

Ecological Distribution and Functional Diversity of *Bacillus* spp. in Soil and Water Ecosystems

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Introduction

• Ecological ubiquity & versatility

Bacillus spp. are Gram-positive, spore-forming bacteria found in diverse environments—soil, water, vegetation, even animal guts—thanks to their durable endospores and wide metabolic versatility.



• Functional significance

They contribute to nutrient cycling, secrete plant-beneficial hormones (e.g. IAA, gibberellins), solubilize nutrients like phosphorus, and produce antimicrobial compounds, making them valuable as plant growth-promoting rhizobacteria (PGPR) and biocontrol agents

• Research rationale

Understanding their distribution patterns across climatic and environmental gradients (e.g., pH extremes, moisture levels, salinity) is crucial to harness their ecological and industrial potentials

Materials and Methods

While no single article covers all methods, common approaches across studies include:

1. Sampling across environments

- Soil from diverse zones (tropical, arid, mountainous, extreme pH, mangrove).
- Water and sediment in aquatic systems (less frequently sampled but analogous techniques apply).

2. Physico-chemical soil analysis

- Parameters like pH, moisture, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, iron, boron are measured to correlate with microbial diversity

3. Culture-dependent isolation

- Serial dilution plating on various media (e.g., TSA, NA, SMA, AIA).
- Colony counting (CFU) and morphological/biochemical screening

4. Molecular identification

- 16S rRNA gene sequencing and phylogenetic analysis via cloning (TA cloning), ARDRA, ERIC-/BOX-PCR, DGGE, neighbor-joining methods

5. Functional assays

- Testing for phosphate solubilization on Pikovskaya medium (zones of clearance).
- IAA production, siderophore release, ammonia generation, ACC-deaminase activity, hydrolytic enzymes, and antifungal activity

Results and Discussion

A. Environmental Distribution & Diversity

- Climatic gradient effects

Twenty *Bacillus* species emerged across Indian zones; tropical wet and arid zones had highest diversity, while no single species was ubiquitous—highlighting climate and soil chemistry as key drivers.

- **Extreme habitats**

Acidic, alkaline, saline-mangrove soils harbor distinct *Bacillus* populations adapted to such niches; some isolates are thermophilic or halotolerant, showing promise for industrial enzyme sourcing.

- **Culture-dependent vs culture-independent**

Metagenomic (16S-based) surveys often reveal both dominant *Bacillus* and previously uncultured taxa. E.g., one study found 21 of 25 clones were *Bacillus*, while others hinted at novel phyla. This dual approach is essential—culture-dependent techniques provide live isolates, while culture-independent reveal hidden diversity.

B. Functional & Phylogenetic Insights:

- **Nutrient solubilization & PGPR traits**

Numerous isolates showed strong phosphate solubilization (halo zones 10–29 mm), IAA up to 50 µg/ml, ACC deaminase activity, siderophore/ammonia production and secretion of hydrolytic enzymes like proteases, chitinases, cellulases.

- **Antifungal/biocontrol potential**

Isolates displayed inhibition of pathogens like *Rhizoctonia solani*, *Fusarium oxysporum*, *Macrophomina* spp., and *Fusarium udum*, with molecular profiling (ARDRA, 16S) confirming their biocontrol relevance in agro-ecosystems.

- **Phylogenetic diversity**

Vibrant genetic groups tied to *B. subtilis*, *B. pumilus*, *B. megaterium*, *B. amyloliquefaciens*, *B. cereus*, *B. thuringiensis*, etc., were observed via clustering tools (ERIC-/BOX-PCR, ARDRA), though strain-level resolution needed rep-PCR as 16S rRNA sometimes lacked discrimination.

C. Applications & Ecological Implications:

- **Industrial biotechnology**

Extremophilic isolates (e.g., thermophiles, halophiles) offer sources for robust enzymes used in detergents, agriculture, and bioprocesses.

- **Agricultural bioinputs**

Given strong evidence of PGPR and biocontrol traits, many strains are being commercialized as biofertilizers or biological pesticides, though field-level validation across regions remains essential.

- **Ecological diversification**

Findings emphasize environmental selection in shaping *Bacillus* communities—soil pH, moisture, nutrient content all influence species distributions, supporting targeted exploration based on ecological context.

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