each time and serially diluted until 10^{-4}. By using spread plate technique, 100 µL of each dilution were then plated on tryptone glucose yeast extract agar media (TGY). Each dilution's plates were incubated at 28 °C for 24 hours before being checked for colonies. For long-term storage, the bacterial strains were maintained in peptone glycerol at -80 °C.

Molecular identification of bacteria

The CTAB method (cetyltrimethylammonium bromide) was used to isolate DNA from the bacterial biomass on the plates, and the DNA samples were quantified using the Eppendorf micro-cuvette in Eppendorf Bio-Spectrometer. The samples with an absorbance ratio of 1.8 to 2.0 at A260/280 were considered for further procedure. To identify the bacterial isolates, 16s rDNA PCR was done by using primer pair 27F (5'AGAGTTTGATCCTGGCTCAG 3') 1492R (5'ACGGCTACCTTGTTACGACTT 3'). PCR was performed in a total volume of 25µL, which contained 0.2 µL of GoTaq DNA Polymerase 5 U/mL (Promega, United States), 5 µL of GreenGo TaqR Reaction Buffer 5X (Promega, United States), 2.5 µL of 10 mM dNTP (Promega, United States), 1µL of 10 mM primer forward, 1 µL of 10 mM primer reverse, 2 µL of template DNA and nuclease-free water. The reaction conditions were initial denaturation at 95 °C for 2 min 30 s, followed by 35 cycles of denaturation at 95 °C for 20s, annealing at 57 °C for 30s and extension at 72 °C for 30s. A final extension was performed at 72 °C for 5 min. The obtained amplicon was prepared for sequencing using a Nextera XT library preparation kit in accordance with the manufacturer's recommended procedures. The libraries were sequenced by Sanger sequencing technology. The resulting sequences were edited, compared with others in the GenBank database, using BLAST to find for the most similar sequences. A neighbour-joining phylogenetic tree of the detected sequences was constructed using MEGAX with 1000 boot straps. The reference isolates D-NCIM was received from National Collection of Industrial Micro-organism, Pune.

Seed treatment

The seeds of the foxtail millet variety DHFT 109 were surface sterilized with 0.1% $HgCl_2$ for two minutes and rinsed six to seven times with sterile distilled water. The foxtail millet seeds were treated with three days old cultures (OD=0.6) containing carboxy methyl cellulose (at 1%) as a sticking agent and allowed to dry overnight. Untreated foxtail millet seeds were used as control.

Evaluation of PGPB for plant growth and yield

The culture-treated seeds were sown in black trays filled with black soil in 3 replications. The soil was collected from the college field and was sieved through a mesh sieve and approximately 200 grams were filled into the trays. Two bacteria-treated seeds were sown in each tray. The uninoculated seeds were also sown in the trays as a control. Trays were kept under the greenhouse at maximum temperature 32 °C, 16h light with relative humidity 75%. Booster doses of the bacterial strains (1 ml per cup, 10^7 cfuml^{-1}) were applied 15 days after sowing by the soil drench method. Observations were recorded after 40 days of sowing for shoot length and root length.

The field experiment was conducted in black soil following a completely randomized block design with four replications and sub-plot sizes of 9.45m² in black soil at UHSB, Karnataka (altitude 533 m; 16. 18°N 75. 7° E) during the kharif season. Seeds were treated with four potent bacterial cultures and sown at a depth of about 3cm at a spacing of 45x15cm by line sowing method. Untreated seeds were sown in control plots. No chemical fertilizers or pesticides were applied on the crop. The crop was harvested on the 105th day after sowing and the following observations such as net plot grain weight, net plot ear-head weight, net plot fodder weight, and ear-head length were recorded.

Statistical analysis

The pot culture and field experiment were subjected to the analysis of variance (ANOVA) technique to evaluate the efficiency of PGP agents. The significance of differences between the treatment means was tested at $P = 0.01$ and 0.05.

Results

The present investigation was undertaken to identify rhizobacterial isolate having plant growth promotion activity. The bacterial strains were initially isolated from the sorghum rhizosphere by serial dilution method and plating on the TGY. The isolates were identified as *Bacillus cereus* (DRS-3A), *Pantoea stewartii* (DRS-3B), *Pseudomonas putida* (DRS-3C), and *Bacillus subtilis* (LBPS) using 16s rDNA sequencing. The seeds of the foxtail millet variety DHFT 109 were

inoculated with isolated bacterial strains in order to identify their effects, on shoot and root length (crop growth) under greenhouse condition and net plot grain weight, net plot ear-head weight, net plot fodder weight and ear-head length under field condition.

Our analysis revealed that, the bacterial isolates significantly improved the growth of foxtail millet seedlings in terms of both root and shoot length over mock control (Table 1). The highest shoot length of 28.66 cm was recorded in the treatment of *Pseudomonas putida* isolate, followed by isolates *Bacillus subtilis* (25.66cm), *Bacillus cereus* (24.83cm), and *Pantoea stewartii* (23.6cm) over the control (15.66cm). The isolate *Bacillus cereus* produced the highest root length (19.33cm) in comparison to *Pantoea stewartii* (16.66cm), *Bacillus subtilis* (16.33cm), *Pseudomonas putida* (15.33cm) and control group (13.33cm).

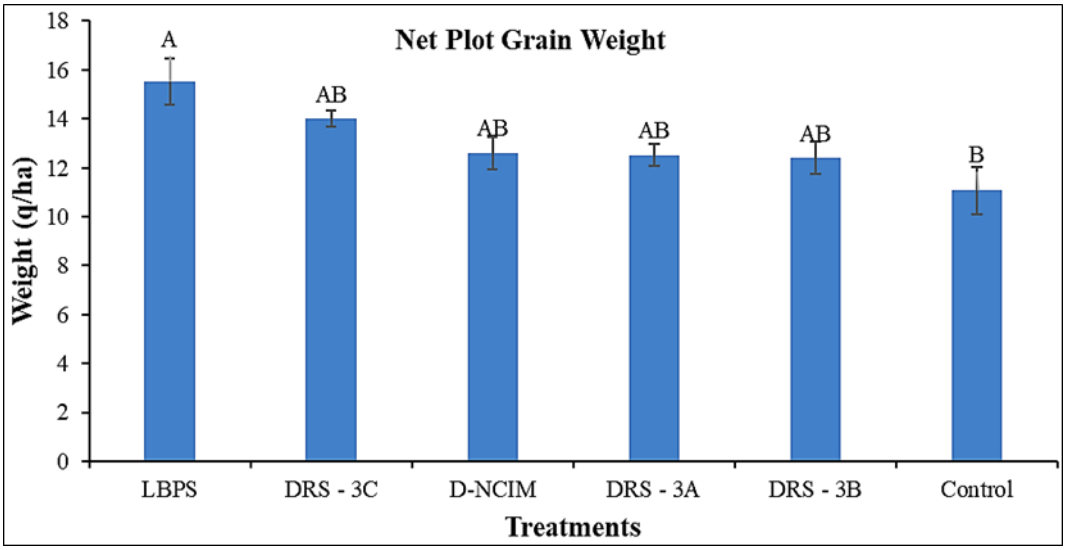
Table 1: Effect of seed treatment with bacterial strains on shoot and root length of foxtail millet under greenhouse conditions

No.	Treatment	Shoot Length (cm)	Root Length (cm)
1.	DRS-3A	24.83	19.33
2.	DRS-3B	23.60	16.66
3.	DRS-3C	28.66	15.33
4.	LBPS	25.66	16.33
5.	Control	15.66	13.33

Under field conditions, the bacterial strains significantly enhanced crop yield compared to control treatment (Table 2). Among the four bacterial cultures, *Bacillus subtilis* showed the best performance in terms of grain weight, ear-head weight, fodder weight, and ear-head length compared to the other three cultures (Fig.1). *Bacillus subtilis* enhanced grain weight, ear-head weight and fodder weight up to 4.47kg, 4.8kg and 8.98kg, respectively, over the control. Ear-head length was also increased by *Bacillus subtilis* up to 6.92cm over uninoculated controls.

Table 2: Effect of seed treatment with PGPR on net plot grain weight, net ear head weight, net fodder weight and net ear head weight of foxtail millet under field conditions

Treatment/ Parameter	Net Plot Grain Weight (q/ha)	Improvement (%)	Net Plot Ear Head Weight (q/ha)	Improvement (%)	Net Plot Fodder Weight (q/ha)	Improvement (%)	Net Plot Ear Head Length (cm)	Improvement (%)
Control	11.06	0.00	15.9	0.00	18.06	0.00	16.26	0.00
DRS-3A	12.52	13.20	16.9	6.29	21.95	21.54	21.98	35.18
DRS-3B	12.39	12.03	16.18	1.76	24.95	38.15	21.45	31.92
DRS-3C	14	26.58	16.81	5.72	23.52	30.23	20.65	27.00
LBPS	15.53	40.42	20.7	30.19	27.04	49.72	23.18	42.56
C.D.	1.9		1.95		4.57		3.98	
S.Em ±	0.63		0.65		1.52		1.32	



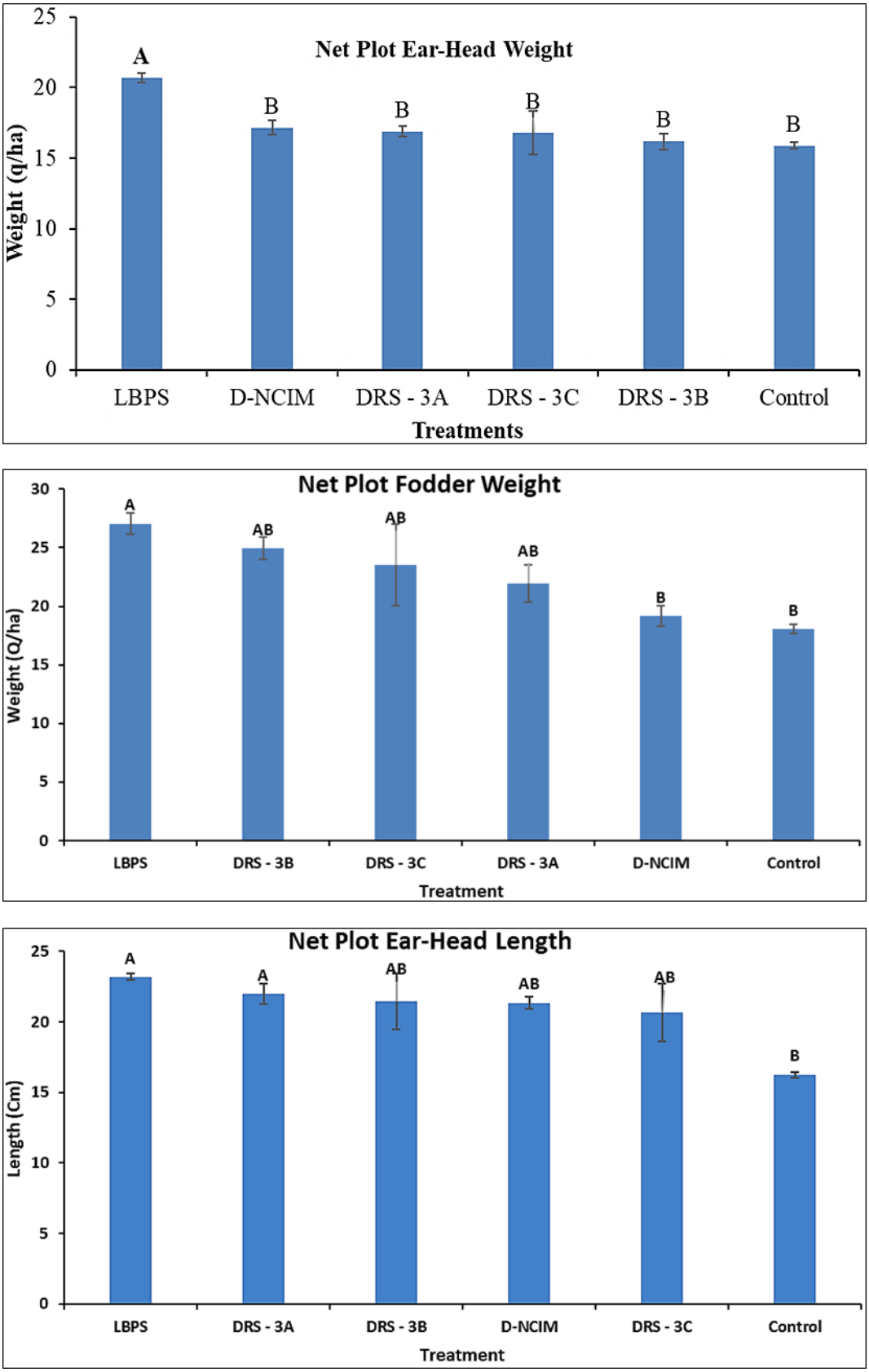


Fig 1: Effect of PGPR on the net plot grain weight, net plot ear-head weight, net plot-fodder weight, and net plot ear head length on 105th day after sowing under field condition

Discussion

Plant growth promoting rhizobacteria (PGPR) are rhizosphere bacteria that can boost plant growth through a range of mechanisms. Studies on the effect of PGPR inoculation on plant growth of *Zea mays* revealed a significant increase in plant height and dry weight of shoot over the Uninoculated plants (Zeffa *et al*., 2019) [32]. (Cohen *et al*., 1980) [7] also observed that the inoculation of *Z. mays* with strains of *A. brasilense* increased plant dry weight from 50% to 100%. (Okon *et al*., 1983) [21] reported a significant increase in the

dry shoot weight of *S. italica* due to inoculation with *A. brasilense*. The increase in dry shoot weight was up to 57% with the inoculation of *A. brasilense* Cd strain alone, while in combination with *A. brasilense* strain AZ39, the increase rose to 91%. When the Streptomyces strains were evaluated for their PGP activity and germination percentage on rice seedlings, the shoot and root length was significantly enhanced over the control (Gopalakrishnan *et al*., 2012) [13]. In the field, the Streptomyces strains greatly improved the panicle length, filled grain numbers and weight, panicle weight, 1000 seed weight, tiller numbers, total dry matter, root length (39-65%), root volume (13-30%), root dry weight (16-24%), grain yield (9-11%) and stover (11-22%) over the control. Despite the fact that using plant beneficial micro-organism such as PGPR in place of agrochemicals to improve plant growth is one of the most promising approaches. The utilization of plant growth promoting bacteria in modern agriculture is still limited. To increase the chances of PGPR strains becoming more widely accepted in the future, we investigated the influence of plant associated rhizobacteria on crop growth and yield of foxtail millet. A total of four strains were isolated from sorghum rhizosphere grown under semi-arid conditions. 16S rDNA sequencing revealed that they belonged to three different genera *Bacillus*, *Pantoea*, and *Pseudomonas*. The mechanisms of plant growth and nutrient uptake both consume more energy. However, plants primed by PGPR consumed less energy to activate these processes (Niu *et al*., 2011) [20], hence plants will have more energy to devote to other crucial metabolic processes like reproduction and yield.

The findings of our greenhouse and field experiment revealed that the crop growth and yield was increased in the PGPR-treated plants over the uninoculated control. The highest shoot length was noticed in *Pseudomonas putida* treatment (28.66cm), which is 83.7% higher than in untreated conditions. On the other hand, it also enhanced the net plot grain weight, net plot fodder weight, ear head length up to 26.58%, 30.23% and 27.0%, respectively over controlled treatment. Under field conditions, Pseudomonas are active root colonisers capable of moving from seed to root and promotes plant yield. Initially, it was assumed that ability of the pseudomonas to promote growth was mostly due to their ability to exclude harmful microbes from the rhizosphere. However, (Lifshitz *et al*., 1987) [18] discovered that in gnotobiotic circumstances, the growth enhancement of canola by a nitrogen fixer strain and a non-fixer mutant of *P. putida* GR12-2 was caused by phosphate solubilization, instead of nitrogen fixation. The same strain of *P. putida* GR12-2 induced a two to three fold increase in root length in canola seedlings as a result of IAA production (Xie *et al*., 1996) [29]. *P. putida* does not fix nitrogen, but it does generate IAA, solubilizes phosphate, and releases antifungal substances. Hence, more than one mechanism may be used by this organism to increase plant growth. The maximum root length of 19.33 cm was recorded in the treatment of *Bacillus cereus*, which is 45% higher than the control condition and also this strain improved the net plot fodder weight and net plot ear head length up to 21.54% and 35.18%, respectively over uninoculated treatment. *Bacilus subtilis* showed the best performance among the isolated strains with 32.29% improvement in net-plot grain weight, 15.27% improvement in net plot ear head weight, and 44.44% improvement in net-plot fodder weight, and 35.85% improvement in net-plot ear-head length. *Bacillus* sp. are advantageous to plants through a wide range of mechanisms, including biofilm production, converting the complex form of essential nutrients (P and N), liberating ammonia from nitrogenous organic matter, fixing atmospheric N_2, siderophore production, phytohormone production, and exudation of ACC deaminase. It also inhibits the pathogenic microbial growth, and strengthens pest defense mechanisms. In the present study, we found that *Bacillus subtilis* and *Bacillus cereus* improved both crop growth and yield of foxtail millet. Hence, one or more of the above mechanisms may be accountable for growth improvement as exhibited by isolates (Beauregard *et al*., 2013; Hayat *et al*., 2010; Ding *et al*., 2005; Arkhipova *et al*., 2005; Xu *et al*., 2013) [5, 14, 8, 2, 30]. *Pantoea stewartia* strain increased the shoot length upto 50.70% over control group and it also enhanced net pot fodder weight and net pot ear head length upto 38.15% and 31.92%, respectively. It is suspected that nitrogen and phosphate dissolving and indole-3-acetic acid property of the *Pantoea* sp. is responsible for this outcome (Rungrueng *et al*., 2021) [23].

Although roots were not inspected for colonisation in our study, the data on net plot grain weight, ear head weight, fodder weight and ear head length strongly suggest that the rhizobacteria must have been established in the foxtail millet rhizosphere contributing to improved yield without external application of fertilizers.

Conclusion

The present study confirmed that PGPR's exhibit high efficiency even under drought conditions by enhancing root volume in foxtail millet. PGPR's enabled foxtail millet to absorb more moisture and nutrients from the soil and increasing shoot length, improving photosynthesis and overall grain yield. Isolated PGPR's may be used as effective bio-fertilisers in the cultivation of foxtail millet and other crops.

References

1. Adesemoye AO, Torbert HA, Kloepper JW. Plant Growth-Promoting Rhizobacteria Allow Reduced Application Rates of Chemical Fertilizers. Microbial Ecology. 2009;58(4):921-929.
2. Arkhipova TN, Veselov SU, Melentiev AI, Martynenko EV, Kudoyarova GR. Ability of bacterium Bacillus subtilis to produce cytokinins and to influence the growth and endogenous hormone content of lettuce plants. Plant and Soil. 2005;272(1-2):201-209.
3. Antoun H, Prevost D. Ecology of Plant Growth Promoting Rhizobacteria. In: Siddiqui ZA, Ed., PGPR: Biocontrol and Biofertilization, Springer, Berlin, 2005, 1-38.
4. Bashan Y. Inoculants of plant growth-promoting bacteria for use in agriculture. Biotechnology Advances. 1998;16(4):729-770.
5. Beauregard PB, Chai Y, Vlamakis H, Losick R, Kolter R. Bacillus subtilis biofilm induction by plant polysaccharides. Proceedings of the National Academy of Sciences, 2013, 110(17).
6. Choi YY, Osada K, Ito Y, Nagasawa T, Choi MR, Nishizawa N. Effects of Dietary Protein of Korean Foxtail Millet on Plasma Adiponectin, HDL-Cholesterol, and Insulin Levels in Genetically Type 2 Diabetic Mice. Bioscience, Biotechnology and Biochemistry. 2005;69(1):31-37.

7. Cohen E, Okon Y, Kigel J, Nur I, Henis Y. Increase in Dry Weight and Total Nitrogen Content in *Zea mays* and *Setaria italica* Associated with Nitrogen-fixing *Azospirillum* spp. Plant Physiology. 1980;66(4):746-749.
8. Ding Y, Wang J, Liu Y, Chen S. Isolation and identification of nitrogen-fixing bacilli from plant rhizospheres in Beijing region. Journal of Applied Microbiology. 2005;99(5):1271-1281.
9. Egamberdieva D, Adesemoye AO. Improvement of Crop Protection and Yield in Hostile Agroecological Conditions with PGPR-Based Biofertilizer Formulations. Bioformulations: For Sustainable Agriculture, 2016, 199-211.
10. Glick BR. The enhancement of plant growth by free-living bacteria. Canadian Journal of Microbiology. 1995;41(2):109-117.
11. Glick BR, Penrose DM, Li J. A Model for the Lowering of Plant Ethylene Concentrations by Plant Growth-promoting Bacteria. Journal of Theoretical Biology. 1998;190(1):63-68.
12. Glick BR, Patten CL, Holguin G, Penrose DM. Biochemical and genetic mechanisms used by plant growth promoting bacteria. Imperial College Press, London, 1999.
13. Gopalakrishnan S, Humayun P, Vadlamudi S, Vijayabharathi R, Bhimineni RK, Rupela O. Plant growth-promoting traits of Streptomyces with biocontrol potential isolated from herbal vermicompost. Biocontrol Science and Technology. 2012;22(10):1199-1210.
14. Hayat R, Ali S, Amara U, Khalid R, Ahmed I. Soil beneficial bacteria and their role in plant growth promotion: a review. Annals of Microbiology. 2010;60(4):579-598.
15. Kloepper JW, Tuzun S, Zehnder GW, Wei G. Multiple Disease Protection by Rhizobacteria that Induce Systemic Resistance-Historical Precedence. Phytopathology®. 1997;87(2):136-137.
16. Kumar A, Verma H, Singh VK, Singh PP, Singh SK, Ansari WA, *et al*. Role of *Pseudomonas* sp. in Sustainable Agriculture and Disease Management. Agriculturally Important Microbes for Sustainable Agriculture, 2017, 195-215.
17. Lata C, Gupta S, Prasad M. Foxtail millet: a model crop for genetic and genomic studies in bioenergy grasses. Critical Reviews in Biotechnology. 2012;33(3):328-343.
18. Lifshitz R, Kloepper JW, Kozlowski M, Simonson C, Carlson J, Tipping EM, *et al*. Growth promotion of canola (rapeseed) seedlings by a strain of Pseudomonas putida under gnotobiotic conditions. Canadian Journal of Microbiology. 1987;33(5):390-395.
19. Mayak S, Tirosh T, Glick BR. Plant growth-promoting bacteria confer resistance in tomato plants to salt stress. Plant Physiology and Biochemistry. 2004;42(6):565-572.
20. Niu DD, Liu HX, Jiang CH, Wang YP, Wang QY, Jin HL, *et al*. The Plant Growth-Promoting Rhizobacterium Bacillus cereus AR156 Induces Systemic Resistance in Arabidopsis thaliana by Simultaneously Activating Salicylate and Jasmonate/Ethylene-Dependent Signaling Pathways. Molecular Plant-Microbe Interactions®. 2011;24(5):533-542.
21. Okon Y, Heytler PG, Hardy RWF. N_2 Fixation by Azospirillumbrasilense and Its Incorporation into Host Setariaitalica. Applied and Environmental Microbiology. 1983;46(3):694-697.
22. Rai M. Nutritive cereals. In: Survey of Indian agriculture. Chennai: The Hindu, 2002, 59-62.
23. Rungrueng P, Sodium S, Chalee C, Kalawong S, Sungthongw K. *Pantoea* spp. Application to Increase the Growth and Yield of Rice 'Pathum Thani 1.' Asian Journal of Plant Sciences. 2021;21(1):94-98.
24. Schumann P, Stackebrandt E, Goodfellow M. (Editors), Nucleic Acid Techniques in Bacterial Systematics (Modern Microbiological Methods). XXIX + 329 S., 46 Abb., 28 Tab. Chichester-New York, 1991.
25. Shaharoona B, Arshad M, Zahir Z. Effect of plant growth promoting rhizobacteria containing ACC-deaminase on maize (*Zea mays* L.) growth under axenic conditions and on nodulation in mung bean (*Vigna radiata* L.). Letters in Applied Microbiology. 2006;42(2):155-159.
26. Sharma R, Girish AG, Upadhyaya HD, Humayun P, Babu TK, Rao VP, *et al*. Identification of Blast Resistance in a Core Collection of Foxtail Millet Germplasm. Plant Disease. 2014;98(4):519-524.
27. Siddiqui ZA. (Ed.), PGPR: Biocontrol and Biofertilization. Springer, Dordrecht, 1-38.
28. Van Meeteren M, Tietema A, Van Loon E, Verstraten J. Microbial dynamics and litter decomposition under a changed climate in a Dutch heathland. Applied Soil Ecology. 2008;38(2):119-127.
29. Xie H, Pasternak J, Glick BR. Isolation and Characterization of Mutants of the Plant Growth-Promoting Rhizobacterium Pseudomonas putida GR12-2 That Overproduce Indoleacetic Acid. Current Microbiology. 1996;32(2):67-71.
30. Xu M, Sheng J, Chen L, Men Y, Gan L, Guo S, Shen L. Bacterial community compositions of tomato (*Lycopersicum esculentum* Mill.) seeds and plant growth promoting activity of ACC deaminase producing Bacillus subtilis (HYT-12-1) on tomato seedlings. World Journal of Microbiology and Biotechnology. 2013;30(3):835-845.
31. Yang X, Wan Z, Perry L, Lu H, Wang Q, Zhao C, *et al*. Early millet use in northern China. Proceedings of the National Academy of Sciences. 2012;109(10):3726-3730.
32. Zeffa DM, Perini LJ, Silva MB, De Sousa NV, Scapim CA, Oliveira ALMD, *et al*. Azospirillum brasilense promotes increases in growth and nitrogen use efficiency of maize genotypes. PLOS ONE. 2019;14(4):e021-5332.