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Research Article

Growth Promotion of Rice (*Oryza sativa L.*) Seedlings Using Plant Growth-Promoting Rhizobacteria (PGPR) Isolated from Northwest Ethiopia

Zewdu Teshome Awlachew[1] **and Gebeyehu Yibeltie Mengistie**[2]

[1]*Department of Biology, College of Natural and Computational Sciences, University of Gondar, P. O. Box 196, Gondar, Ethiopia*
[2]*Department of Biology, College of Natural and Computational Sciences, Debark University, P. O. Box 90, Debark, Ethiopia*

Correspondence should be addressed to Zewdu Teshome Awlachew; teshomeawlachew@gmail.com

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Plant growth-promoting rhizobacteria (PGPR) are beneficial soil microorganisms that colonize plant roots and enhance plant growth by a wide variety of mechanisms. In this work, five Bacillus and two Cyanobacteria isolates were successfully isolated and characterized. A pot experiment was conducted to evaluate the effect of PGPR on the growth of three cultivars of rice seedlings. Pots were laid down in a complete random design and 100 ml of spore and Cyanobacteria suspension were poured on the soil surface surrounding each seedling. After 45 days, the seedlings were uprooted and shoot and root parameters were recorded. All the *Bacillus* and Cyanobacteria isolates showed positive effects on the growth of rice seedlings as compared to control; however, their effectiveness varies from isolate to isolate and also from cultivar to cultivar. Bacterial isolates B3 and B5 showed the highest mean value and statistically significant difference ($P < 0.05$) in most of the root and shoot parameters of cultivars Jegna and Getachew, respectively, as compared to other bacterial isolates. Both cyanobacterial isolates showed the highest and statistically significant difference ($P < 0.01$) in almost all the above ground and underground growth parameters compared to other bacterial isolates in all the three cultivars of rice. Similarly, C2 and C1 recorded the highest growth promotion efficacy of shoot and root length (50.07% and 78.27%) on Edget and Getachew cultivars, respectively. Hence, the present study suggests that the use of PGPR isolates such as B3, B5, C1, and C2 as inoculant biofertilizers might be beneficial for rice cultivation as they enhanced the growth of rice seedlings.

1. Introduction

Agriculture is one of the human activities that contributes most to the increasing amount of chemical pollutants through excessive use of synthetic chemical fertilizers and pesticides, which leads to environmental damage with potential risks to human health. In order to feed the ever-growing human population, sustainable agriculture is very important.

Ethiopia is endowed with a broad diversity of climates suitable for successful growth of most types of temperate and tropical crops. However, the country is suffering with food insecurity and famine due to climatic variability and the poor performance of the agricultural sector. The importance of rice crops *(Oryza sativa* L.) in the Ethiopian agriculture is increasing from time to time [1]. However, an increasing trend of importing rice is practicing which proved that demand of rice is quite higher than the domestic production [2].

Rice is the most important staple food in several developing countries [3, 4]. There is an increasing trend in area coverage and volume of production of rice in Ethiopia [2]. However, the mean national rice productivity (2.8 t/ha) of Ethiopia is quite low compared to the global average productivity (4.4 t/ha) even though 6 tones ha-1 has been reported on research fields [5] which calls for the concerted effort in increasing the productivity. Rice ranked second after maize in terms of productivity among cereals, which proved as it will play a significant role for food security in Ethiopia [6].

Towards a sustainable agricultural vision, crops production needs to be ready with disease resistance, salt tolerance, drought tolerance, heavy metal stress tolerance, and better nutritional value. To fulfill the above preferred crop properties, one possibility is to use soil microorganisms (bacteria, fungi, algae, etc.) that increase the nutrient uptake capacity and water use efficiency of plants [7]. Microorganisms are important for agriculture in order to promote the circulation of plant nutrients and reduce the need for chemical fertilizers.

The high-yielding rice variety has resulted in an increase in rice production but requires large amounts of chemical fertilizers, leading to health hazards and environmental pollution. In order to make rice cultivation sustainable and less dependent on chemical fertilizers, it is important to know how to use plant growth-promoting rhizobacteria (PGPR) that can biologically fix nitrogen and solubilize phosphorus that can contribute to the improvement of rice growth. Recently, there has been a growing interest in the application of PGPR due to their efficacy in different beneficial characteristics such as biological control and growth promoting agents in many crops [8].

PGPR exert a beneficial effect upon plant growth [9]. Among these, PGPR benefit plants in several ways such as nitrogen fixation, potassium and phosphate solubilization, production of plant growth regulators, siderophore production, hydrolyzing enzymes production, biocontrol agents against pests, and diseases by inducing plant systemic resistance [10].

PGPR have been reported in rice [11]. According to the report of Aw et al. [12]; PGPR in rice increased the grain yield up to 51.3% and 9.16% in greenhouse and paddy fields, respectively, in arsenic accumulated soil of China. Mixed PGPR microbial inoculant significantly promoted plant and root growth, tiller numbers, plant dry weight, and nutrient accumulations than uninoculated control in rice [13]. García de Salamone et al. [14] reported the increase of root length, shoot length, aerial biomass, and nutrient uptake of rice genotypes in response to the PGPR application. Rice plants inoculated with the bacterial isolates recorded an improved plant growth and higher photosynthetic capacity signified by the higher chlorophyll content [14]. Sousa et al. [15] also reported the potential role of actinomycetes because of their significant ecological roles in nutrient cycling and plant growth promotion.

Various other research reports have been published on the growth promotion of PGPR strains in a variety of crops. An increase in the root and shoot length, fresh weight, dry weight, and nutrient uptake has been reported in lentil [16] and cowpea [17]. Utilization of Cyanobacteria as biofertilizers has been reported by several researchers. The reports of various studies revealed an increase of up to 19.5% in rice crop yields [18].

Different crops growing in different agroclimatic regions and soil types may have different effective PGPR strains. Therefore, it is necessary to cultivate region-specific PGPR strains for the development of suitable bio-inoculum to obtain maximum yield and nutrient content of a specific crop. The utility of PGPR as inoculant biofertilizers of rice in Ethiopia is not well understood. Data on the effect of Cyanobacteria for the growth of rice in Ethiopia are also inadequate. Therefore, the present study was undertaken to screen PGPR strains that are compatible with rice genotypes in enhancing the growth of rice seedlings in Northwest Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. The laboratory experiment was done at the Microbiology laboratory of Department of Biology, University of Gondar, Ethiopia, while the field experiment was conducted at Shinta Research site of the University. Gondar is located in the north western Ethiopia at a latitude of 12° 36′ N and longitude of 37° 28′ E with an elevation of 2133 meter above sea level. According to the CSA [19] report, Gondar has 20°C average temperature and 1800 mm rain fall and the warmest average maximum temperature is 29°c in March and May.

2.2. Study Design. The study design was a randomized, purposeful, and laboratory-based experiment.

2.3. Sampling and Sample Collection Method. The soil sample used for Cyanobacteria isolation was collected from three different sites around Gondar by a sterilized spatula and transferred to a wide mouth sterilized bottle. The sediment sample used for bacterial isolation was collected from three different sites of Lake Tana. Lake Tana is the largest lake in Ethiopia and is the source of the Blue Nile with an average elevation of 1911 meters above sea level. All the sediment samples were collected with the help of sterilized polyethylene bags, labeled and transported to the microbiology laboratory, and stored at 4°C for further studies. Different rice genotype seeds were obtained from the Woreta Rice Research Center. The seedlings of rice were prepared at Shinta field experiment station.

2.4. Isolation, Characterization, and Identification of Bacillus Species. Physical pretreatment methods were applied to the sediment samples through air and heat drying to facilitate the isolation of *Bacillus* species. *Bacillus* species were isolated through serial dilution followed by spread plates and streak plates for purification from physically pretreated sediments. The purified colonies were characterized morphologically (colony color, form, margin, and elevation); microscopically (endospore formation and shape); and biochemically and physiologically (Gram reaction, indole test, catalase test, MRVP test, TSI test, citrate utilization, and hydrolysis of starch, gelatin, casein, and urea, growing at various NaCl concentrations and temperatures) [20]. Bergey's manual of determinative bacteriology was used as a guide to identify the isolates.

2.5. Cyanobacteria Isolation and Characterization. Serial dilution was performed by taking 1gm of soil sample.

From the suspension, 0.1 ml was spread on BG11 medium [21] containing cyclohexamide (100 μg/ml) and incubated at $25 \pm 2^{\circ}$C for 7 days for the isolation of Cyanobacteria aseptically. After purification, the colonies were characterized morphologically and stored at 4°C for further use.

2.6. Inoculum Preparation and Pot Experiment. The experiment was performed in 2018 from March to June at the University of Gondar, Biology Department. To prepare the inoculum, a purified single *Bacillus* colony was transferred to a 100 ml flask containing 25 ml of nutrient broth and grown aerobically at 30°C for 24 hours. Similarly, a single filament of Cyanobacteria was transferred to 100 ml flasks containing 25 ml of BG11 and grown aerobically in the flasks. Then, the bacterial and cyanobacterial suspensions were diluted in sterile distilled water before being inoculated into the seedling.

Pot experiments in laboratory were conducted to evaluate the effect of Cyanobacteria and Bacillus species on rice seedlings. Healthy seeds of rice were selected and sown on the prepared soil. The selected seedlings were dipped three times into sterile water to remove the attached soil and dipped into bacterial spore suspensions and cyanobacterial filament suspension or distilled water (control) for 30 minutes immediately before transferring to the prepared pot, and each pot received three seedlings [22]. The experiment was carried out in sterilized pots (20 cm diam.) containing sterilized soil. Pot and soil sterilization was performed by 5% formalin solution. Three replications were used for each treatment in a CRD manner. For each treatment, 100 ml of a spore suspension and Cyanobacteria suspension at the same concentration as the one used to treat seedlings were poured on the soil surface surrounding each seedling. Pots were observed regularly and watered up to field capacity for 45 days. After 45 days, the seedlings were uprooted, and shoot and root fresh and dry weights and root and shoot lengths were measured and recorded. Efficacy test was applied to determine the effectiveness of each isolate from each variety on each growth parameter by the following formula:

$$\text{Efficacy} = \text{treated} - \text{control/treated} \times 100\%. \quad (1)$$

2.7. Root to Shoot Ratio. The root to shoot ratio was calculated by dividing dry weight of root biomass to the dry weight of shoot biomass according to Rogers et al., [23].

2.8. Data Analysis. The collected data were statistically analyzed by using SPSS 20 software version and one-way ANOVA. The effect of isolated *Bacillus* strains on growth promotion effect was compared using the least significant difference (LSD) at a 5% probability level ($P \leq 0.05$).

3. Results and Discussion

3.1. Colony Characteristics of Bacillus Isolates. Based on the results of morphological, biochemical, endospore forming property and Bergey's manual of systematic bacteriology the isolated species were classified as *Bacillus*. Five distinct *Bacillus* colonies with different growth characteristics were successfully isolated from sediment samples of Lake Tana and were represented as B1, B2, B3, B4, and B5, where "B" stands for *Bacillus* (Table 1). Similarly, 2 cyanobacterial species were isolated from the samples collected around Gondar.

3.2. Physiological and Biochemical Characteristics of Bacillus Isolates. Biochemical characteristics result indicated that all the isolates produced catalase. Bacillus isolates B1, B2, and B5 had the capacity to produce H_2S gas and acid while Bacillus isolates B2, B3, and B4 utilized citrate as a carbon source (Table 2). It was revealed that all the isolates hydrolyzed casein except B5. Isolates B1 and B4 were able to hydrolyze starch while gelatin hydrolysis was observed in all species except B2 (Table 2). The isolates showed growth at varying temperatures (20–55°C). Only B3 was able to grow at 20°C (low temperature) while B1 was tolerant to 45 and 55°C (high temperature). All the isolates except B3 were able to grow at 5% sodium chloride, whereas only B3 was resistant to 10% sodium chloride (Table 2).

3.3. Isolation of Cyanobacteria. From the soil sample used to isolate cyanobacterial strains on a nitrogen-free medium (BG11), two types of colonies were obtained and purified through the streak plate method. Isolates were designated as C1 and C2, where "C" stands for cyanobacteria. The isolates were identified based on morphological and microscopic observation (Table 3).

3.4. The Effect of Bacillus and Cyanobacteria on the Growth of Rice Seedlings. In the pot experiment of rice plants, comparison of control and treatment plants with one-way ANOVA showed that treatment groups have significant difference in shoot length, shoot fresh and dry weight, root length as well as fresh and dry weight of root as compared to control. Similarly, the effects of different *Bacillus* and *Cyanobacteria* isolates are not the same in different rice cultivars. Among the five *Bacillus* isolates, B3 showed the highest shoot length, shoot fresh weight, shoot dry weight, root length, root fresh weight, and root dry weight with Cv. X-jegna at $P < 0.05$level of significance difference while B5 isolate did not show a statistically significant effect on vegetative characters of Cv. X-jegna (Table 4). Also, it was showed that among all treatments, C2 showed the highest mean value in all growth parameters. Root traits are important for the competitive ability of the crops in utilizing soil resources and water uptake; hence, cyanobacterial isolates C1 and C2 showed a higher root to shoot ratio in all the three cultivars (Tables 4–6). In rice, for instance, greater root growth contributed to improved competitive ability

Table 1: Morphological and microscopic results of *Bacillus* isolates.

Colony character	*Bacillus species*				
	B1	B2	B3	B4	B5
Color	White	White	White	White	White
Form	Circular	Circular	Circular	Irregular	Circular
Elevation	Convex	Convex	Flat	Flat	Flat
Margin	Entire	Entire	Entire	Lobate	Entire
Endospores	+	+	+	+	+
Shape	Rod	Rod	Rod	Rod	Rod

Table 2: Physiological and biochemical characteristics of *Bacillus* isolates recovered from Lake Tana sediment samples.

Biochemical and physiological tests	*Bacillus isolates*				
	B1	B2	B3	B4	B5
Gram RXN	+	+	+	+	+
Catalase test	+	+	+	+	+
Casein hydrolysis	+	+	+	+	−
Citrate utilization	−	+	+	+	−
VP test	−	−	+	−	−
MR test	+	−	−	+	+
Indole test	+	+	−	−	+
H_2S production	+	+	−	−	+
Glucose (acid)	+	+	−	+	+
Glucose (gas)	+	−	−	−	+
Urea hydrolysis	+	−	+	+	−
Starch hydrolysis	+	−	−	+	−
Gelatin hydrolysis	+	−	+	+	+
Resistance to 5% NaCl	+	+	−	+	+
Resistance to 7% NaCl	+	+	−	+	−
Resistance to 10% NaCl	+	−	−	−	−
Growth at 20°C	−	−	+	−	−
Growth at 30°C	+	+	+	+	+
Growth at 37°C	+	+	+	+	+
Growth at 45°C	+	−	−	−	−
Growth at 55°C	+	−	—	−	−

Note. + growth,—no growth.

Table 3: Colony morphology of cyanobacteria isolates.

Morphology of the isolate	*Cyanobacterial isolates*	
	C1	C2
Colonial vs filamentous	Coiled filament	Colonial
Color	Greenish	Greenish
Margin	Entire	Entire
Form	Unbranched filament	Circular
Gram reaction	—	—
Shape	Spherical bed like	Cylinderical

[24]. Mengistie and Awlachew [25] also reported that tomato (*Solanum lycopersicum*) seedlings growth was significantly increased due to *Bacillus* species.

Isolate B3 showed a higher mean value on most vegetative and root growth characteristics of Cv. Edget as compared to other bacterial isolates; however, it was not statistically different with other bacterial isolates (Table 5). Among cyanobacterial isolates, C2 showed a higher mean value on both underground and aboveground parameters. The vegetative growth parameters of both *Cyanobacteria* isolates showed highly statistically significant difference ($P < 0.01$) compared with all bacterial isolates (Table 5).

Among the five *Bacillus* isolates, B5 showed a statistically significant difference ($P < 0.05$) in almost all the root and shoot parameters of Cv. Getachew as compared to the other bacterial isolates. *Cyanobacteria* isolate C2 showed higher mean value of both root and shoot characteristics as compared to all other treatments of bacterial and cyanobacterial isolates with a highly statistically significant difference of the control ($P < 0.01$) (Table 6).

Table 4: The effect of *Bacillus* and cyanobacteria isolates on the growth of Rice Cv. X-jegna seedlings.

Treatment	*Upper ground growth parameter*			*Underground growth parameter*			RSR
	Shoot length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root length (cm)	Root fresh weight (g)	Root dry weight (g)	
B1	46.0 ± 1.15 b*	6.00 ± 0.11 b*	4.21 ± 0.12 b*	21.33 ± 0.3 b*	2.8 ± 0.06 b*	1.80 ± 00b*	0.42
B2	40.6 ± 0.66 b*	4.9 ± 0.05 b*	3.46 ± 0.13 b*	17.3 ± 0.32c*	2.53 ± 0.01 b*	1.50 ± 0.05c*	0.433
B3	52.3 ± 1.20a*	7.10 ± 0.05a*	5.1 ± 0.05a**	24.6 ± 0.33 b*	3.13 ± 0.03a*	1.95 ± 0.02 b*	0.38
B4	50.3 ± 0.33a*	6.23 ± 0.28 b*	4.08 ± 0.08 b*	21.6 ± 0.88 b*	2.89 ± 0.05 b*	1.92 ± 0.02 b*	0.47
B5	38.0 ± 2.30 ns	4.00 ± 0.11 ns	2.7 ± 0.04 ns	14.6 ± 0.33 ns	1.0 ± 0.10 ns	0.54 ± 0.11 ns	0.2
C1	57.0 ± 0.6a**	7.50 ± 0.1a**	5.56 ± 0.1a**	27.0 ± 0.57a*	4.50 ± 0.05a*	2.79 ± 0.05a*	0.50
C2	58.0 ± 0.6a**	7.53 ± 0.0a**	5.56 ± 0.1a**	28.3 ± 0.7a**	4.80 ± 0.1a**	3.06 ± 0.0a**	0.6
Cont.	36.0 ± 4.00	3.65 ± 0.05	2.65 ± 0.05	14.5 ± 0.50	0.95 ± 0.05	0.43 ± 0.06	0.16
LSD at 0.05	3.21	2.19	3	3.12	0.98	1.2	—

Values are mean ± Standard error of three replications, *indicates statistically significant at $p < 0.05$ with control, ** indicates statistically significant at $p < 0.01$ (highly significant deference with control), ns indicates not statistically significant. Means in each column followed by the same letter are not significantly different at $p < 0.05$ according to Fisher's LSD, RSR = Root to shoot ratio (Root dry weight divided by shoot dry weight).

Table 5: The effect of *Bacillus* and Cyanobacteria on the growth of Rice Cv. Edget seedlings.

Treatment	*Upper ground growth parameter*			*Underground growth parameter*			RSR
	Shoot length (cm)	Shoot fresh weight(g)	Shoot dry weight(g)	Root length (cm)	Root fresh weight(g)	Root dry weight(g)	
B1	40.0 ± 1.00 b*	5.33 ± 0.24 b*	3.6 ± 0.11 b*	1 7.3 ± 0.66 c*	1.96 ± 0.03 b*	1.40 ± 0.11 b*	0.38
B2	48.3 ± 1.2 b*	5.73 ± 0.14 b*	3.95 ± 0.02 b*	2 1.3 ± 0.33 b*	2.66 ± 0.14 b*	1.73 ± 0.03 b*	0.43
B3	49.6 ± 0.33 b*	6.32 ± 0.33 b*	4.46 ± 0.37 b*	2 1.3 ± 0.66 b*	. 2.86 ± 0.03 b*	1.76 ± 0.03 b*	0.39
B4	34.0 ± 1.15 ns	4.33 ± 0.08 ns	2.10 ± 0.05 ns	1 4.6 ± 0.33 ns	1.60 ± 0.05 ns	0.9 ± 0.05 ns	0.42
B5	41.0 ± 0.57 b*	5.40 ± 0.11 b*	3.30 ± 0.15 b*	16.6 ± 0.33c*	1.90 ± 0.05 c*	0.90 ± 00 ns	0.27
C1	58.3 ± 1.45a**	7.53 ± 0.08a**	6.10 ± 0.06a**	28.6 ± 0.33a*	4.10 ± 0.20 a*	2.69 ± 0.04a*	0.44
C2	63.3 ± 0.33a**	7.93 ± 0.03a**	6.41 ± 0.04a**	31.0 ± 1.2a**	4.6 ± 0.03a**	3.00 ± 0.1a**	0.46
Cont.	31.6 ± 0.88	4.0 ± 0.10	2.03 ± 0.04	3.6 ± 0.88	1.43 ± 0.03	0.399	0.40
LSD at 0.05	3.8	3.12	0.7	0.57	0.64	0.54	—

Values are mean ± Standard error of three replications, *indicates statistically significant at $p < 0.05$ with control, **indicates statistically significant at $p < 0.01$ (highly significant deference with control), ns indicates not statistically significant, Means in each column followed by the same letter are not significantly different at $p < 0.05$ according to Fisher's LSD, RSR = Root to shoot ratio (Root dry weight divided by shoot dry weight).

Table 6: The effect of *Bacillus* and Cyanobacteria on the growth of Rice Cv. Getachew seedlings.

Treatment	*Upper ground growth parameter*			*Underground growth parameter*			RSR
	Shoot length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root length (cm)	Root fresh weight (g)	Root dry Weight (g)	
B1	38.66 ± 0.3 ns	4.8 ± 0.1 ns	3.00 ± 0.1 ns	16.6 ± 0.3 ns	1.80 ± 0.1 ns	1.07 ± 0.03 ns	0.35
B2	50.0 ± 0.6 b*	5.60 ± 0.6 b*	3.73 ± 0.1 b*	24.0 ± 0.6 b*	3.00 ± 0.1 b*	1.96 ± 0.03 b*	0.52
B3	53.3 ± 0.7 b*	5.80 ± 0.1 b*	3.76 ± 0.1 b*	25.0 ± 0.6 b*	3.13 ± 0.1 b*	2.10 ± 0.05 b*	0.55
B4	54.3 ± 0.9 b*	5.50 ± 0.1 b*	3.73 ± 0.1 b*	25.0 ± 0.6 b*	3.03 ± 0.0 b*	2.16 ± 0.08 b*	0.57
B5	43.0 ± 0.6c*	5.13 ± 0.1 b*	3.03 ± 0.0 ns	20.0 ± 0.6c*	2.10 ± 0.1c*	1.48 ± 0.06c*	0.48
C1	63.3 ± 4.6a**	7.66 ± 0.3a*	5.22 ± 0.2a*	29.0 ± 1.2a*	5.2 ± 0.2a*	4.06 ± 0.17a**	0.77
C2	63.3 ± 0.7a**	9.40 ± 0.2a**	6.20 ± 0.12a**	32.0 ± 0.6a**	6.0 ± 0.1a**	4.73 ± 0.06a**	0.76
Cont.	38.6 ± 0.9	4.8 ± 0.10	2.89 ± 0.0	16.3 ± 0.3	1.75 ± 0.1	1.00 ± 0.00	0.34
LSD at 0.05	4.01	3.1	0.9	4.06	3.1	0.98	

Values are mean ± Standard error of three replications, *indicates statistically significant at $p < 0.05$ with control, **indicates statistically significant at $p < 0.01$ (highly significant deference with control), ns indicates not statistically significant, Means in each column followed by the same letter are not significantly different at $p < 0.05$ according to Fisher's LSD, RSR = Root to shoot ratio (Root dry weight divided by shoot dry weight).

3.5. Efficacy of Bacillus and Cyanobacteria on Growth Promotion of Rice Seedlings. The highest (50.07%) and the lowest (0.15%) shoot length enhancement were recorded on rice cultivars Edget and Getachew treated with C2 and B1 isolates, respectively. Similarly, the highest (78.27%) and lowest (0.68%) root length enhancement was recorded on rice cultivars Getachew and X-jegna treated with C1 and B5 isolates, respectively (Figure 1, Table 7).

In general, all the bacterial isolates used in this study improved the growth parameter of rice seedlings as compared to the control; however, the Cyanobacteria isolates showed better enhancement (Table 7).

Figure 1: Growth of rice seedlings on the pot experiment.

Table 7: Percentage growth promotion of *Bacillus* and Cyanobacteria isolates on rice seedlings as compared to control.

Treatment	*Rice cultivars*					
	Cv. X-jegna		*Cv. Edget*		*Cv. Getachew*	
	Shoot length (%)	Root length (%)	Shoot length (%)	Root length (%)	Shoot length (%)	Root length (%)
B1	21.73	32.02	21	21.38	0.15	1.80
B2	11.33	16.18	34	36.18	22.8	32.08
B3	31.16	41.05	36.29	36.18	27.57	34.8
B4	28.42	32.03	7.05	6.84	28.91	34.8
B5	5.26	0.68	22.02	18.07	10.23	18.5
C1	36.84	46.29	45.79	52.44	39.04	78.27
C2 Control	37.93	50.53	50.07	52.9	39.02	61.57

Soil microorganisms are known for enhancing growth plants through the circulation of plant nutrients and reduce for the need of chemical fertilizers. Among these, *Bacillus* is known for its plant growth-promoting (PGP) properties by exerting a beneficial effect upon plant growth [9]. Our results indicated that differences in the PGPR properties of the individual isolates made wide-ranging their effectiveness in deferent cultivars. This result was in agreement with the report of references [26,27] who reported that different effectiveness of different isolates was due to the variety of plant growth enhancing mechanisms. According to the report of Aw et al. [12]; PGPRs in rice increased grain yield up to 51.3% and 9.16% in greenhouse and paddy fields respectively.

Our study revealed that significant improvement on shoot length, shoot fresh and dry weights, root length, root fresh, and dry weights was observed in all rice cultivars due to *Bacillus* and *Cyanobacteria* inoculation as compared to control or untreated seedlings. This result is in agreement with the study done by the authors of [28] who reported that plant growth promoting bacteria inoculation on germination and seedling increased vigor of lowland rice and this could be attributed to the production of IAA resulting in longer roots with increased number of root hairs and root laterals by increasing uptake of water [7]. Abd EI-Mageed et al [29] reported that inoculation of *Bacillus* PGPR positively affected growth (i.e., shoot length and shoot dry weight) and nitrogen contents of rice crop. Moreover, the addition of PGPR for rice growth promotion increases micronutrient intake of the plant [30]. Similarly, Wang et al. [31] revealed that utilization of *Cyanobacteria* resulted in an increase of 66% and 58% in the length of roots and weight of leaves of rice, respectively.

4. Conclusion and Recommendation

The present study investigated the effectiveness of PGPR isolates whether they could increase the growth of rice seedlings. Almost all of the isolates significantly increased shoot length, shoot fresh weight, shoot dry weight, root length, root fresh weight, and root dry weight of rice seedlings. Of the seven isolates, three isolates (B3, B5, C1 and C2) showed better performances in growth of all the three cultivars of rice seedlings. For sustainable rice cultivation, the use of PGPR as inoculant biofertilizers is a cost effective way to replace chemical fertilizers which cause adverse effect on the environment. A detailed study of the mechanisms used by PGPR to promote growth together with molecular identification of the isolates is important. In addition, further investigations on the role of PGPR as biofertilizers that have good impacts on plant growth and development are needed, including efficiency tests in greenhouse and field conditions.

Data Availability

The data used to support the findings of this study will be provided upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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