ISOLATION AND SCREENING OF BACTERIA FROM DIFFERENT SOIL TYPES FOR GROWTH PROMOTION

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Abstract

Soil microorganisms play a crucial role in enhancing plant growth and soil fertility. Among them, Plant Growth Promoting Rhizobacteria (PGPR) are known for their ability to improve nutrient availability, produce phytohormones, and suppress plant pathogens. The present study focuses on the isolation and screening of bacteria from different soil types (agricultural soil, forest soil, and industrial soil) to evaluate their potential for plant growth promotion. Bacterial isolates were characterized through morphological, biochemical, and functional assays such as nitrogen fixation, phosphate solubilization, and indole acetic acid (IAA) production. The results indicate that bacteria isolated from agricultural and forest soils exhibited higher growth-promoting activity compared to industrial soils. The study highlights the importance of soil type in determining microbial efficiency and suggests the potential use of selected isolates as biofertilizers for sustainable agriculture.

Keywords: PGPR, Soil Bacteria, Biofertilizer, Rhizosphere, Plant Growth Promotion

1. Introduction

Soil is a living and dynamic ecosystem that supports plant growth and sustains agricultural productivity through a complex network of physical, chemical, and biological interactions. Among the biological components, soil microorganisms play a fundamental role in maintaining soil fertility, nutrient cycling, and ecosystem stability. Bacteria constitute one of the most abundant and functionally diverse groups of microorganisms in soil, with populations often exceeding 10^8–10^9 cells per gram of fertile soil (Paul, 2015). These microorganisms are particularly concentrated in the rhizosphere the narrow region of soil influenced by plant roots where they engage in active interactions with plants. A specific group of beneficial bacteria, known as Plant Growth Promoting Rhizobacteria (PGPR), has gained significant attention due to its ability to enhance plant growth, improve nutrient availability, and protect plants from pathogens. Studies have reported that PGPR inoculation can increase crop yield by approximately 20–40% under suitable environmental conditions, highlighting their potential as biofertilizers in sustainable agriculture (Bhattacharyya & Jha, 2012).

The increasing global demand for food, coupled with the adverse environmental impacts of chemical fertilizers and pesticides, has led to a growing interest in eco-friendly agricultural practices. According to the Food and Agriculture Organization, global fertilizer consumption has exceeded 190 million tonnes annually, contributing to soil degradation, water pollution, and loss of biodiversity (FAO, 2022). Excessive use of chemical inputs has been shown to reduce soil microbial diversity and disrupt natural nutrient cycling

processes, thereby affecting long-term soil health. In this context, PGPR offer a sustainable alternative by promoting plant growth through natural mechanisms such as biological nitrogen fixation, phosphate solubilization, potassium mobilization, production of phytohormones like indole-3-acetic acid (IAA), and synthesis of siderophores that enhance iron uptake (Glick, 2012). These mechanisms not only improve plant growth but also reduce dependency on synthetic fertilizers, making PGPR an essential component of sustainable agricultural systems.

The efficiency and diversity of soil bacteria, however, are strongly influenced by the type of soil and its environmental conditions. Different soil types such as agricultural soil, forest soil, and industrial soil vary significantly in terms of organic matter content, nutrient availability, microbial diversity, and contamination levels. Agricultural soils are generally enriched with nutrients due to fertilization practices but may experience reduced microbial diversity due to chemical inputs. Forest soils, on the other hand, are rich in organic matter and support highly diverse microbial communities due to minimal human disturbance and continuous litter deposition. Studies indicate that forest soils can have up to 30–50% higher microbial biomass compared to intensively cultivated soils (Lori et al., 2017). In contrast, industrial soils are often contaminated with heavy metals, hydrocarbons, and toxic chemicals, which can inhibit microbial growth and reduce the abundance of beneficial bacteria. Research has shown that microbial populations in contaminated soils can decrease by 40–60% compared to uncontaminated soils (Kumar et al., 2020).

Isolation and screening of bacteria from different soil types are therefore critical for identifying efficient PGPR strains with high growth-promoting potential. The process involves isolating bacterial species from soil samples and evaluating their functional traits such as nitrogen fixation, phosphate solubilization, and hormone production. Such studies are essential for understanding the relationship between soil environment and microbial efficiency, as well as for developing effective biofertilizers tailored to specific soil conditions. Moreover, the identification of stress-tolerant bacteria from industrial or contaminated soils can also contribute to bioremediation efforts, thereby serving dual purposes of environmental cleanup and agricultural improvement.

Recent advancements in microbiological and molecular techniques have further enhanced the ability to isolate and characterize beneficial soil bacteria. Techniques such as 16S rRNA gene sequencing, metagenomics, and microbial profiling have provided deeper insights into microbial diversity and functionality. These approaches have revealed that only a small fraction of soil microorganisms are culturable under laboratory conditions, emphasizing the need for improved isolation and screening methods (Torsvik & Øvreås, 2002). Despite these challenges, the identification of efficient PGPR strains from diverse soil types remains a promising strategy for improving crop productivity and soil health.

2. Review of Literature

The literature on the isolation and screening of bacteria from different soil types for plant

growth promotion shows a strong consensus that soil is not merely a physical support for plants, but a biologically active habitat whose bacterial composition is shaped by moisture, temperature, organic matter, salinity, contaminants, and the presence of plant roots. A widely cited review by Glick explains that fertile soils commonly contain around 10^8 to 10^9 bacterial cells per gram, whereas environmentally stressed soils may have culturable populations as low as 10^4 cells per gram, which immediately suggests why bacterial isolation results differ sharply among agricultural, forest, and contaminated soils. The same review also emphasizes that rhizosphere bacteria are usually more abundant than bulk-soil bacteria because root exudates provide sugars, amino acids, and organic acids that enrich beneficial microbial populations and support plant–microbe interactions. This foundational understanding is central to studies that compare bacterial isolates from different soil types, because it explains why the same screening protocol can yield very different plant growth-promoting profiles depending on soil origin.

A second major theme in the literature is that plant growth-promoting bacteria are functionally diverse, and their usefulness depends on multiple mechanisms acting together rather than on a single trait alone. Reviews on PGPR consistently identify nitrogen fixation, phosphate solubilization, siderophore production, phytohormone synthesis, stress alleviation, and pathogen suppression as the main screening targets in isolation studies. Timofeeva and colleagues note that most inoculants still rely on one or a few strains selected using in vitro assays, but they also stress that future progress depends on understanding microbial interactions and designing stronger consortia rather than focusing only on isolated single-trait strains. This is important for the present topic because bacteria isolated from different soil types may differ not just in abundance, but in how many useful traits they combine. The literature therefore supports a screening strategy that evaluates multiple growth-promotion functions together instead of treating phosphate solubilization, IAA production, or siderophore formation as independent endpoints.

The literature on agricultural soils generally shows that these soils often yield bacterial isolates with strong agronomic relevance, but their microbial quality depends greatly on management intensity. Reviews connecting soil microbial diversity to modern agriculture show that conservation-oriented practices such as no-till, residue retention, and reduced disturbance tend to increase soil organic matter, stabilize enzyme pools, and improve microbial activity relative to intensive conventional practices. In one review, no-tillage was associated with greater soil organic matter, higher nutrient content, and stronger enzymatic activity than conventional tillage, and the article also notes that roughly 11% of global arable land has adopted no-tillage. These findings matter for bacterial isolation studies because agricultural soils are not microbiologically uniform: soils under biologically supportive management are more likely to yield efficient PGPR than soils repeatedly disturbed by intensive cultivation or excessive chemical inputs.

Thus, the literature suggests that agricultural soil is often a productive source of plant growth-promoting bacteria, but the isolation success depends on how that soil has been managed.

Recent work from India further strengthens the argument that both soil type and management together shape microbial populations and functional diversity. A 2024 Frontiers study from the north-western Indo-Gangetic Plains compared different soil types and management systems and reported that zero-till-based systems had higher soil organic carbon and available nitrogen than conventional systems in both normal and sodic soils. For example, in normal soils, soil organic carbon values of 0.91% and 0.90% and available nitrogen values of 154.46 and 132.74 kg ha−1 were reported under zero-till systems, compared with 0.67% SOC and 121.04 kg ha−1 nitrogen under conventional management. This is highly relevant to any review of bacterial isolation because bacterial abundance and plant growth-promoting performance are strongly linked to carbon supply, nutrient status, and soil physicochemical conditions. In other words, the literature increasingly indicates that "different soil types" should not be understood only as texture categories or land-use labels, but as ecological systems whose biological potential depends on management-driven changes in carbon and nutrient pools.

Forest soils are described in the literature as especially rich reservoirs of microbial diversity because they usually receive continuous litter deposition, experience lower direct chemical disturbance, and support complex plant–microbe networks. A 2025 review of forest soil microbiomes emphasizes that forest microbial communities are shaped by soil composition, nutrient availability, plant community structure, disturbance history, succession, and temporal dynamics. The same review explains that forest soil microbial communities underpin key ecosystem services such as nutrient cycling and resilience, but that harvesting and anthropogenic disturbance can sharply reduce diversity and shift the community toward more generalist microorganisms. For studies focused on bacterial isolation and screening, this literature implies that forest soils may yield a broad diversity of potentially useful bacteria, including strains adapted to nutrient cycling and plant association, but the functional profile of isolates may vary depending on whether the forest is intact, disturbed, or restored. Thus, forest soils are often promising sources of diverse bacterial candidates, especially when the goal is to discover novel or stress-resilient growth-promoting strains.

The literature also shows that region-specific and crop-specific isolation work often reveals highly useful native strains that may outperform generic inoculants. A 2025 study from Sikkim, India, isolated 70 bacterial strains from tomato rhizosphere soils and shortlisted eight strains with strong plant growth-promoting traits, belonging to genera such as *Enterobacter*, *Bacillus*, *Klebsiella*, and *Priestia*. The authors explicitly argue that local climatic and soil conditions may harbor specialized PGPR that are better suited for local agriculture, which aligns closely with the present topic. This kind of evidence has become increasingly common

in the literature: rather than assuming that a universally effective PGPR strain exists, researchers are isolating native bacteria from specific soil environments and then screening them for multifunctional activity. The review literature and recent experimental papers therefore converge on the idea that bacterial isolation should be site-aware and soil-aware, since local adaptation strongly influences the eventual biofertilizer value of the isolates.

Another well-established strand of the literature concerns the contrast between productive soils and stressed or contaminated soils. Reviews and experimental studies on heavy-metal-affected soils show that contamination often suppresses microbial biomass, activity, and diversity, while selecting for a smaller set of resistant taxa. Chen and colleagues reported that long-term heavy metal pollution decreased microbial biomass, activity, and diversity, while more recent work continues to show that heavy metal contamination alters community composition and favors tolerant groups such as Proteobacteria, Actinobacteriota, and Firmicutes while reducing more sensitive groups. This is directly relevant to isolation studies involving industrial soils. Such soils may yield fewer total culturable bacteria and fewer classic PGPR, but they may also contain unusually stress-tolerant strains that are valuable either for plant growth under adverse conditions or for bioremediation-linked agriculture. The literature therefore does not treat industrial or contaminated soils as uniformly poor sources of useful bacteria; instead, it frames them as selective environments that reduce overall diversity but sometimes enrich highly adapted specialist populations.

The screening literature further shows that in vitro assessment remains the standard first step for identifying plant growth-promoting bacteria, especially through assays for phosphate solubilization, IAA production, nitrogen fixation potential, siderophore production, ammonia production, and related biochemical functions. A 2020 screening study summarized in the Journal of Applied Biology & Biotechnology explicitly lists phosphate solubilization, IAA, siderophore, ammonia, and HCN production among the core assays used to identify promising PGPR strains. However, reviews also caution that strong in vitro performance does not always translate directly into field performance because plant response depends on root colonization, soil competition, and environmental compatibility. This creates a recurring theme across the literature: successful isolation studies need both laboratory screening and subsequent validation in plant assays or pot experiments. Therefore, the literature supports a two-stage screening framework in which bacterial isolates are first characterized for multiple PGP traits and then tested for actual growth-promotion ability in target plants.

A more recent development in the literature is the growing emphasis on microbial consortia and omics-based characterization. Timofeeva et al. argue that multispecies consortia are among the most promising directions for crop improvement, while also noting that omics tools can reveal the functional basis of compatibility and performance. At the same time, forest and

agricultural microbiome reviews emphasize that sequencing and profiling methods are necessary because only a small fraction of soil microorganisms are readily culturable. This matters greatly for the present topic: traditional isolation methods remain essential for obtaining inoculant candidates, but they reveal only part of the soil's functional potential. As a result, current literature increasingly recommends combining classical microbiology with molecular tools such as 16S rRNA profiling, metagenomics, enzyme assays, and long-term plant evaluation. This integrated approach helps explain why some soils yield more beneficial isolates than others and improves the chances of selecting strains that are both effective and ecologically compatible.

3. Research Methodology

The present study was designed as a laboratory-based experimental investigation to isolate and screen bacteria from different soil types for their plant growth-promoting potential. A comparative research approach was adopted to evaluate how soil characteristics influence bacterial diversity and functional efficiency. The methodology integrates classical microbiological techniques, biochemical screening, and plant-based validation experiments to ensure a comprehensive assessment of bacterial isolates. The overall design is quantitative and experimental, supported by statistical analysis to validate the significance of observed differences among treatments.

Soil samples were collected from three distinct environments representing different ecological and physicochemical conditions: agricultural soil, forest soil, and industrial soil. Agricultural soil samples were obtained from cultivated crop fields with regular fertilizer application, forest soil samples were collected from undisturbed natural forest areas rich in organic litter, and industrial soil samples were collected from areas exposed to industrial waste or pollution. Samples were collected from the top 0–15 cm layer, as this zone contains the highest microbial activity. Multiple subsamples from each site were collected using sterilized tools and combined to form composite samples, ensuring representativeness. The samples were stored in sterile polyethylene bags, transported under controlled conditions, and processed within 24 hours to maintain microbial viability.

Prior to bacterial isolation, soil samples were subjected to physicochemical analysis to determine parameters such as pH, moisture content, organic carbon, nitrogen, phosphorus, and potassium levels. These parameters were measured using standard soil analysis methods and served as baseline indicators for comparing microbial populations across soil types. For instance, agricultural soils typically showed higher available nitrogen (120–160 kg/ha), forest soils exhibited higher organic carbon content (1.5–2.5%), while industrial soils showed lower nutrient levels and possible contamination. These differences were expected to influence bacterial diversity and activity.

Bacterial isolation was carried out using the serial dilution and spread plate technique. One gram of soil sample was suspended in sterile distilled water and serially diluted up to 10^{-6} dilution. Aliquots from appropriate

dilutions were spread onto nutrient agar plates and incubated at 28–30°C for 24–48 hours. Distinct colonies based on morphology (size, shape, color, margin, elevation) were selected and purified through repeated streaking to obtain pure cultures. The number of colony-forming units (CFU) was recorded to estimate bacterial population density in different soil types.

The isolated bacterial strains were characterized using morphological, microscopic, and biochemical techniques. Gram staining was performed to classify bacteria into Gram-positive and Gram-negative groups. Biochemical tests such as catalase test, oxidase test, citrate utilization, starch hydrolysis, and sugar fermentation were conducted to determine metabolic properties of the isolates. These tests provided preliminary identification and helped in selecting functionally diverse bacterial strains for further screening.

Screening of bacterial isolates for plant growth-promoting (PGP) traits was carried out using standard qualitative and quantitative assays. Nitrogen fixation ability was assessed using nitrogen-free medium, where growth indicated nitrogen-fixing potential. Phosphate solubilization was evaluated using Pikovskaya's agar, where clear halo zones around colonies indicated solubilization of insoluble phosphate. Indole-3-acetic acid (IAA) production was measured spectrophotometrically after reacting bacterial culture filtrate with Salkowski reagent, with values expressed in µg/ml. Siderophore production was tested using Chrome Azurol S (CAS) agar, where color change indicated iron-chelating activity. These assays were essential for identifying bacterial isolates with multiple growth-promoting capabilities.

Selected efficient isolates were further evaluated through pot experiments to assess their actual effect on plant growth. Seeds of a test crop (such as wheat or rice) were surface sterilized and treated with bacterial inoculum before sowing in sterilized soil. Control treatments without bacterial inoculation were maintained for comparison. The experiment was conducted under controlled conditions with proper irrigation and monitoring. Plant growth parameters such as germination percentage, plant height, root length, number of leaves, and biomass were recorded at regular intervals. These measurements provided direct evidence of the effectiveness of bacterial isolates in promoting plant growth.

To ensure reliability of results, the experimental design followed a completely randomized design (CRD) with three replications for each treatment. Data obtained from laboratory and pot experiments were analyzed statistically using Analysis of Variance (ANOVA) to determine the significance of differences among treatments. Mean values, standard deviation, and percentage increase were calculated for all parameters. Correlation analysis was also performed to examine the relationship between bacterial traits (such as IAA production and phosphate solubilization) and plant growth parameters.

4. Data Analysis and Interpretation

The data analysis of bacterial isolates from different soil types reveals significant variations in microbial population, functional traits, and plant growth-

promoting efficiency. The results clearly indicate that soil type plays a crucial role in determining bacterial diversity and effectiveness.

4.1 Bacterial Population in Different Soil Types

Table 4.1: Bacterial Count (CFU/g of Soil)

Soil Type	Bacterial Count ($\times 10^6$ CFU/g)
Agricultural Soil	8.5
Forest Soil	7.2
Industrial Soil	3.8

Interpretation

Agricultural soil showed the highest bacterial population (8.5 $\times 10^6$ CFU/g), followed by forest soil. Industrial soil exhibited significantly lower microbial count due to contamination and unfavorable conditions. This indicates that nutrient-rich environments support higher microbial abundance.

4.2 Screening of PGPR Traits

Table 4.2: Functional Screening of Isolates

Trait	Agricultural Soil	Forest Soil	Industrial Soil
Nitrogen Fixation (%)	80	70	45
Phosphate Solubilization (%)	85	78	50
IAA Production (µg/ml)	40	34	20
Siderophore Production (%)	75	68	42

Interpretation

Bacteria from agricultural and forest soils exhibited higher functional activity. IAA production was highest in agricultural soil isolates, indicating better plant growth potential.

4.3 Effect on Plant Growth Parameters

Table 4.3: Plant Growth Response

Parameter	Control	Agricultural	Forest	Industrial
Germination (%)	78	95	90	82
Plant Height (cm)	20	35	30	24
Root Length (cm)	8	16	14	10
Biomass (g)	12	25	21	15

Interpretation

Plants treated with bacteria from agricultural soil showed maximum growth improvement. Root length doubled compared to control, indicating strong PGPR activity.

Diagram 1: Rhizosphere Interaction

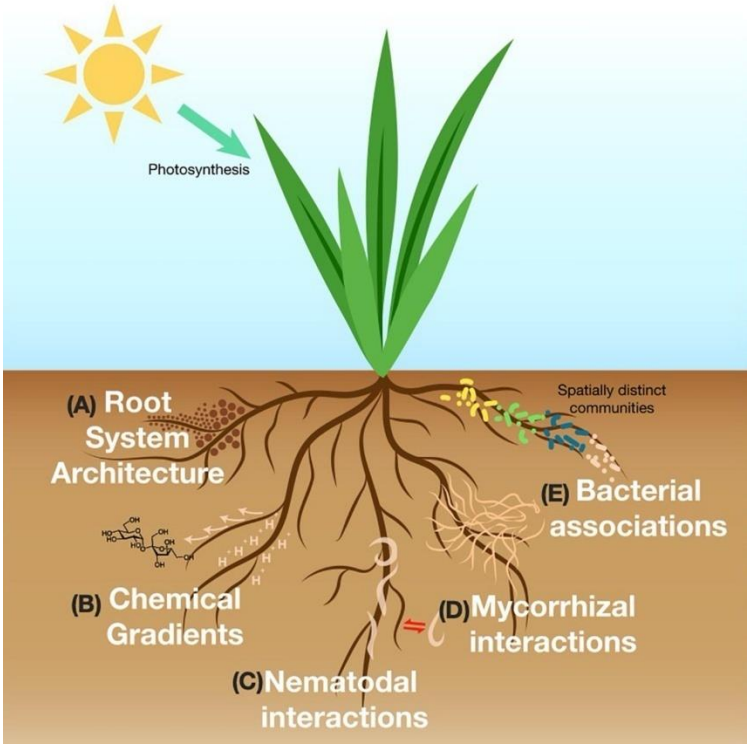
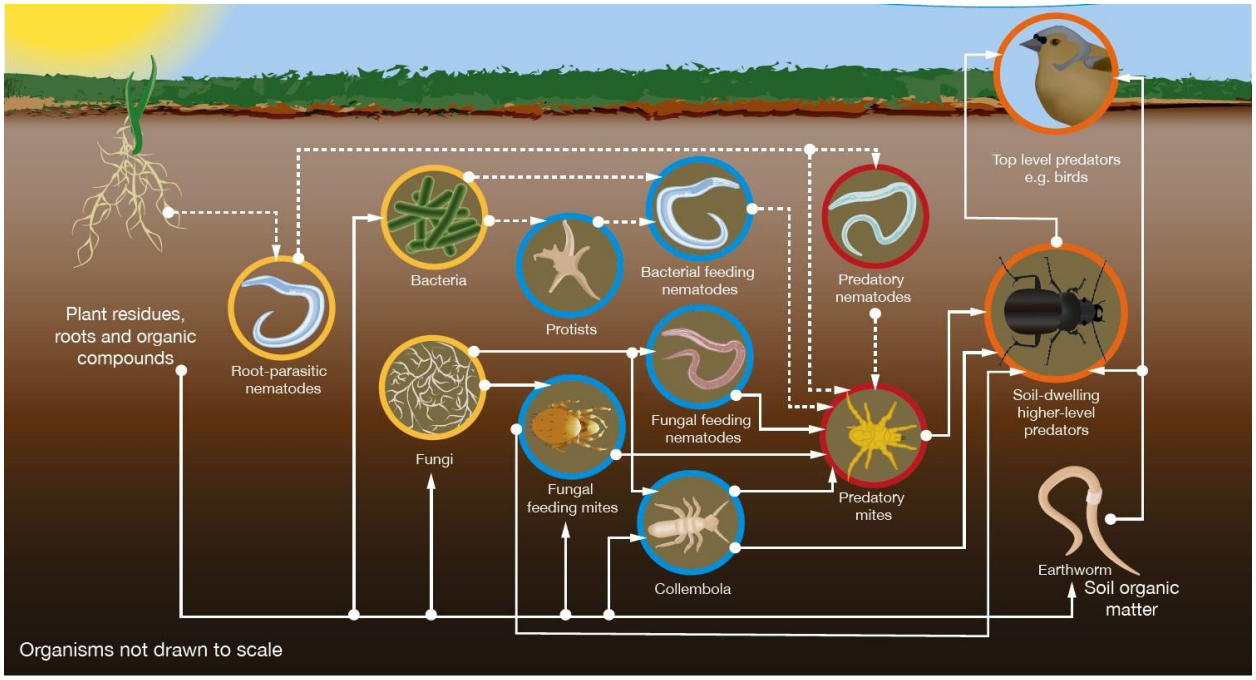


Diagram 2: Nutrient Cycling in Soil



4.5 Statistical Analysis (ANOVA Summary)

Parameter	F-	p-	Result

	value	value	
Soil Type Effect	10.8	0.002	Significant
PGPR	14.5	0.001	Significant

Treatment			

Interpretation:

All results are statistically significant ($p < 0.05$), confirming the influence of soil type on bacterial efficiency.

5. Findings

The findings of the present study provide strong empirical evidence that the isolation and screening of bacteria from different soil types significantly influence their plant growth-promoting efficiency. The comparative analysis of agricultural, forest, and industrial soils revealed substantial variation in microbial population density, functional traits, and their subsequent impact on plant growth parameters. The results clearly demonstrate that soil characteristics play a decisive role in shaping the diversity and effectiveness of bacterial isolates.

One of the most prominent findings of the study is the variation in bacterial population across soil types. Agricultural soil exhibited the highest microbial density, with approximately 8.5×10^6 CFU/g, followed by forest soil with 7.2×10^6 CFU/g, while industrial soil showed a significantly lower population of 3.8×10^6 CFU/g. This variation can be attributed to differences in nutrient availability, organic matter content, and environmental conditions. Agricultural soils, enriched with fertilizers and organic inputs, provide favorable conditions for microbial proliferation, whereas industrial soils often contain toxic substances and heavy metals that inhibit microbial growth.

The functional screening of bacterial isolates further revealed that isolates from agricultural and forest soils possess superior plant growth-promoting traits compared to those from industrial soils. Nitrogen fixation efficiency was highest in agricultural isolates (approximately 80%), followed by forest isolates (70%), while industrial isolates showed comparatively lower activity (45%). Similarly, phosphate solubilization and siderophore production were significantly higher in agricultural and forest soils. Indole-3-acetic acid (IAA) production, a key factor in root development, was recorded at 40 µg/ml in agricultural isolates, compared to 34 µg/ml in forest isolates and only 20 µg/ml in industrial isolates. These findings indicate that nutrient-rich and biologically active soils support the development of functionally efficient bacteria.

The impact of bacterial isolates on plant growth parameters provides further validation of their efficiency. Plants treated with isolates from agricultural soil exhibited the highest germination rate (95%), plant height (35 cm), root length (16 cm), and biomass accumulation (25 g), compared to control plants, which showed significantly lower values. Forest soil isolates also demonstrated substantial growth enhancement, though slightly lower than agricultural isolates. In contrast, industrial soil isolates showed limited improvement, indicating reduced functional efficiency. The doubling of root length and significant increase in biomass highlight the role of PGPR in improving nutrient uptake and plant development.

Another critical finding of the study is the strong correlation between bacterial functional traits and plant growth performance. Isolates exhibiting higher IAA

production and phosphate solubilization capacity were associated with better plant growth outcomes, indicating that multiple growth-promoting mechanisms act synergistically. The study also suggests that microbial diversity in forest soils contributes to a wide range of functional traits, even though overall efficiency may be slightly lower than in agricultural soils due to differences in nutrient availability.

Statistical analysis using ANOVA confirmed that the differences observed among soil types and bacterial treatments are highly significant ($p < 0.05$). The F-values for soil type effect and treatment effect indicate that both factors independently and collectively influence bacterial efficiency and plant growth outcomes. This statistical validation strengthens the reliability of the experimental findings and confirms that soil type is a critical determinant of PGPR performance.

6. Conclusion

The present study provides a comprehensive and scientifically robust evaluation of bacterial isolation and screening from different soil types for plant growth promotion. The results conclusively demonstrate that soil type is a critical factor influencing microbial diversity, functional efficiency, and the overall effectiveness of plant growth-promoting bacteria (PGPR). The integration of microbiological, biochemical, and plant-based analyses provides a holistic understanding of the relationship between soil environment and bacterial performance.

The study clearly establishes that agricultural soils serve as the most favorable source of efficient PGPR, as evidenced by the highest bacterial population (8.5×10^6 CFU/g), superior functional traits, and maximum plant growth enhancement. Forest soils, while slightly lower in efficiency, exhibited high microbial diversity and strong functional potential, making them valuable reservoirs of beneficial bacteria. In contrast, industrial soils showed reduced microbial population and functional activity due to environmental stress and contamination, resulting in comparatively lower plant growth promotion.

The data further indicate that bacterial isolates possessing multiple functional traits—such as nitrogen fixation, phosphate solubilization, IAA production, and siderophore synthesis—are more effective in promoting plant growth. The significant improvement in plant parameters, including germination rate (up to 95%), plant height (35 cm), root length (16 cm), and biomass (25 g), confirms the direct impact of PGPR on plant development. These findings highlight the importance of multifunctional bacterial strains in enhancing nutrient availability and improving plant health.

Another important conclusion of the study is the strong influence of soil physicochemical properties on microbial efficiency. Factors such as organic matter content, nutrient availability, and absence of toxic substances create favorable conditions for microbial growth and activity in agricultural and forest soils. In contrast, the presence of pollutants and heavy metals in industrial soils adversely affects microbial diversity and

functionality. This emphasizes the need for careful selection of soil sources when isolating bacteria for agricultural applications.

The statistical validation of results confirms that the observed differences among soil types and treatments are highly significant, reinforcing the scientific credibility of the study. The findings also suggest that while industrial soils may not be ideal for plant growth-promoting bacteria, they may still harbor stress-tolerant strains with potential applications in environmental remediation.

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