



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(8): 191-197
Received: 14-05-2026
Accepted: 18-06-2026

The authors' details and affiliations
are provided below, following the
reference section

Isolation and characterization of plant growth- promoting rhizobacteria from the rhizosphere of common bean (*Phaseolus vulgaris* L.) in high-altitude regions of Kashmir

Seema Nargis, Mushtaq Ahmad Malik, Malik Asif Aziz, Zaffar Mahdi Dar,
Khalid Hussain Bhat, Showkat Maqbool, AA Saad, Zohra Shabir, MM
Rifana Ajam, Raaqib Rasool Parray and Gousia Gani

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i8c.6222>

Abstract

Common bean (*Phaseolus vulgaris* L.) is one of the most important grain legumes worldwide owing to its high nutritional value, protein content and ability to establish symbiotic associations with beneficial soil microorganisms. As a major pulse crop, it contributes significantly to food security and sustainable agriculture through biological nitrogen fixation, thereby reducing dependence on synthetic fertilizers. However, excessive use of chemical fertilizers adversely affects soil health, beneficial microorganisms and the environment, highlighting the need for eco-friendly alternatives. Plant growth-promoting rhizobacteria (PGPR) inhabiting the rhizosphere play a pivotal role in enhancing plant growth, improving nutrient availability and protecting plants against pathogens. These beneficial microorganisms promote plant growth through both direct mechanisms, including biological nitrogen fixation, phosphate solubilization, production of indole-3-acetic acid (IAA) and enhanced nutrient uptake and indirect mechanisms such as hydrogen cyanide (HCN) production, competition for nutrients and ecological niches, induction of systemic resistance and antagonism against phytopathogens. In legumes, root-secreted flavonoids facilitate symbiotic interactions with rhizobia and other beneficial microorganisms, resulting in improved root development, nodulation and nutrient acquisition. Bacterial IAA stimulates root elongation and branching, thereby increasing the root surface area available for nutrient absorption, while phosphate-solubilizing bacteria convert insoluble phosphorus into forms readily available to plants. In this work, we collected soil samples from the common bean rhizosphere in the high altitude locations of the Kupwara district of Kashmir Valley. A total of 30 PGPR-producing bacteria were isolated and tested for several PGPR activities, including HCN, IAA and phosphorus solubilization. These multifunctional characteristics make PGPR effective biofertilizers and biocontrol agents capable of enhancing crop productivity while maintaining soil fertility. Therefore, the exploitation of rhizosphere-competent PGPR represents a sustainable and environmentally friendly strategy for improving common bean production and reducing reliance on chemical inputs in modern agriculture.

Keywords: Common bean, PGPR, HCN, IAA, phosphate solubilization

1. Introduction

The common bean (*Phaseolus vulgaris* L.) is one of the world's most consumed leguminous crops (Castro Guerrero *et al.*, 2016) [7]. In Latin America, it is the main staple food in people's diet because of its high nutritional quality (Torres *et al.*, 2017) [23], with a protein range of ~16%-33% depending on different landraces (Luna-Vital *et al.*, 2015) [16]. As a legume, it is connected with microbes that fix nitrogen. It minimizes the usage of synthetic fertilizers, which is crucial for sustainable agriculture. Common beans originated in Mexico, Central America and South America and were domesticated approximately 8,000 years ago. This has resulted in adaptation to Mediterranean conditions in two key gene pools, Mesoamerican and Andean (Castro-Guerrero *et al.*, 2016) [7]. Common bean (*Phaseolus vulgaris* L.) is a significant pulse crop in the Fabaceae family that has grown in favor among Indian farmers because to its high profitability, short growth cycle and adaptability to a wide range of agroclimatic conditions. As a result, increasing output appears to be one of the options for meeting the demand for this pulse crop, which can be

Corresponding Author:
Gousia Gani
Division of Basic Sciences and
Humanities, Faculty of
Agriculture, Sher-e-Kashmir
University of Agricultural Sciences
and Technology of Kashmir,
Wadura, Sopore, Jammu and
Kashmir, India

accomplished either by the use of chemical fertilizers or the application of rhizosphere competent plant growth boosting bacteria. However, the usage of chemical fertilizers is not environmentally beneficial because it harms microorganisms, plants and soil. Microorganisms play an important role in agriculture by increasing the supply of plant nutrients and reducing the need of chemical fertilizers. Biofertilizers based on microorganisms could be a highly effective microbial stimulant in agriculture due to their various plant development activities (Joseph and Lawrence, 2007) [14]. The rhizosphere is a unique location inhabited by numerous microorganisms capable of influencing plant growth. These favorable plant-microbe interactions in the rhizosphere can improve soil fertility (Dastager *et al* 2011) [9]. Microbial community-plant root interactions are complicated, allowing plants to absorb nutrients from the soil via a variety of methods. However, in the rhizosphere, just 1% to 2% of bacteria can boost plant development (Antoun *et al* 2001) [3]. Plant growth boosting rhizobacteria are bacteria that inhabit the rhizosphere and encourage plant development, either directly or indirectly. Root secreted flavonoids are important signals for legume-rhizobial and legume-mycorrhizal interactions and their establishment. Rhizobia, along with other PGPRs, colonize legume roots and can directly boost plant growth by influencing the host's physiological and biochemical properties. Bacteria are common microbes in the rhizosphere, and many of them have PGPRs, which promote plant growth. Their method of action involves the synthesis of indole-3-acetic acid (IAA), soil phosphorus solubilization and nutrient delivery. Various soil microorganisms create naturally occurring auxins, including indole-3-acetic acid (IAA), as a direct mechanism for promoting plant development (Spaepen and Vanderleyden 2011) [22]. IAA specifically affects plant growth promotion and root nodulation. Bacterial IAA improves root surface area and length, giving the plant better access to soil nutrients. Furthermore, bacterial IAA loosens plant cell walls, allowing for greater root exudation, which supplies additional nutrients to encourage the proliferation of beneficial rhizosphere bacteria (Glick, B.R.2012) [12]. Phosphate solubilizing bacteria (PSB) are known to solubilize phosphate in soil by acidity, chelation, or enzymatic processing, as well as motility or adhesion of bacteria in the root, all of which aid in legume-Rhizobium symbiosis. PGPR can also be used as biocontrol agents against plant diseases, either by stimulating the plant's natural defensive systems, antagonism, or antibiosis (El kinany S *et al.*, 2017) [11]. This is achieved through a variety of methods, including the formation of hydrogen cyanide (HCN) (Goswami D *et al* 2015) [13] and direct competition for nutrients and space inside the rhizosphere (Laslo É *et al* 2010) [15].

2. Materials and Methods

2.1 Soil Sample Collection

The common bean rhizosphere soil samples were gathered from a healthy common bean field in Kupwara, Kashmir. Bacterial strains were isolated from either the rhizoplane or the roots of healthy common bean plants. The rhizosphere soil samples were immediately taken to the laboratory and stored at 4 °C for future isolation and species diversity studies.

2.2 Isolation of Bacteria from Soil Samples

The microflora were isolated from the collected common bean rhizospheric soil using King's B media and the serial dilution

process and then cultured for 24 hours at 28 °C until bacterial colonies formed. Individual colonies were selected for further purification and streaked on King's B plates.

2.3 Characterization of isolates

Pure culture generated thirty rhizobacterial isolates, which were identified as KB1, KB2, KB3, KB4, KB5, KB6, KB7, KB8, KB9, KB10, KB11, KB12, KB13, KB14, KB15, KB16, KB19, KB20, KB21, KB22, KB23, KB24, KB25, KB26, KB27, KB29, and KB30. The morphological properties of each isolated colony were investigated using King's B plates. Following three days of incubation, numerous colony features were detected, including size, shape, color, elevation, and the presence and location of endospores. Each rhizobacterial isolate was biochemically characterized using Gram's reaction (Dubey and Maheshwari 2006) [10].

2.4 Indole Acetic Acid (IAA) Determination

According to Brick *et al.*, (1991) [5], indole acetic acid production was discovered. A loopful of each isolated culture was mixed with 20 milliliters of Luria Bertani (LB) broth (tryptone 10 g, yeast extract 5.0 g, NaCl 10 g, distilled water 1 lit., pH 7.0), which contained 0.2% L-tryptophan. The broth was then cultured for 24 hours on a rotary shaker at 28°C before being centrifuged for 15 minutes at 10, 000 rpm. Salkowski's reagent (100 ml 35% perchloric acid and 2 ml freshly prepared 0.5 M FeCl₂ solution) was mixed with 2 ml of supernatant and 2-3 drops of o-phosphoric acid. The sample was then incubated at room temperature for 30 minutes in the dark. The appearance of a pink colour indicated the formation of IAA. On a different day, the quantitative analytical method was utilized to quantify IAA generation. The samples were examined with varied amounts of tryptone in nutritious broth, and absorbance at 530 nm was measured using a visible spectrophotometer. The spectrophotometry results were used to produce a standard IAA solution curve that illustrated the relationship between the standard IAA solution and its absorbance.

2.5 Assay for Phosphate Solubilization

The method of (Pikovskaya, 1948) was employed to detect phosphate solubilization. Bacterial isolates were grown on Pikovskaya's agar (HIMEDIA) plates for 2–3 days at 28 ± 2 °C. Following that, the plates were examined for the creation of halo zones around the colonies.

$$\text{Solubilization Efficiency} = \frac{\text{Solubilization diameter}}{\text{Growth diameter}} \times 100$$

2.6 Hydrogen Cyanide.

According to Cappuccino and Sherman (1992) [6], each bacterial isolate underwent a qualitative ammonia production test. Nutrient broth was used to quantify ammonia generation over a 24-hour period at 30 degrees Celsius and 150 rpm. Nutrient broth supernatants devoid of cells were supplied with 5% Nessler's reagent, whereas nutrient broth that had not been inoculated served as the control. For positive isolates, the supernatant color shifted from pale to deep yellow. The ammonium sulfate standard curve with concentrations ranging from 0 to 100 mM was used to cultivate the quantity of ammonia produced, and absorbance was measured at 425 nm (Chrouqi *et al.*, 2017) [8].

Table 1: Morphological characterization of PGPR (*Pseudomonas*) isolates from Common bean rhizosphere

S. No.	Isolates	colony morphology	Shapes	Size	Endospore	Grams Rxn
1	KB-1	Raised, Non gummy, yellow	Round	Medium	Absent	-ve
2	KB-2	Raised, light yellow	Round	Small	Absent	-ve
3	KB-3	Raised, nongummyentire, transparent, yellow	Round	Medium	Absent	-ve
4	KB-4	Raised, smoothshiny, yellowish	Round	Medim	Absent	-ve
5	KB-5	Raised, Nongummy, light yellow	Irregular	small	Absent	+ve
6	KB-6	Raisedsmooth shiny, yellowish, orderless	Round	small	Terminal	-ve
7	KB-7	Raised, flat, Brown, ordeless transparent	Irregular	Small	Absent	-ve
8	KB-8	Flat, entire, transparent, creamy	Rod	small	Central	+ve
9	KB-9	Raised, shineysmooth, transparent, offwhite	Circular	Small	Absent	-ve
10	KB-10	Rhizoid, Gummy, offwhite	Irregular	Medium	Absent	-ve
11	KB-11	Raised, shineysmooth, transparent, yellow	Round	small	Absent	-ve
12	KB-12	Flat, entire, transparent, creamy	Irregular	Small	Absent	-ve
13	KB-13	Nongummy.Raised, transparent, yellow	Round	Small	Absent	-ve
14	KB-14	Raised, entire, transparent, yellowish	Rod	Medium	Central	+ve
15	KB-15	Flat, transparent, yellowish	Circular	Medium	Absent	-ve
16	KB-16	Raised, entire, transperant, offwhite	Rod	Small	Absent	-ve
17	KB-17	Raised, transparent, light yellow	Round	medium	Absent	-ve
18	KB-18	flat, entire, transparent, creamy	Rod	Small	Central	-ve
19	KB-19	Raised, non gummy, transparent, yellowish	Round	Small	Absent	-ve
20	KB-20	Flat, entire, transparent, creamy	Irregular	Medium	Terminal	-ve
21	KB-21	Raised, entire, transparent, lightyellow	Round	Small	Central	+ve
22	KB-22	Flat, gummy, transparent, yellowish	Irregular	Medium	Terminal	-ve
23	KB-23	Flat, entire, transparent, offwhite	ROD	Small	Terminal	-ve
24	KB-24	Raised, entire, transparent, yellowish	Rod	Medium	Central	+ve
25	KB-25	Flat, entire, transparent, Lightyellow	Round	Small	Absent	-ve
26	KB-26	Raised, entire, transparent, greenish	Irregular	Small	Absent	-ve
27	KB-27	Flat, entire, transparent, light yellow	Round	Small	Central	+ve
28	KB-28	Raised, entire, transparent, offwhite	Irregular	Medium	Absent	-ve
29	KB-29	Flat, transparent, nongummy, cremish	Rod	Small	Absent	-ve
30	KB-30	Raised, entire, transparent, yellowish	Rod	Medium	Terminal	-ve

Table 2: Biochemical characterization of PGPR (*Pseudomonas*) isolates from common bean rhizosphere

S. No.	Isolates	CUT	OT	CT	MR
1	KB-1	+	+	+	+
2	KB-2	+	+	+	+
3	KB-3	-	+	+	+
4	KB-4	+	—	-	-
5	KB-5	+	+	+	+
6	KB-6	+	+	+	—
7	KB-7	+	—	+	+
8	KB-8	+	+	-	+
9	KB-9	-	+	+	—
10	KB-10	—	+	+	-
11	KB-11	+	—	—	—
12	KB-12	+	—	+	+
13	KB-13	+	+	+	-
14	KB-14	-	+	-	+
15	KB-15	+	+	+	—
16	KB-16	—	-	+	-
17	KB-17	+	+	-	-
18	KB-18	+	-	+	+
19	KB-19	-	+	+	-
20	KB-20	+	+	+	+
21	KB-21	-	-	-	+
22	KB-22	—	+	+	—
23	KB-23	+	+	+	+
24	KB-24	+	+	+	-
25	KB-25	+	+	-	-
26	KB-26	-	+	+	—
27	KB-27	+	—	+	+
28	KB-28	+	-	+	+
29	KB-29	-	+	+	—
30	KB-30	—	+	+	—

Table 3: List of plant growth promoting activities (Production of IAA, HCN and Phosphorus solubilization) of all 32 PGPR isolates

S. No.	Isolates	IAA	HCN	Solubilization zone Diameter (mm)	Colony zone Diameter (mm)	Solubilization efficiency (%)
1	KB-1	4.17 ^{mn} (17.43)	4.23 ^e (17.93)	3.37 ^{nop} (11.35)	1.44 ^{stu} (2.11)	234
2	KB-2	4.06 ^{mn} (16.53)	3.00 ^{lm} (9.05)	2.76 ^v (7.65)	2.07 ^{mnp} (4.31)	133.3
3	KB-3	4.31 ^l (18.63)	3.29 ^k (10.85)	3.05 ^{rs} (9.35)	1.61 ^{rst} (2.61)	189.4
4	KB-4	3.27 ^q (10.73)	3.98 ^{gh} (15.85)	3.16 ^{qr} (10.05)	2.98 ^{bcd} (8.91)	106
5	KB-5	3.44 ^q (11.83)	4.40 ^d (19.45)	2.29 ^s (8.75)	2.45 ^{ijkl} (6.01)	93.4
6	KB-6	4.72 ^{fgh} (22.33)	4.10 ^f (16.85)	3.54 ^{ijk} (12.55)	2.07 ^{mnp} (4.31)	171
7	KB-7	4.66 ^{gh} (21.73)	2.97 ^m (8.85)	3.41 ^{lmno} (11.65)	2.86 ^{cde} (8.21)	119.2
8	KB-8	4.54 ^{ij} (20.63)	3.07 ^{lm} (9.45)	3.48 ^{klm} (12.15)	2.70 ^{efg} (7.31)	128.8
9	KB-9	4.44 ^{ijk} (19.73)	3.47 ^l (12.05)	4.45 ^a (20.65)	2.45 ^{ijkl} (6.01)	181.6
10	KB-10	5.07 ^a (25.73)	4.54 ^c (20.65)	4.41 ^b (19.45)	3.25 ^a (10.61)	135.6
11	KB-11	4.37 ^{kl} (19.13)	5.26 ^a (27.75)	4.21 ^c (17.75)	1.41 ^{tu} (2.01)	298.5
12	KB-12	4.86 ^{cde} (23.63)	4.36 ^d (19.05)	4.04 ^{ef} (16.35)	1.64 ^{rs} (2.01)	246.3
13	KB-13	3.90 ^o (15.23)	4.57 ^c (20.95)	4.09 ^{cde} (17.05)	2.28 ^{klm} (2.71)	179.3
14	KB-14	4.94 ^{bc} (24.43)	4.04 ^{fg} (16.35)	3.65 ^{ghi} (13.35)	2.66 ^{efgh} (5.21)	137.2
15	KB-15	3.82 ^o (14.63)	3.53 ^j (12.45)	4.50 ^{ab} (20.25)	2.05 ^{nop} (7.11)	219.5
16	KB-16	4.74 ^{fg} (22.53)	3.05 ^{lm} (9.35)	4.44 ^{ab} (19.75)	2.23 ^{lmn} (5.01)	199.1
17	KB-17	4.43 ^{jk} (19.63)	4.61 ^c (21.25)	3.68 ^{gh} (13.55)	2.47 ^{hijk} (6.11)	156.2
18	KB-18	4.52 ^{ij} (20.43)	4.10 ^f (16.85)	3.52 ^{kl} (12.45)	1.89 ^{pq}	189.2
19	KB-19	4.92 ^{bcd} (24.23)	3.65 ^j (13.35)	3.62 ^{hij} (13.15)	1.37 ^u	274.2
20	KB-20	3.18 ^{fg} (10.13)	4.83 ^b (23.35)	3.47 ^{klmn} (12.05)	2.57 ^{ghij}	135
21	KB-21	5.01 ^{ab} (25.13)	2.61 ^q (6.85)	3.74 ^g (14.05)	2.72 ^{efg}	137.5
22	KB-22	4.38 ^{kl} (19.23)	4.78 ^b (22.85)	3.51 ^r (9.95)	1.73 ^{qr}	202.8
23	KB-23	4.09 ^{mn} (16.73)	3.21 ^k (10.35)	2.56 ^u (6.55)	2.64 ^{fghi}	96.9
24	KB-24	4.82 ^{def} (23.23)	3.29 ^h (15.35)	3.32 ^{op} (11.05)	2.43 ^{ijkl}	136.6
25	KB-25	3.57 ^p (12.73)	4.34 ^{de} (18.85)	3.27 ^{pq} (10.75)	2.47 ^{hijk}	132.3
26	KB-26	4.54 ^{ij} (20.63)	4.05 ^{fg} (16.45)	3.51 ^{kl} (12.35)	2.00 ^p	175.5
27	KB-27	4.71 ^{fgh} (22.23)	2.83 ^r (8.05)	3.40 ^{mno} (11.55)	2.12 ^{mno}	160.3
28	KB-28	4.05 ⁿ (16.43)	3.46 ^j (11.95)	3.99 ^f (15.95)	3.18 ^{ab}	125.4
29	KB-29	4.76 ^{efg} (22.73)	3.10 ^g (9.65)	4.17 ^{cd} (17.45)	3.03 ^{bc}	131.1
30	KB-30	4.63 ^{hi} (21.43)	4.04 ^{fg} (16.35)	4.09 ^{def} (16.75)	2.81 ^{def}	145.5

3. Results and Discussion

The study's purpose is to develop effective rhizobacterial isolates for promoting common bean plant growth. Thirty rhizobacteria isolates were collected and identified using morphological and biochemical characteristics. Table 1 lists the morphological traits of all 30 PGPR isolates, which mostly included colony features and Gram's nature. Each rhizobacterial isolate has unique biochemical properties, which are given in Table 2.

3.1 IAA Production

Plant hormones may be natural or synthetic. There are various categories of phytohormones, the most well-known being the auxin group. Microorganisms that live in the rhizosphere of diverse plants are likely to synthesize and release auxin as secondary metabolites. IAA is the primary auxin involved in a wide range of plant physiological functions. The amount of IAA produced by rhizobacteria is quantitatively measured using the Salkowski method (Dubey and Maheshwari, 2006) [10]. IAA, a phytohormone, is widely regarded the most important natural auxin. IAA may play a key role in regulating plant development. Approximately 80% of rhizospheric bacteria are capable of producing IAA. When L-tryptophan is added to bacterial growth media, it is regarded a precursor to IAA synthesis. Plant root exudates are a natural source of L-tryptophan that enhances auxin production in the plant root zone, while rhizosphere micro flora is blocked (Ahmadloo *et al.*, 2014) [2]. Several PGPRs from the genera *Azospirillum*, *Azotobacter*, *Bacillus*, *Burkholderia*, *Enterobacter*, *Pantoea*, and *Pseudomonas* have been found to produce IAA in the presence of tryptophan as a precursor (Tsavkelova *et al.*, 2007) [24]. Out of 30 isolates, four (KB-14, KB-19, KB-12 and KB-29) were found to produce significant levels

of IAA, while the remaining isolates produced moderate amounts.

3.2 HCN Production

It was originally believed that HCN production play its role in plant growth promotion by suppressing the plant pathogens (Voisard, *et al.*, 1989) [25]. However, this concept has recently been changed. It has been believed that HCN production indirectly increases phosphorus availability by chelation and sequestration of metals and indirectly increases the nutrient availability to the rhizobacteria and host plants (Rijavec *et al.*, 2016) [20]. The production of HCN by PGPR are independent of their genus, thus they are used as biofertilizers or biocontrol to enhance crop production and these are being used as biofertilizer in growth promotion and yield enhancement. Bacteria *Micrococcus* sp. and *Bacillus* sp. can produce HCN. HCN is a secondary metabolite produced by bacteria engaged in plant pathogen biocontrol, and it acts as a potential antifungal. HCN inhibits the function of enzymes that have a cofactor in the form of metal ions, such as Cu²⁺, on cytochrome C oxidase. Species of rhizobacteria that create cyanide, particularly *Pseudomonas* and *Bacillus*. The production and control of HCN have the potential to be exploited in reducing infections to enhance sustainable agriculture (Sehrawat *et al.*, 2022) [21]. Out of 30 isolates only 5 were found to produce significant level of HCN Production while the remaining isolates produce moderate amount.

3.3 Phosphate Solubilization

Phosphorus is the second most important nutrient for plant growth, behind nitrogen (N). The majority of phosphorus in soil is in the form of insoluble phosphates, which plants cannot absorb directly. Despite a substantial P reservoir, the number of

accessible forms for plants is often minimal. The majority of soil phosphorus is contained in insoluble forms, while plants absorb it only in two soluble forms, monobasic and dibasic ions (Bhattacharyya and Jha, 2012) ^[4]. To combat P deficit in soils, phosphatic fertilizers are frequently applied in agricultural fields. Plants absorb a little quantity of applied phosphatic nutrients, and the remainder is quickly transformed into insoluble complexes in the soil (Bruto *et al.*, 2014) ^[17]. However, using phosphate fertilizers on a regular basis is not only expensive but also harmful to the environment. This has prompted a search for an environmentally safe and economically viable approach for increasing crop output in low P soils. In this setting, organisms coupled with phosphate-solubilizing activity, sometimes termed phosphate-solubilizing microorganisms (PSM), can offer the accessible fertilizers. Phosphate-solubilizing bacteria (PSB) are considered promising biofertilizers among the many PSM(s) that live in the rhizosphere because they may feed plants with P from sources that would otherwise be unavailable due to multiple processes (M.S. Khan *et al.*, 2006) ^[18]. Bacterial taxa such as *Azotobacter*, *Bacillus*, *Beijerinckia*, *Burkholderia*, *Enterobacter*, *Erwinia*, *Flavobacterium*, *Microbacterium*, *Pseudomonas*, *Rhizobium*, and *Serratia* have been identified as the most important phosphate-solubilizing bacteria (A. Zaidi, *et al* 2006) ^[1]. In this investigation, only five of the 30 isolates had the highest phosphate solubilization.



Plate 1: Isolates on king's B media

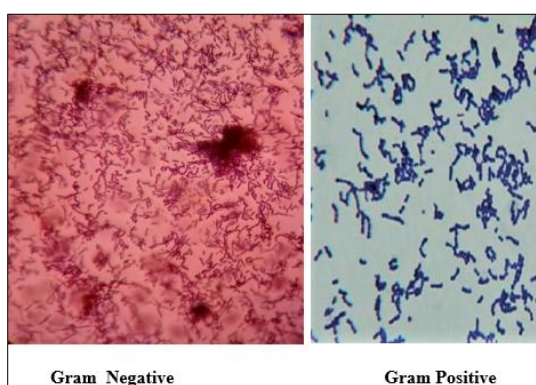


Plate 2: Grams reaction



Plate 3: Citrate utilization test

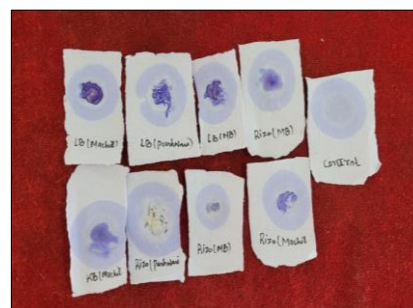


Plate 4: Oxidase test

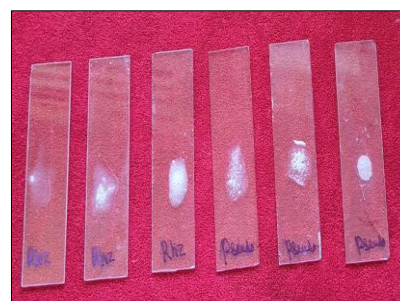


Plate 5: Catalase test

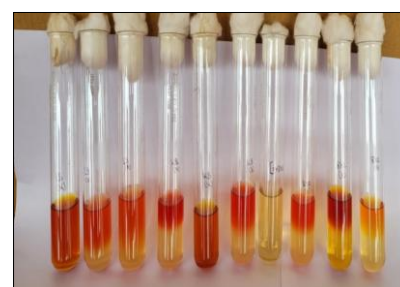


Plate 6: Methyl red test



Plate 7: Indole Acetic Acid Production



Plate 8: HCN Production

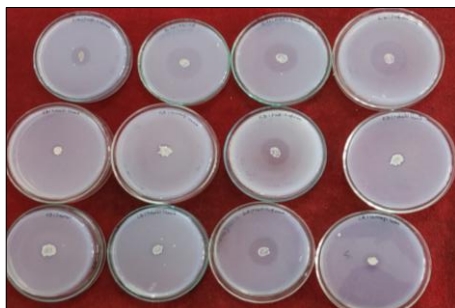


Plate 9: Phosphate solubilization

4. Conclusion

In this study, plant growth-promoting rhizobacteria were isolated from the rhizosphere of common beans. Based on the findings, it was concluded that all of the isolates connected with common bean root soil had plant growth-promoting properties such as phosphate solubilization, phytohormone production (IAA production) and HCN production. The results of this study clearly show that rhizobacterial isolates can be employed as bioinoculants, either alone or in combination in the sustainable production of agricultural crops.

References

- Zaidi MS, Khan M, Ahemad M, Oves M. Plant growth promotion by phosphate solubilizing bacteria. *Acta Microbiologica et Immunologica Hungarica*. 2009;56:263-284.
- Ahmadloo F, Tabari M, Azadi P, Hamidi A. Effect of plant growth promoting rhizobacteria (PGPRs) and stratification on germination traits of *Crataegus pseudoheterophylla* Pojark. *Scientia Horticulturae*. 2014;172:61-67.
- Antoun H, Kloepper JW. Plant growth promoting rhizobacteria (PGPR). In: Brenner S, Miller JH, editors. *Encyclopedia of genetics*. New York: Academic Press; 2001. p. 1477-1480.
- Bhattacharyya PN, Jha DK. Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. *World Journal of Microbiology and Biotechnology*. 2012;28:1327-1350.
- Brick JW, Bostock RM, Silverstone SE. Rapid in situ assay for indoleacetic acid production by bacteria immobilized on nitrocellulose membrane. *Applied and Environmental Microbiology*. 1991;57:535-538.
- Cappuccino JC, Sherman N. *Microbiology: A laboratory manual*. New York: Benjamin/Cummings Publishing Company; 1992.
- Castro-Guerrero NA, Isidra-Arellano MC, Mendoza-Cozatl DG, Valdés-López O. Common bean: A legume model on the rise for unraveling responses and adaptations to iron, zinc, and phosphate deficiencies. *Frontiers in Plant Science*. 2016;7:600.
- Chrouqi L, Ouahmane L, Jadrane I, Koussa T, Al Feddy MN. Screening of soil rhizobacteria isolated from wheat plants grown in the Marrakech region (Morocco, North Africa) for plant growth promoting activities. *Journal of Materials and Environmental Science*. 2017;8:3382-3390.
- Dastager SG, Deepa CK, Pandey A. Potential plant growth promoting activity of *Serratia nematodiphila* NII-0928 on black pepper. *World Journal of Microbiology and Biotechnology*. 2011;27:259-265.
- Dubey RC, Maheshwari DK. *Practical microbiology*. New Delhi: S. Chand and Company; 2006.
- El Kinany S, Haggoud A, Benbouaza A, Bouaichi A, Hassan Achbani E. Plant growth promotion and bacterial canker control of *Lycopersicon esculentum* L. cv. Campbell 33 by biocontrol agents. *Journal of Crop Protection*. 2017;6:235-244.
- Glick BR. Plant growth-promoting bacteria: Mechanisms and applications. *Scientifica*. 2012.
- Goswami D, Patel K, Parmar S, Vaghela H, Muley N, Dhandhukia P, et al. Elucidating multifaceted urease producing marine *Pseudomonas aeruginosa* BG as a cogent PGPR and bio-control agent. *Plant Growth Regulation*. 2015;75:253-263.
- Joseph B, Lawrence R. Characterization of plant growth promoting rhizobacteria associated with chickpea (*Cicer arietinum* L.). *International Journal of Plant Production*. 2007;1:141-152.
- Laslo É, György É, Mara G, Tamás É, Ábrahám B, Lányi S. Screening of plant growth promoting rhizobacteria as potential microbial inoculants. *Crop Protection*. 2012;40:43-48.
- Luna-Vital D, Mojica L, González de Mejía E, Mendoza S, Loarca-Piña G. Biological potential of protein hydrolysates and peptides from common bean (*Phaseolus vulgaris* L.): A review. *Food Research International*. 2015;76(Pt 1):39-50.
- Bruto M, Prigent-Combaret C, Muller D, Monne-Loccoz Y. Analysis of genes contributing to plant-beneficial functions in plant growth-promoting rhizobacteria and related Proteobacteria. *Scientific Reports*. 2014;4:6261.
- Khan MS, Zaidi A, Wani PA. Role of phosphate-solubilizing microorganisms in sustainable agriculture: A review. *Agronomy for Sustainable Development*. 2006;27:29-43.
- Pikovskaya RI. Mobilization of phosphates in soil in connection with the vital activities of some microbial species. *Microbiologiya*. 1948;7:362-370.
- Rijavec T, Lapanje A. Hydrogen cyanide in the rhizosphere: Not suppressing plant pathogens, but rather regulating availability of phosphate. *Frontiers in Microbiology*. 2016;7:1785.
- Sehrawat A, Sindhu SS, Glick BR. Hydrogen cyanide production by soil bacteria: Biological control of pests and promotion of plant growth in sustainable agriculture. *Pedosphere*. 2022;32(1):15-38.
- Spaepen S, Vanderleyden J. Auxin and plant-microbe interactions. *Cold Spring Harbor Perspectives in Biology*. 2011;3:a001438.
- Torres R, Pérez C, Suárez N. Influencia de la inoculación de rizobacterias sobre la germinación de semillas de frijol común (*Phaseolus vulgaris* L.). In: V Congreso Forestal Español. Montes y Sociedad: Saber Qué Hacer; 2017. p. 56-60.
- Tsavkelova EA, Cherdyntseva TA, Botina SG, Netrusov AI. Bacteria associated with orchid roots and microbial production of auxin. *Microbiological Research*. 2007;162:69-76.
- Voisard C, Keel C, Haas D, Défago G. Cyanide production by *Pseudomonas fluorescens* helps suppress black root rot of tobacco under gnotobiotic conditions. *EMBO Journal*. 1989;8:351-358.

Author's details

Seema Nargis

Division of Basic Sciences and Humanities, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Mushtaq Ahmad Malik

Division of Basic Sciences and Humanities, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Malik Asif Aziz

Division of Basic Sciences and Humanities, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Zaffar Mahdi Dar

Division of Basic Sciences and Humanities, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, Jammu and Kashmir, India

Khalid Hussain Bhat

Division of Basic Sciences and Humanities, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, Jammu and Kashmir, India

Showkat Maqbool

Division of Agri-statistics and Economics, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

AA Saad

Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Zohra Shabir

Division of Plant Pathology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

MM Rifana Ajam

Division of Plant Pathology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Raaqib Rasool Parray

Division of Basic Sciences and Humanities, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India

Gousia Gani

Division of Basic Sciences and Humanities, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura, Sopore, Jammu and Kashmir, India